California Coastal Commission

Climate Change and Sea Level Rise Websites

The California Coastal Commission is in the process of updating its webpages related to climate change and sea level rise. When completed, these pages will provide up to date information on best available science, tools and resources for addressing impacts, and information on actions the Commission and other partners are taking to prepare for these changes, all in a simple and visually compelling way. To view the changes that have already been made to these pages visit:

Climate Change: www.coastal.ca.gov/climate/climatechange.html
Sea Level Rise: www.coastal.ca.gov/climate/slr/

Revised Draft Sea Level Rise Policy Guidance

The Coastal Commission has also recently released the Public Review Draft of its Revised Sea Level Rise Policy Guidance. The revised Guidance provides an overview of best available science on sea level rise for California and recommended steps for addressing sea level rise in Coastal Commission planning and regulatory decisions. It includes updates on related efforts and state actions, and incorporates the feedback the Commission received during a 120-day public comment period following the release of the first draft Guidance.

Revisions were coordinated with other California state efforts related to climate change and adaptation, including the *2014 Safeguarding California* document produced by the California Natural Resources Agency. The revised draft reflects the broad concepts and strategies in *Safeguarding California* - particularly the *Coast and Oceans* chapter - and complements it by providing information specific to the Coastal Act, including Local Coastal Programs and Coastal Development Permits. The full revised draft can be downloaded at www.coastal.ca.gov/climate/slrguidance.html

Coastal Conservancy
Climate Ready
Helping California communities meet the challenge of a changing climate

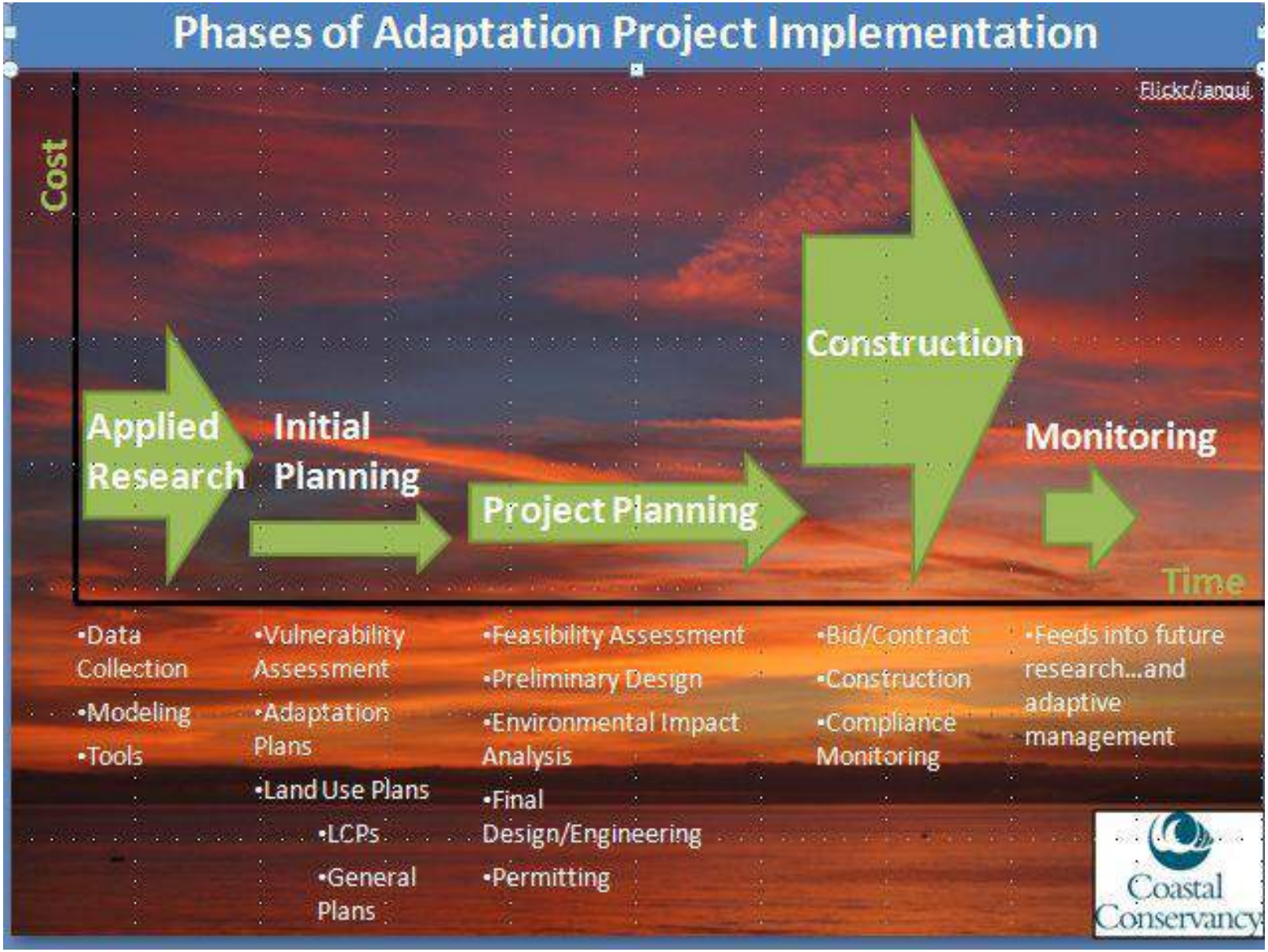
California State Coastal Conservancy's Climate Ready Programmatic Priorities

California coastal counties are the home to approximately 32 million people, generate billions in revenue, and support millions of jobs. However, in the face of a changing climate our California coastal region will experience more severe impacts from the combined effects of higher air and water temperatures, altered precipitation patterns, sea-level rise, salinity changes, ocean acidification, more severe El Niño climate events, increased storm frequency and intensity, higher coastal erosion rates, saltwater intrusion, and greater fire intensity and frequency. These impacts will only worsen many problems that coastal areas already face and will require new approaches to managing coastal resources in the face of a changing climate.

Projects selected for funding under the Climate Ready program will be those that best incorporate the following Climate Ready Programmatic Priorities (adapted in part from climate-smart principles developed by the National Wildlife Federation Climate Change Adaptation Principles, 2011, Resource Legacy Fund, 2012 and Climate Smart Practices by Point Blue, 2013):

1. Safeguard coastal communities by using nature-based solutions that provide co-benefits for people, wildlife, and the economy.
2. Prioritize projects that maximize short and long term public benefits and capitalize on the inherent abilities for natural coastal systems to adapt to change.
3. Promote collaboration among various stakeholders and multiple sectors. Establish and expand non-traditional alliances to accelerate effective problem-solving between and among public and private resource managers, scientists, and decision-makers.
4. Incorporate the best available science by utilizing peer-reviewed and well-documented climate science, climate adaptation strategies, sea level rise projections, and management practices.
5. Focus on future climatic and ecological conditions for coastal communities rather than the past.
6. Design actions from a landscape, ecosystem, and watershed perspective on a regional scale.
7. Account for a high degree of uncertainty by developing and implementing strategies that provide the greatest benefits across a range of possible future climate and sea level rise scenarios.

8. Minimize energy use and greenhouse gas emissions. Enhance the ability of natural systems to sequester greenhouse gases.
9. Address the needs of low-income and other underserved coastal populations that will be highly impacted by climate change.
10. Promote on-the-ground demonstration projects that implement innovative approaches or enhance understanding of effective coastal management strategies and will potentially lead to broader change to policies, regulations, or to duplicating the effort elsewhere;
11. Incorporates a project-appropriate outreach or educational component.


Phases of Adaptation Project Implementation
Flickr/ianqui
Cost
Time
Applied Research
Initial Planning
Project Planning
Construction
Monitoring
•Data Collection
•Modeling
•Tools
•Vulnerability Assessment
•Adaptation Plans
•Land Use Plans
•LCPs
•General Plans
•Feasibility Assessment
•Preliminary Design
•Environmental Impact Analysis
•Final Design/Engineering
•Permitting
•Bid/Contract
•Construction
•Compliance Monitoring
•Feeds into future research...and adaptive management
Coastal Conservancy

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Sea Level Rise Resiliency Projects Supported by the Coastal Conservancy
(As of June 2015)

The Coastal Conservancy supports California's coastal communities prepare for sea level rise resiliency by leading and funding the most time sensitive and informative components of applied research, adaptation planning, engineering, and the design and implementation of effective multi-benefit adaptation projects.

For over a decade, the Conservancy has been working to address coastal erosion, including the planning and implementation of managed retreat projects at Surfers Point and at Pacifica State Beach. The Conservancy's Climate Ready program was launched in 2013 after the legislature and governor empowered the Conservancy with a new authority to prepare for and mitigate the effects of climate change. The program has completed two grant rounds and is recommending funding for a third round in June 2015.

The first two grant rounds resulted in requests for nearly 186 projects totaling nearly $40 million in funds for a full range of adaptation and greenhouse gas reduction planning and implementation projects. The Conservancy authorized funding for 31 projects, totaling $5.2 million, 13 of these address sea level rise impacts. A third grant round was advertised in October 2014 and resulted in requests for $23 million for 108 projects. 13 projects totaling $1.9 million are proposed for Conservancy approval in June 2015. Of these, 10 projects support planning or implementation of actions that address sea level rise.

Below is a list of the projects and project phased that the Coastal Conservancy has funding to support sea level rise resiliency. The list contains projects that are subject to the Conservancy's approval in June 2015, as noted with a *.

Applied Research (data collection, modeling, tool development)

*Humboldt Coastal Dunes Morphology	Humboldt
San Francisco Bay Living Shorelines Wave Reduction Assessment	SF Bay
San Francisco Bay Marsh Model	SF Bay Region
Monterey Bay Coastal Hazards Zone Map	Monterey
County of Santa Barbara Future Coastal Hazards Model	Santa Barbara
*Kelp Forest Hydrodynamics Study Palos Verdes Peninsula	Los Angeles
Southern California Regional Coastal Storm Modeling System	So CA Region

Initial Planning (vulnerability assessments, adaptation plans, land use plans)

Humboldt Bay Shoreline Sea Level Rise Vulnerability Assessment	Humboldt

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*Humboldt Dunes Vulnerability and Adaptation Assessment	Humboldt
Humboldt Collaborative on Coastal Resilience	Humboldt
San Francisco Baylands Goals Climate Change Technical Update	San Francisco Bay
*Crissy Field Seal Level Rise Vulnerability Assessment	San Francisco
San Mateo County Shoreline Vulnerability Assessment	San Mateo
City of Benicia Vulnerability Assessment	Solano
Monterey Bay Sea Level Rise Vulnerability Assessment	Monterey
The Nature Conservancy Adaptation Strategies Cost-Benefit Analysis	Monterey
Goleta Slough Sea Level Rise Vulnerability Assessment	Santa Barbara
Southern California Wetland Restoration Sea Level Rise Strategies	Southern California
City of Hermosa Beach Infrastructure Vulnerability Assessment	Los Angeles
Los Angeles County Public Beach Facility Vulnerability Assessment	Los Angeles
Imperial Beach Vulnerability Assessment	San Diego

Project Planning (feasibility assessments, preliminary design, environmental impact analysis, final design and engineering, permitting)

City of Arcata Living Shoreline Project	Humboldt
Humboldt Bay Dredged Materials Reuse Feasibility Study	Humboldt
* Bolinas Lagoon Conceptual Creek, Floodplain, Wetland Restoration Design	Marin
*Marin County Sea Level Rise Vulnerability Assessment	Marin
*Bel Marin Keys Wetland Restoration and Flood Protection Design	Marin
East Bay Dischargers Authority Decentralized Infrastructure Feasibility	Alameda
Ocean Beach Managed Retreat Master Plan	San Francisco
Bay Area Ecosystems Climate Change Consortium	SF Bay Area
Baylands Ecosystem Habitat Goals Technical Update	SF Bay Area
San Francisquito Creek Joint Powers Authority Shoreline Resilience Plan	San Mateo
SF Airport and San Mateo Co Creek Flood Management Plan	San Mateo
*Salinas River State Park Restoration Design and CEQA	Monterey
County of Santa Barbara Coastal Hazard Adaptation Strategies	Santa Barbara
Conservation Management Planning For Ventura River	Ventura
Ormond Beach Wetland Restoration Plan	Ventura
City of Imperial Beach SLR Resiliency Strategies	San Diego
*Cardiff Beach Living Shoreline Dune Restoration Design	San Diego

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Construction (wetland restoration, subtidal restoration and flood protection, managed retreat)

City of Arcata Living Shoreline Project	Humboldt
*Humboldt Dunes Restoration Demonstration Project	Humboldt
Sears Point Wetland and Watershed Restoration Project	Sonoma
San Francisco Bay Living Shoreline	Marin & Alameda
Hamilton Wetland Restoration	Marin
Sonoma Creek Tidal Marsh Restoration	Sonoma
Pacifica/Linda Mar State Beach Retreat and Restoration	San Mateo
South Bay Salt Pond Restoration Project (Multiple Sites)	Alameda & San Mateo
Eden Landing Marsh Transition Zone Restoration	Alameda
Surfer's Point Managed Retreat Project	Ventura
*Newport Bay Oyster and Eelgrass Restoration	Orange

Monitoring

*Humboldt Dunes Restoration Demonstration Project	Humboldt
San Francisco Bay Living Shoreline	Marin & Alameda
South Bay Salt Pond Restoration Project (Multiple Sites)	Alameda & San Mateo
Hamilton Wetland Restoration	Marin
*Newport Bay Oyster and Eelgrass Restoration Monitoring	Orange

Adapting to Rising Tides
Nine County Work Program

Regional Assessment and Adaptation Project

SAN FRANCISCO BAY CONSERVATION AND DEVELOPMENT COMMISSION

(MARCH 2015)

Adapting to Rising: Tides Nine County Assessment

Over the past four years, assessments of the region's vulnerability to current and future flooding have become more coordinated and are beginning to produce recommended actions to improve resilience. Some of the region's more comprehensive, guiding projects include the San Francisco Bay Conservation and Development Commission's Adapting to Rising Tides Program (ART), the Silicon Valley 2.0 project, and the City of San Francisco's Sea Level Guidance for Capital Planning. While these projects were conducted in different parts of the region and were led by different agencies, the sponsors coordinated to ensure similar methods were used to determine the areas at risk for current and future flooding, to assess vulnerabilities and developing strategies.

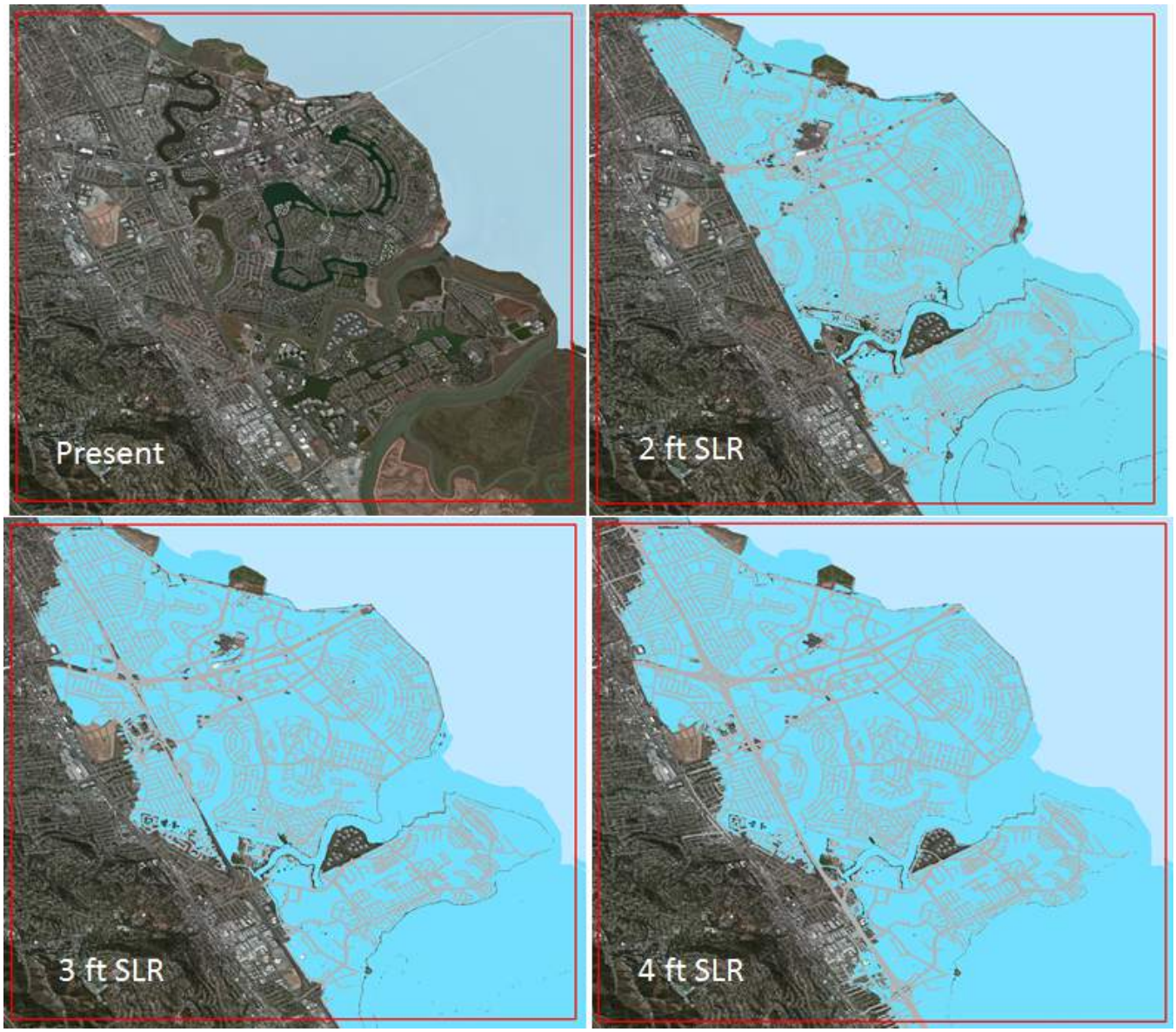
These and other efforts around the region clearly show that the most effective and efficient approach to assessing and responding to current and future flooding risks is to develop a uniform approach to exposure mapping, assessing risks, and developing actions across the region. A consistent approach will facilitate funding and action at local, regional, state and federal scales, providing the information and data necessary to pursue strategies ranging from legislative and regulatory changes to site specific strategies to address local vulnerabilities. As demonstrated by the ART program, conducting this work at the regional scale can also build capacity at the local level, and provide findings and actions at the regional, local, sector and component scales that can be used to jumpstart planning and action.

Why focus on understanding and addressing current and future flooding rise in the Bay Area?

While storm events and sea level rise will be an issue for all of California, the Bay Area faces some unique challenges as well as current opportunities that make it timely to advance a regional project with a focus on transportation assets and services. These include:

- The highest density development in the Bay Area was built along the shoreline on fill. This has resulted in numerous critical assets on or near the shoreline at a very low elevation with ad-hoc, or no shoreline protection.
- Based on findings from assessments to date, it is difficult to address this problem within a single agency or jurisdiction. Coordination among multiple jurisdiction and agencies is critical for successful adaptation. The Bay Area's nine-counties and the significant number of transportation and flood protection agencies makes this coordination challenging, and require work on these issues starts well before the region's people, infrastructure, economy and environment face these risks.
- A significant percentage of the Bay Area's critical transportation infrastructure is at risk from current and future flooding. This includes the majority of the region's interstates, rail lines serving passenger and cargo, two of the three international airports, several of the region's general aviation airports, and a number of the region's transit agency assets and services.

Figure 1. Foster City Transportation Infrastructure under SLR scenarios



	Exposure of transportation assets within area shown					
	2ft SLR		**3FT SLR**		**4FT SLR**	
	Miles	Acres	Miles	Acres	Miles	Acres
High Importance Roads	5.7	103.2	16.8	304.9	26.9	488.5
Local Connecting Roads	27.7	201.4	33.6	244.0	33.6	244.2
Local Roads / High Importance	33.5	203.0	50.4	305.3	51.5	312.2
Local Roads	60.1	364.1	79.7	482.9	79.9	484.4
Local Roads / Minor Importance	95.1	576.2	109.5	663.8	110.0	666.4

Current Opportunities

While the risks are significant, there is a great opportunity to build on the findings, recommendations and relationships that have been developed by work underway in the region. The current opportunities include:

- Using the findings and recommendations from the ART program and related efforts to jump-start work in other parts of the region.
- Strengthening the relationships that have been built through work across jurisdictions, agencies and sectors within efforts, such as ART. These cross-jurisdictional, multiple asset efforts not only allow for the development of actions that provide multiple benefits and protect multiple assets, they also allow different agencies, organizations, jurisdictions, interested parties, asset owners, community members and others to assess the potential risks and consequences together and, together, develop actions that work in the real world.

Why is it timely to address this issue now?

Communities throughout the region are undertaking adaptation planning at various scales and using differing approaches. The ART program and other efforts demonstrate that the region benefits greatly from coordination and consistency. With significant work already completed in Alameda and Santa Clara Counties and in the transportation and parks and recreation sectors, the region has a strong understanding of the issues and how to approach them to get to action. Ongoing and new projects getting underway need support. These include assessments in San Mateo County, Contra Costa County and Marin County, the Highway 37 Stewardship Study, the Regional Hazard Mitigation Plan update, and work on a resilience chapter for the region's Sustainable Communities Strategy. It is very timely to initiate an assessment and develop recommendations and support for the region to ensure consistency and efficiency for these efforts. In every ART effort, the participants consistently request this kind of action, and inquire what the region is doing on this issue. The Regional Assessment and Adaptation Project would fill this gap and ensure that the efforts around the region are well supported, consistent and resulting in outcome-oriented actions.

Why the Adapting to Rising Tides approach should be used to conduct the Regional Assessment and Adaptation Project.

The ART approach is a road-tested adaptation planning process that will ensure that assessment and adaption - from local, to county, to regional - are outcome-oriented with results that can be integrated across scales and sectors. ART has been developed, tested and refined based on experience doing the work and with valuable feedback from the agencies and organizations that participate in ART working groups. An important characteristic of the ART approach - which differentiates it from other adaptation planning processes - is the integration of sustainability into each step across all sectors and scales of the assessment and planning effort. Sustainability in ART includes society and equity, environment, economy and governance. Addressing governance challenges and opportunities is critical to achieving sustainable and successful adaptation; the issues at hand cannot be solved without the active engagement of community members, elected officials, the private sector, non-profits, and governments.

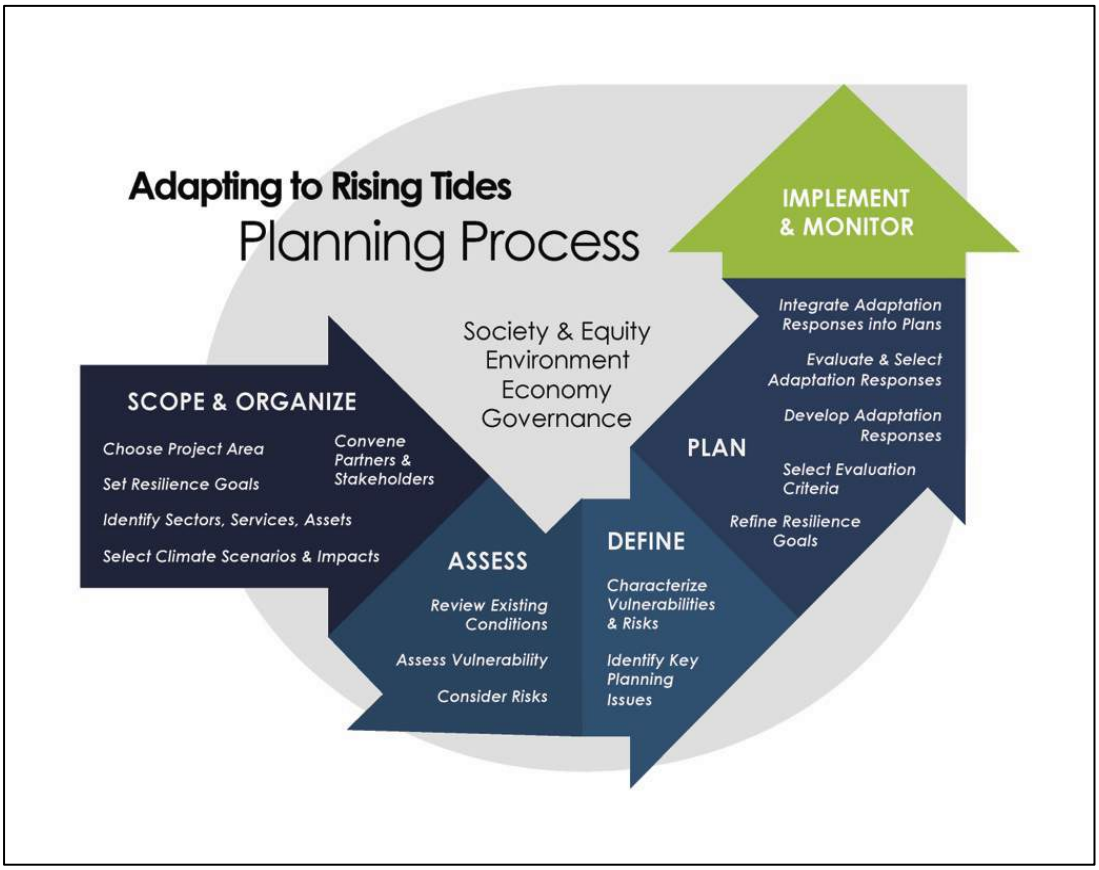
The core features of ART that will result in a successful Regional Assessment and Adaptation Project include:

- Considers sustainability from start to finish
  A core aspect of ART is consideration of the relevance and implications of all aspects of sustainability in each step of the planning process, from who is included in the initial working group list to what evaluation criteria are selected to evaluate adaptation responses.
- Convenes and engages a working group to build local capacity and ensure outcomes resonate locally
  ART convenes working groups with diverse perspectives and expertise that together develop a shared understanding of the issues, builds trust among stakeholders, and achieves buy-in for collaborative problem solving.
- Can be applied to different geographies, sectors and hazards
  ART builds an understanding of the underlying causes and components of vulnerability and consequences at different scales - from individual assets, systems and sectors, to large and small project areas, to different hazards including flooding and earthquakes
- Clear outcomes and communications materials
  ART develops summarized assessment findings that are concise and clearly communicate the planning issues in a manner approachable to a wide variety of audiences.

- Results in a robust and transparent vulnerability assessment that makes the case for adaptation
  To build a strong and actionable case for adaptation, ART adheres to transparent decision-making throughout the planning process. ART guidance, tools and information help maintain transparency and support clear communication to stakeholders about the decisions and project outcomes, including resilience goals developed and agreed upon by the working group and evaluation criteria that clearly lay out priorities and objectives.
- Establishes a clear roadmap for taking action
  ART establishes a clear road map for taking action on planning issues by collaboratively developing adaptation responses with one or more actions and options for making implementation real by clarifying roles and responsibilities, the timing and sequencing of actions, and the individual and collective next steps for getting started and possible funding sources and ways to include in existing plans, maintenance and practices.

The Adapting to Rising Tides Approach

Figure 1: Adapting to Rising Tides Planning Process



The steps in the ART approach to adaptation planning include:

I. Scope & Organize: Identify the scale of the project and the working group members. Determine the assets along the shoreline for the entire region that need to be protected. Develop resilience goals for the project with the working group to guide the work of the project.

II. Assess: Conduct detailed sea level rise and storm event mapping for the shoreline areas not included in other studies and analyze the extent, depth, and pathways of inundation caused by overtopping of specific shoreline segments. Use ART assessment questions to develop information and data about the assets included in the project area.

III. Define: Identify vulnerabilities and risks for assets and the consequences on the environment, economy, equity and governance.

IV. Plan: Develop multi-objective adaptation strategies at various scales that address the vulnerabilities and risks from sea level rise and storm events. Further refine applicable adaptation strategies that were developed as part of other studies. Develop evaluation criteria to prioritize adaptation responses and weigh their effects on the environment, economy, equity and governance.

V. Implement and Monitor: Develop and recommend adaptation responses that serve as a roadmap for taking action to address vulnerable assets / areas, and provide implementation plans.

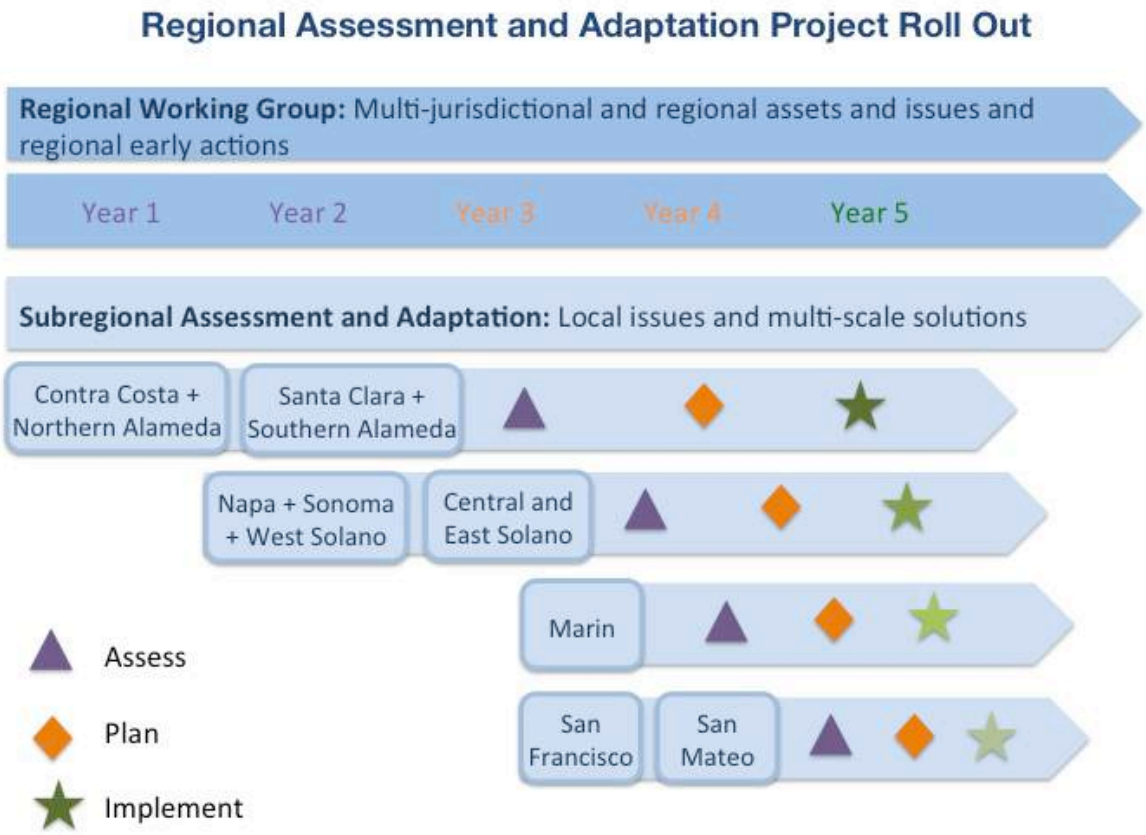
Expected Outcomes of the Regional Assessment and Adaptation Project

- Uniform vulnerability assessments across the entire region
- Identification of early actions and priority actions for transportation assets and services.
- Assessments of multiple assets, e.g., at the sector/system, representative asset, asset and component scales and at multiple scales, including agencies at the local, regional, state and federal scales.
- Identification of governance, information, functional and physical vulnerabilities that lead directly to developing appropriate timing and sequencing of actions, identification of key actor(s) to be involved, and the scale and priority of issues.
- Identification of owners and responsible actors for the local, regional, state and federal assets and functions in the region.
- Consequences of the failure or disruption of the assets and systems assessed.
- County/subregional and a regional-scale working groups to ensure that findings and outcomes are being addressed at appropriate scales.
- Building capacity within federal, state and local agencies, organizations and jurisdictions that work within each county to ensure assessments translate into action.
- Adaptation responses that include: the vulnerability addressed by the response; specific adaptation actions for the vulnerability; the actors that need to be involved for implementing the actions; the type, order and scale of the actions; possible funding mechanisms; and level of priority.
- Priority actions at agency, local, regional, state and federal scales.
- Regional agreement on the tools, processes, models and data used in adaptation planning.

Transportation Assets and Services

- Interstates (I-80, I-880, I-580)
- State Routes (SR-37, SR-237)
- US Route 101
- Toll plazas and bridge approaches
- Bay Area Rapid Transit and Caltrain
- Cargo and passenger rail
- Local streets and roads
- San Francisco International Airport
- Oakland International Airport
- Ports of Oakland, SF, Richmond
- San Francisco Bay Trail
- Ferry service
- Local transit providers

Project Elements and Timeline



I. Project Initiation

- First three months: Initiate project.
- Identify the resources already available, such as the existing ART Program website (ART Portfolio), ART findings and ART approach developed from previous projects, ART working group members and partners, ART team members, data and information regarding assets, systems, agencies and organizations, flooding scenarios and completed and on-going work of other agencies.
- Hire team members.
- Establish office space- location, hardware, software and other resources.
- Communicate the approach, project timeline, roles and responsibilities and outcomes with the appropriate regional and county Commissions and local agencies, organizations and jurisdictions through presentations, one and two page information sheets and possibly a regional or a set of subregional kick off meeting or meetings or a meeting in each county.

- Develop multi-year work plan for assessing all nine counties–including an identification of the phasing of the subregional work and the relationship between the vulnerability assessments and the development of the adaptation responses at the agency, local, subregional, regional, state and federal scales. Base the decision on phasing the subregional efforts on the outreach already conducted as part of the ART program, the communication initiated for this effort, regional and state priorities and existing information and data available for each subregion.
- Develop and issue requests for proposals for consultant assistance.

II. Subregional Assessments and Adaptation Development

The project will use the ART methodology developed in the ART Pilot project in Alameda County and refined in further ART efforts to conduct county scale assessments and develop adaptation responses for the region. The methodology will be refined in subregion to include existing reports, processes and local conditions as described in the county modules. Taken together, the work will result in outcomes and deliverables will result in a regional story of climate risk and response. Existing reports, plans, projects and studies conducted within each county or subregion will be evaluated at the initiation of each module so that relevant local and regional data and information can be leveraged. For example, where there is adequate data and information about a specific geography or sector, the scope of the county assessment will be adjusted to ensure an efficient use of staff, stakeholder, and partner resources.

	Pre-Roll Out	Year 1	Year 2	Year 3	Year 4	Year 5
Regional Integration Working Group		✚ Δ ◆ ★	✚ Δ ◆ ★	✚ Δ ◆ ★	✚ Δ ◆ ★	✚ Δ ◆ ★
Alameda ART Project Area	✚ Δ ◆	★	★	★	★	★
Contra Costa + Albany and Berkeley	✚	Δ	◆	★	★	★
Santa Clara + Fremont and Newark		✚ Δ	◆	★	★	★
Napa + Sonoma + Western Solano County			✚	Δ ◆	★	★
Central and East Solano			✚	Δ	◆	★
Marin			✚	Δ	◆	★
San Francisco				✚	Δ ◆	★
San Mateo				✚	Δ ◆	★

✚ = Working Group ◆ = Adaptation Responses
Δ = Assessment ★ = Implementation

III. Regional Integration

At the regional scale, a working group will be convened to enable the assessments and adaptation options developed at the county scale to consider the issues, assets and services that are regional in scale or cross county jurisdictional lines, and that there is an integration of the findings to support a regional understanding of the issues and the actions that are needed. The ART program has worked with a variety of agencies and organizations with local, regional, state-wide and federal interests, and would propose that these partnerships and collaborations continue, particularly with the Joint Policy Committee (JPC), the Federal Emergency Management Administration (FEMA), National Oceanic and Atmospheric Administration's Coastal Services Center (NOAA CSC), the Metropolitan Transportation Commission (MTC), the California Department of Transportation (CalTrans) and the Association of Bay Area Governments. The regional working group will be convened on an ongoing basis throughout the five-year project and will align work, data, resources, information, findings and processes from the subregional projects. The regional working group will also enable early action at the regional scale, including action on information and governance vulnerabilities, as well as building capacity to support county, local and sector specific efforts.

Next Steps – what happens beyond the 5 years?

How will this five-year project position the region to understand and respond to current and future flooding? Some of the on-going work that would be necessary to carry the region forward to implementing adaptation responses includes:

- Continue to use the ART program to bring on new information, data, resources, approaches and support to efforts at all scales.
- Identify early actions and priority actions for transportation assets and services.
- Support the implementation of early actions across jurisdictional and agency boundaries.
- Identifying and developing funding sources to implement adaptation actions.
- Construction, and monitoring adaptations to support adaptive management and to identify for thresholds for future actions.

Budget

Staffing (salary + benefits)

Position	Detail/Number	Expense
ART Program Director	1.0 FTE	$750,000
ART Projects Manager	1.0 FTE	$675,000
Program Logistics & Coordination	1.0 FTE	$600,000
Project Lead	1.0 FTE	$600,000
Project Lead	1.0 FTE	$600,000
Project Lead	1.0 FTE	$600,000
Project Lead	1.0 FTE	$600,000
Project Associate	1.0 FTE	$562,500
Project Associate	1.0 FTE	$562,500
Project Associate	1.0 FTE	$562,500
Subtotal:	**10.0 FTE**	**$6,418,125**

Equipment (one time purchases)

Budget Item	Detail/Number	Expense
Hardware	Laptops, desktop GIS computer, plotter, color printer/copier, internet 3G cards, presentation easels	$29,000
Software	ESRI ArcGIS, file sharing, project management	$20,000
Subtotal:		**$49,000**

Consultant Support

Budget Item	Detail/Number	Expense
Coastal engineering		$1,500,000
Geospatial analysis and mapping		$1,500,000
Planning and design: environmental, economic, land use		$1,500,000
Graphic Design and print production		$500,000
Website hosting and maintenance		$100,000
Subtotal:		**$5,100,000**

Logistics (materials and travel)

Budget Item	Detail/Number	Expense
Working Group Meetings	Name badges, refreshments, room rental fees	**$100,000**
Regional Steering Committee Materials	Name badges, refreshments, room rental fees	**$100,000**
Travel	Local travel to project and program meetings, in-state and out-of-state conferences and workshops	**$100,000**
Subtotal:		**$300,000**

Annual Budget – 5 year total

Subtotal (from above)		**$11,867,125**
Program overhead (15%)		**$1,780,069**
TOTAL		**$13,647,194**

Appendix: County Assessment and Adaptation Modules

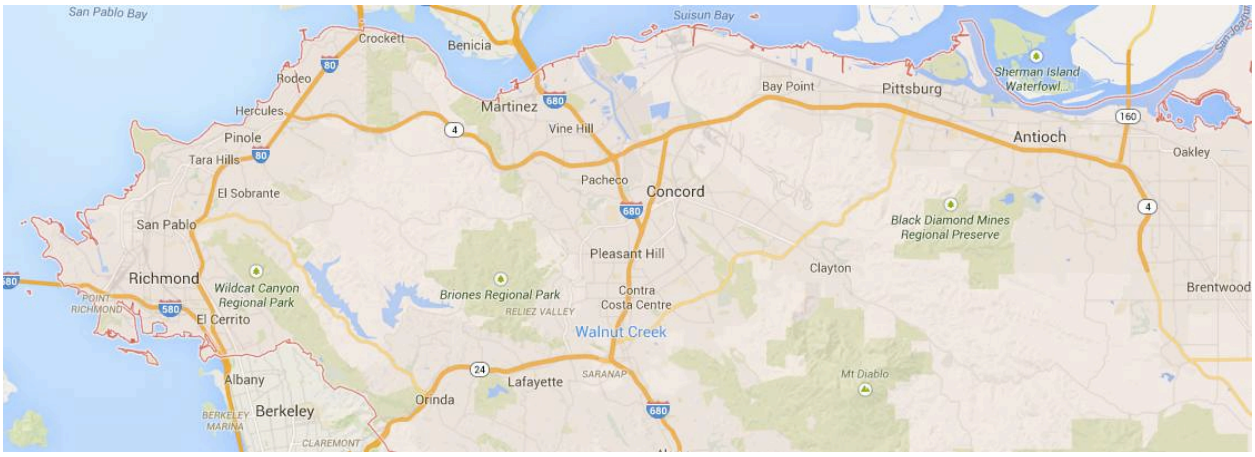
The project will use the ART methodology developed in the ART Pilot project in Alameda County and refined in further ART efforts to conduct county scale assessments and develop adaptation responses in all nine Bay Area counties. The methodology will be refined in each county to include existing reports, processes and local conditions as described in the county modules. Taken together, the work will result in outcomes and deliverables will result in a regional story of climate risk and response. Existing reports, plans, projects and studies conducted within each county will be evaluated at the initiation of each module so that relevant local and regional data and information can be leveraged. For example, where there is adequate data and information about a specific geography or sector, the scope of the county assessment will be adjusted to ensure an efficient use of staff, stakeholder, and partner resources.

The county-scale assessments will be multi-asset and will include locally and regionally significant transportation and transit assets and services such as:

- Interstates (I-80, I-880, I-580)
- State Routes (SR-37, SR-237)
- US Route 101
- Toll plazas and bridge approaches
- Bay Area Rapid Transit and Caltrain
- Cargo and passenger rail
- Local streets and roads
- San Francisco International Airport
- Oakland International Airport
- Ports of Oakland, SF, Richmond
- San Francisco Bay Trail
- Ferry service
- Local transit providers

Contra Costa + Northern Alameda County (Albany and Berkeley)

Working Group	*Vulnerability Assessment*	*Refined maps*	*Shoreline delineation*	*Overtopping analysis*
ART Project Working Group, first meeting March 2015	ART multi-sector assessment of west and central county initiated Dec 2014	No	Draft in review, April 2015	No



The Contra Costa County module will expand and build on the recently initiated ART multi-sector adaptation project in west and central Contra Costa County (from Richmond to Bay Point) to include the County's eastern shoreline and Albany and Berkeley in Northern Alameda County. The Contra Costa ART project is convening a stakeholder working group to help assess shoreline communities and infrastructure, including regionally significant highway corridors 1-80, I-580 and I-680, the Benicia-Martinez Bridge, most of the region's refineries, and the Union Pacific and Burlington Northern Santa Fe rail corridors.

The module will focus on developing a detailed understanding of regionally significant asset systems, such as the rail corridor, and focus areas within the county where local vulnerabilities could have regionally significant consequences. It will leverage the inter-agency ART Transportation Vulnerability Assessment and Adaptation Options projects (BCDC, MTC, Caltrans and BART). It will also leverage findings of ART focus area projects in Hayward and Oakland/Alameda, the Regional Housing and Community Risk project conducted by BCDC and ABAG, and ART working group member projects including Capitol Corridor's intercity passenger rail hot spots assessment and BART's Climate Adaptation Project.

Additionally, local studies of current and future flood hazard risk, such as the City of Berkeley's recently completed Local Hazard Mitigation Plan, the County's Northern Waterfront Economic Development Initiative, and the County's Lower Walnut Creek Restoration Project will be reviewed and relevant information will help to enrich the assessment of vulnerabilities and consequences and the selection of adaptation responses.

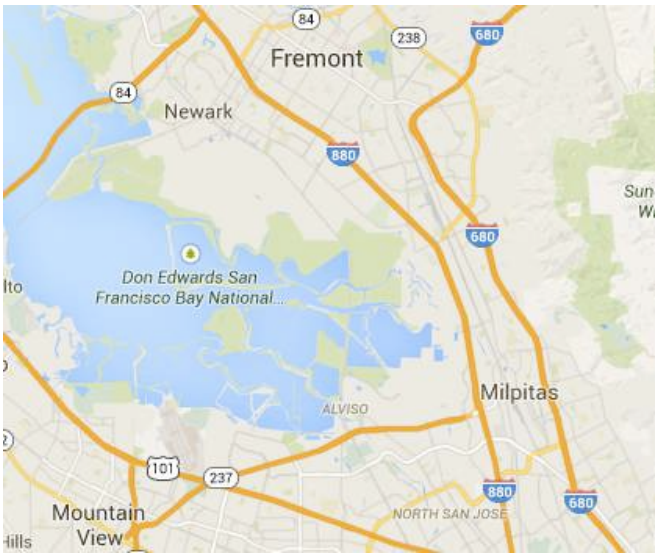
A suite of refined inundation maps, and a detailed shoreline delineation and overtopping analysis developed by Alameda County Public Works is available to support the this module. Additional analyses will be necessary for much of Contra Costa County shoreline, including the eastern shoreline. In particular, refined inundation maps and an overtopping analysis will be needed. The San Francisco Estuary Institute (SFEI) has completed a draft shoreline delineation using the ART Alameda County methodology with technical support from AECOM. The draft delineation has been and reviewed by county staff, and the final shoreline delineation is expected in April 2015.

Santa Clara + Southern Alameda County (Fremont and Newark)

Working Group	*Vulnerability Assessment*	*Refined maps*	*Shoreline delineation*	*Overtopping analysis*
No	SV 2.0 county-wide and sector scale assessment of all climate impacts including sea level rise	No	Yes, 2014	No

The module will include Fremont and Newark in Southern Alameda County and the Santa Clara County shoreline. It will focus on developing a detailed understanding of regionally significant asset systems, such as the rail corridor, and focus areas within the county where local vulnerabilities could have regionally significant consequences. It will leverage the inter-agency ART Transportation Vulnerability Assessment and Adaptation Options projects (BCDC, MTC, Caltrans and BART), the Regional Housing and Community Risk project conducted by BCDC and ABAG, and ART working group member projects including Capitol Corridor's intercity passenger rail hot spots assessment and BART's Climate Adaptation Project.

It will also build on information developed for the Silicon Valley 2.0 (SV 2.0) project, a countywide, sector-scale project that used an approach similar to the ART Alameda County project. Findings from SV 2.0 should therefore provide a reasonable amount of information that can be used in the module to develop a refined understanding of specific shoreline locations, assets, or asset systems to support the development of adaptation responses. The SV 2.0 Decision-Support Tool and Climate Adaptation Strategic Guide expected to be publicly available by April 2015.



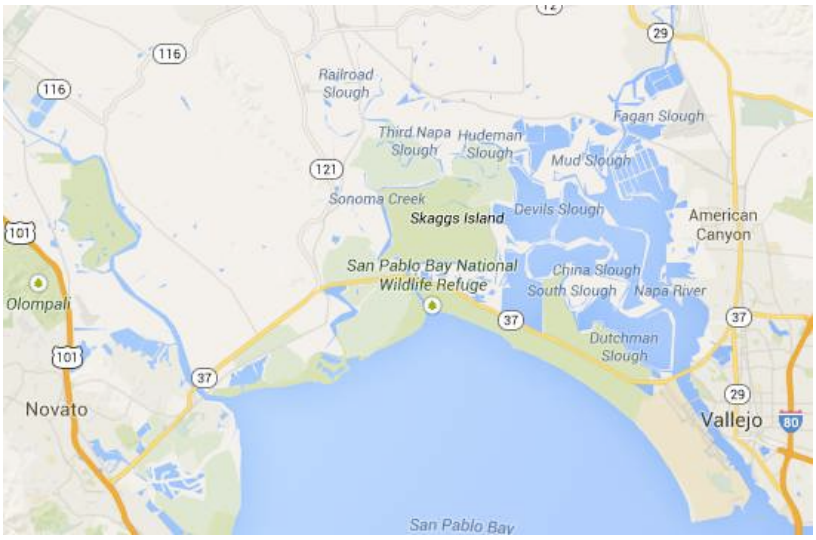
The module will also leverage the South San Francisco Bay Shoreline Study, which is a joint project of U.S. Army Corps of Engineers, the Santa Clara Valley Water District and the State Coastal Conservancy.

A suite of refined inundation maps and detailed shoreline delineation and overtopping analysis developed by Alameda County Public Works is available to support this module, however refined inundation maps and an overtopping analysis will be needed for Santa Clara County. The Santa Clara County shoreline has been delineated using the ART methodology developed in Alameda County by the SV 2.0 project. Current efforts of the Santa Clara Valley Water District to better understand the shoreline topographic features that provide flood protection features will be leveraged in this effort. Lastly, local studies of current and future flood hazard risk will be reviewed and all relevant information will be used to enrich the assessment findings.

Napa + Sonoma + Western Solano County

Working Group	*Vulnerability Assessment*	*Refined maps*	*Shoreline delineation*	*Overtopping analysis*
No	No	Limited and in progress, for Hwy 37 project	In progress, April 2015	No

The Napa + Sonoma + Western Solano County module will being with a review of all relevant existing reports, plans, projects and studies conducted in the counties to determine how and if they can support the assessment to be conducted. A critical study that will be investigated is the Highway 37 Stewardship Study that is investigating strategies to improve current and future resilience of the Highway 37 corridor along the Solano, Napa and Sonoma County shoreline. This project is bringing together transportation and environmental agency partners and resources protection agencies to collaboratively finding a context-appropriate solution to the challenges that may come with sea level rise. The module will also leverage the inter-agency ART Transportation Vulnerability Assessment and Adaptation Options projects (BCDC, MTC, Caltrans and BART), the Regional Housing and Community Risk project conducted by BCDC and ABAG and the ART working group member Capitol Corridor's intercity passenger rail hot spots assessment.

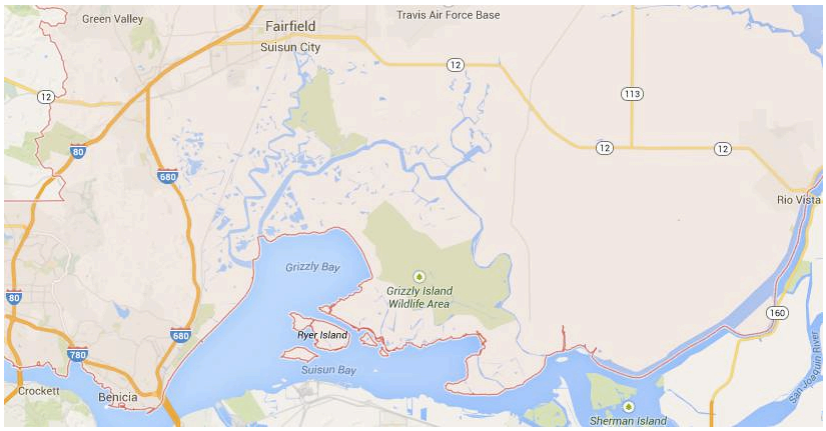


Additionally, local and county efforts to understand and address current and future flood hazard risks will be reviewed and all relevant information will be used to enrich the assessment findings. The Sonoma County Climate Action 2020 study, published in December 2014 by the Regional Climate Protection Authority and the North Bay Climate Adaptation Initiative, is a broad level adaptation analysis and vulnerability study that evaluated potential impacts current and future hazards may have on residents, built infrastructure, and natural and working lands. Sonoma County is also working to update the outer coast Local Coastal Plan to incorporate climate change including sea level rise.

A limited number of refined inundation maps are being developed for the Highway 37 Stewardship Study, and will be available to support the module as well as efforts to better understand the shoreline topographic features that provide flood protection features will be leveraged in this effort. The San Francisco Estuary Institute (SFEI) has completed a draft shoreline delineation using the ART Alameda County methodology with technical support from AECOM. The delineation is in progress and is expected to be complete in April 2015.

Central and East Solano County

Working Group	*Vulnerability Assessment*	*Refined maps*	*Shoreline delineation*	*Overtopping analysis*
No	Yes, City of Benicia only	Limited and in progress, for Hwy 37 project	In progress, April 2015	No



The Central and East Solano County module will being with a review of all relevant existing reports, plans, projects and studies conducted in the county to determine how and if they can support the assessment to be conducted. A critical study that will be investigated is the Highway 37 Stewardship Study that is investigating strategies to improve current and future resilience of the Highway 37 corridor along the Solano, Napa and Sonoma County shoreline. This project is bringing together transportation and environmental agency partners and resources protection agencies to collaboratively finding a context-appropriate solution to the challenges that may come with sea level rise.

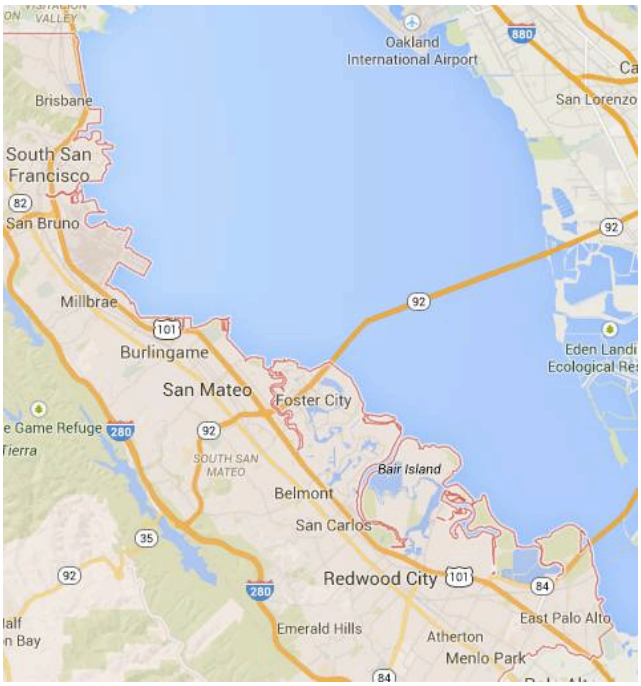
The module will build from and leverage findings local studies such as the City of Benicia Vulnerability Assessment and Adaptation project, which begin in July 2014 and will conclude in July 2015. This local scale project applied the ART approach to engage local stakeholders, including members of the public, to assess the vulnerability of shoreline infrastructure and natural habitats. Based on the assessment findings climate strategies were developed, evaluated, and prioritize with input from community members, City staff, and various local, regional, and state agencies. The module will also leverage the inter-agency ART Transportation Vulnerability Assessment and Adaptation Options projects (BCDC, MTC, Caltrans and BART), the Regional Housing and Community Risk project conducted by BCDC and ABAG and the ART working group member Capitol Corridor's intercity passenger rail hot spots assessment.

Additional shoreline analyses will be necessary for much of the Solano County shoreline, including the eastern shoreline. In particular, refined inundation maps and an overtopping analysis will be needed. The San Francisco Estuary Institute (SFEI) has completed a draft shoreline delineation using the ART Alameda County methodology with technical support from AECOM. The delineation is in progress and is expected to be complete in April 2015.

San Mateo

Working Group	*Vulnerability Assessment*	*Refined maps*	*Shoreline delineation*	*Overtopping analysis*
Maybe, SCC Funded Project	No	No	In progress, April 2015	No

The San Mateo County module will being with a review of all relevant existing reports, plans, projects and studies conducted in the county to determine how and if they can support the assessment to be conducted. Critical studies to be investigated include a county-wide adaptation planning process for both the bayside and outer coasts that will be initiated in 2015, a local project in Mountain View that analyzed the vulnerability of the shoreline to 8 and 32 inches of sea level rise, and identified and prepared cost estimates for strategies to address the flood risk.



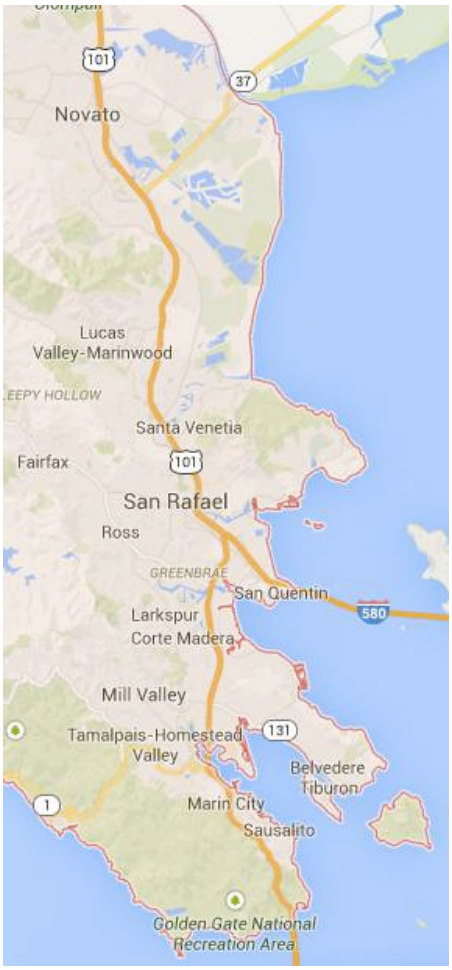
The module will leverage the inter-agency ART Transportation Vulnerability Assessment and Adaptation Options projects (BCDC, MTC, Caltrans and BART, the Regional Housing and Community Risk project conducted by BCDC and ABAG, and BART's Climate Adaptation Project.

Additional shoreline analyses will be necessary, including refined inundation maps and an overtopping analysis will be needed. The San Francisco Estuary Institute (SFEI) has completed a draft shoreline delineation using the ART Alameda County methodology with technical support from AECOM. The delineation is in progress and is expected to be complete in April 2015.

Marin County

Working Group	*Vulnerability Assessment*	*Refined maps*	*Shoreline delineation*	*Overtopping analysis*
No	No	No	Draft in review, April 2015	No

The Marin County module will being with a review of all relevant existing reports, plans, projects and studies conducted in the county to determine how and if they can support the assessment to be conducted. Critical studies to be investigated include the Southern Marin Pilot Project, San Rafael's Sea Level Rise White Paper, and the C-SMART project to update outer coast Local Coastal Plans to incorporate climate change including sea level rise.



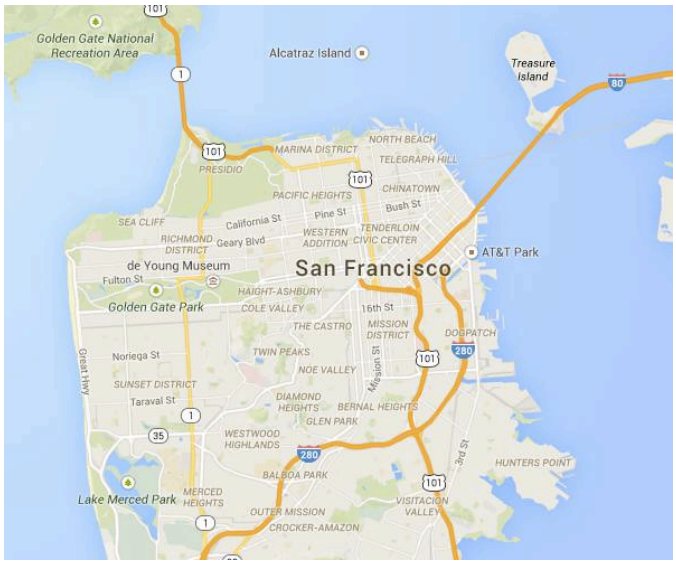
The module will leverage the inter-agency ART Transportation Vulnerability Assessment and Adaptation Options projects (BCDC, MTC, Caltrans and BART, the Regional Housing and Community Risk project conducted by BCDC and ABAG, and BART's Climate Adaptation Project.

Additional shoreline analyses will be necessary for Marin County, including refined inundation maps and an overtopping analysis. The San Francisco Estuary Institute (SFEI) has completed a draft shoreline delineation using the ART Alameda County methodology with technical support from AECOM. The delineation is in progress and is expected to be complete in April 2015.

San Francisco

Working Group	*Vulnerability Assessment*	*Refined maps*	*Shoreline delineation*	*Overtopping analysis*
Maybe, SF Adapt	No	Yes, 2014	Yes, 2014	Yes, 2014

The San Francisco County module will being with a review of all relevant existing reports, plans, projects and studies conducted in the county to determine how and if they can support the assessment to be conducted. Critical studies to be investigated include the San Francisco Public Utility Commission's Bayside Urban Watershed Planning study and Sewer Service Improvement Program, a 20-year, multi-billion dollar citywide program to upgrade aging sewer infrastructure to ensure a reliable and seismically safe sewer system that is resilient to climate change. In addition, the Port of San Francisco's Waterfront Seawall study to assess seismic vulnerability will be used to understand the impact of a failure of this critical flood and shoreline protection infrastructure. This module will also leverage efforts of the inter-agency San Francisco Climate Adaptation Working Group (SF Adapt). This group is focusing on understanding and addressing sea level rise along Ocean Beach and shores, flooding from storm surges and extreme rain events, an increased likelihood of extreme heat, and decreased fog that supports the region's iconic redwoods and local ecosystems.



The module will leverage the inter-agency ART Transportation Vulnerability Assessment and Adaptation Options projects (BCDC, MTC, Caltrans and BART, the Regional Housing and Community Risk project conducted by BCDC and ABAG, and BART's Climate Adaptation Project.

A full suite of refined inundation maps, a shoreline delineation and an overtopping analysis developed by the San Francisco Public Utility Commission's Sewer Service Improvement Program using the ART methodology are available to support this module.

Current Assessment, Adaptation, Implementation Status

	Scope	Assess				Plan	Implement
	Working Group	**Vulnerability Assessment**	**Refined sea level rise and storm maps**	**Shoreline delineation**	**Overtopping analysis**	**Adaptation Responses**	**Action Feasibility and Initiation**
Alameda	Yes, ART Alameda County	Yes, ART for most of county	Yes, 2014	Yes, 2014	Yes, 2014	Yes, sector and asset scale	No
Contra Costa	Yes, ART Contra Costa County	Yes, ART initiated for west and central county	No	Draft in review	No	No	No
Marin	No	No	No	Draft in review	No	No	No
Napa	No	No	Limited and in progress, for Hwy 37 project	In progress	No	No	No
San Francisco	Maybe, SF Adapt	No	Yes, 2014	Yes, 2014	Yes, 2014	No	No
San Mateo	Maybe, SCC Funded Project	No	No	In progress	No	No	No
Santa Clara	No	Yes, SV 2.0	No	Complete	No	No	No
Solano	No	Yes, City of Benicia only	Limited and in progress, for Hwy 37 project	In progress	No	Yes, city only	No
Sonoma	No	Maybe	Limited and in progress, for Hwy 37 project	In progress	No	No	No

County Assessment and Adaptation Modules:

Project Steps and Tasks

Step I. Scope and Organize

Define the area and assets to be considered, convene a stakeholder working group, identify and communicate the climate impacts, set project goals, and agree on communications practices.

Resources needs/time requirements:

Project Team (ART Project Manager, Project Lead, 1 or 2 Project Associates)

- Draft workplan and project scoping documents; prepare for /follow-up to first Working Group meeting.

Working Group:

- Attend one 3-hour meeting; follow-up with project team as needed, including participating in subcommittee meeting.

Program Communications:

- Set up project website; assist team with creating a library of communications content for project (e.g., photos, graphics, presentation template, etc)

Program Logistics & Coordination:

- Develop project contacts list; meeting coordination; posting to website.

Geospatial Analyst:

- Set-up project basemap/layers; prepare project area map.

Deliverables and outcomes:

- Project description, including project goals and objectives, work schedule.
- Project area.
- Working Group and subcommittees (if appropriate).
- Roles and responsibilities: Project Team, Working Group, Stakeholders.
- Communication practices and audiences for the outcomes.
- Asset categories/sectors.
- Project resilience goals.

Tasks:

1. Research and review reports, plans, projects and studies that can inform the project

2. Identify and reach out to key project partners and stakeholders

3. Prepare proposed project scope to share with key project partners:

- Proposed project boundary.
- Draft list of asset categories and sectors to be addressed, and proposed level of assessment.
- Draft list of working group members, stakeholders and project team members.
- Proposed roles and responsibilities, communications practices and audiences.

4. Hold project kick-off meeting to convene Working Group, and learn about and agree on:

- Expected project outcomes, communications practices and roles and responsibilities.
- Project area, a list of assets to be addressed.

5. Finalize project scope, including:

- Invite additional participants to join the working group if necessary.
- Finalize project area boundary and create map demonstrating the project boundary and key orienting features and select assets in GIS.
- Finalize asset categories and sectors to be included and level of analysis, follow up with individual working group members, issue experts and others as necessary.
- Meet with communications subcommittee (if appropriate) to finalize communications practices.
- Use working group input to draft project resilience goals and share with working group for their review and input.

Step II. Conduct the Assessment

Conduct an assessment of vulnerabilities and consequences in the project area, and determine when and if assets will be exposed to the selected climate impacts.

Resources needs/time requirements:

Project Team (Project Lead, 1 or 2 Project Associates):

- Conduct assessment including exposure analysis, gather and refine assessment answers, plan for / follow up after second working group meeting.

Working Group:

- Review and ground-truth assessment answers; provide additional information as needed; attend and/or host field visits; attend one 3-hour working group meeting; participate in subcommittee meeting as needed.

Program Logistics & Coordination:

- Meeting coordination; posting to website.
- Geospatial Analyst.
- Prepare asset exposure maps.

Deliverables and outcomes:

- Climate scenarios and impacts statements.
- Compiled assessment data and information for existing conditions, vulnerability, and consequences; confirmed by Working Group and other technical experts.
- Identified gaps in available information and data.
- High level analysis of climate impacts exposure.

Tasks:

1. **Draft climate scenarios and impacts statement, review and summarize best available maps, models, and analyses available, and evaluate asset exposure to the selected climate impacts**
2. **Hold a working group meeting to introduce the assessment:**
   - Describe and obtain input on the assessment process/methods.
   - Present and obtain input on the climate scenarios and impacts, available maps, models and analyses to help evaluate exposure.
   - Obtain feedback on the asset scales to be included in the assessment.

3. **Develop and compile assessment information and ground-truth with Working Group members and other relevant stakeholders:**
   - Develop preliminary assessment answers and share with working group members, asset managers, jurisdiction or owner, those with local knowledge, or those with topical expertise.
   - Provide the maps and climate impacts analysis to technical subcommittee or working group members and ask them to review to ground truth them based on local knowledge of flood management infrastructure and experience during current and past flooding (this review may need to be done with a small group of technical advisors).
4. **Identify information gaps**
5. **Incorporate working group input and finalize the assessment**

Step III. Determine Assessment Outcomes

Summarize answers to the assessment questions as clear, outcome-oriented vulnerability and consequence statements.

Resources needs/time requirements:

Project Team (Project Lead, 1 or 2 Project Associates):

- Summarize assessment outcomes in draft profile sheets; plan for / follow up after third working group meeting.

Working Group:

- Three-hour meeting; two to three hours to review profile sheets and follow up with project team if needed.

Program Communications:

- Assist with layout of finalized profile sheets.

Program Logistics & Coordination:

- Meeting coordination; posting to website.

Deliverables and outcomes:

- Profile sheets that summarize issues, vulnerabilities and consequences for assets addressed in the project.
- An understanding of the unique, shared and overarching vulnerabilities, dependencies and relationships among assets.

Tasks:

1. **Review compiled information from the assessment questions, and develop vulnerability and consequence statements for the assets, sectors, services, agencies or organizations evaluated**
2. **Draft summary profile sheets to be shared with working group members for review and input**
3. **Identify assets, sectors or services that have similar characteristics, conditions or challenges; have particular, or unique, issues, and/or are vulnerable because they are reliant or dependent on other vulnerable assets**
4. **Hold a working group meeting to present and obtain input on the assessment outcomes:**
   - Present final findings of the climate impacts analysis.
   - Discuss observations and outcomes from the field visits (if conducted).
   - Present vulnerability and consequence findings for all or representative assets.
   - Provide draft summary profile sheets for review and feedback.
   - Obtain input on shared, unique, and overarching vulnerabilities, and confirm physical and organizational dependencies and relationships among assets, services and sectors.
5. **Revise the profile sheets with feedback, and update the profile sheets with draft issue statements**
6. **Finalize and share with working group summary profile sheets and high level findings about shared, unique, and overarching vulnerabilities**

Step IV. Define Key Planning Issues

Define and confirm key planning issues, refine project resilience goals.

Resources needs/time requirements:

Project Team (Project Lead, 1 or 2 Project Associates):

- Develop proposed key planning issues and draft adaptation responses; plan for / follow up after Working Group meeting.

Working Group:

- Attend one 3-hour meeting; follow-up with project team as needed, including participating in subcommittee meeting.

Program Logistics & Coordination:

- Meeting coordination; posting to website.

Deliverables and outcomes:

- Confirmed key planning issues to be addressed in the next step.
- Resilience goals that are relevant in light of assessment outcomes.
- Draft adaptation responses.

Tasks:

1. **Develop draft proposed key planning issues for the project**
2. **Review project resilience goals, and based on the assessment outcomes, revise if necessary**
3. **Determine how the adaptation responses will be organized, the type of information to be included, and the level of specificity**
4. **Hold a Working Group meeting to:**
   - Review project resilience goals and discuss if they need to be refined based on the outcome of the assessment.
   - Introduce the Plan step components and expected outcomes, including the organization of the adaptation responses and the type and specificity of information to be included.
   - Discuss and get feedback on proposed key planning issues to be addressed in this next step.
5. **Incorporate input:**
   - Finalize project resilience goals (if revised) based on working group input.
   - Finalize the key planning issues, revisit assessment outcomes to make sure no important issues were left behind, and share with working group.
   - Catalog any asset vulnerabilities or key issues that will not be carried forward for further working group consideration. Note if they should be taken up in the future, either in further collaborative efforts or individually by agencies, organizations or communities.

Step V. Developing Adaptation Reponses

Develop adaptation responses for the key planning issues that lay a clear and transparent path towards implementation.

Resources needs/time requirements:

Project Team (Project Lead, 1 or 2 Project Associates):

- Develop draft adaptation responses; plan for / follow up after Working Group meeting.

Working Group:

- Attend one 3-hour meeting; follow-up with project team as needed, including participating in subcommittee meeting.

Program Communications:

- Assist with layout/preparation of engagement exercise materials.

Program Logistics & Coordination:

- Meeting coordination; posting to website.

Deliverables and outcomes:

- Adaptation responses for the project's key planning issues.

Tasks:

1. Develop draft adaptation responses:

- Conduct research on the adaptation responses, strategies, actions, and implementation options that have been developed by others for similar assets, sectors or services.
- Contact individual working group members, or local and national topical experts, and ask for their best professional judgment on the actions and implementation options that will be the most practical, feasible, and responsive to the issues identified.
- Develop adaptation actions and implementation options for the agreed-upon key planning issues.

2. Hold a Working Group meeting to present draft adaptation responses and obtain working group feedback

3. Review feedback from the working group and revise adaptation responses, and if necessary develop new adaptation responses

4. Prepare and provide to the working group revised summary profile sheets with example actions for review and input

Step VI. Evaluating and Selecting Adaptation Responses

Evaluate adaptation responses against project resilience goals and the four sustainability frames (society and equity, environment, economy and governance).

Resources needs/time requirements:

Project Team (Project Lead, 1 or 2 Project Associates):

- Develop draft evaluation criteria; plan for / follow up after Working Group meeting.

Working Group:

- Attend one 3-hour meeting; follow-up with project team as needed.

Program Logistics & Coordination:

- Meeting coordination; posting to website.

Deliverables and outcomes:

- A set of evaluation criteria to help the working group identify benefits and trade-offs of the different adaptation responses.
- Summarized outcomes of applying the evaluation criteria to the adaptation responses.

Tasks:

1. Develop draft evaluation criteria that will help the working group weigh benefits and trade-offs of each adaptation response against the project resilience goals and the four sustainability frames:

- Determine how to apply the evaluation criteria, e.g., qualitative criteria such as yes/no, or quantitative criteria such as ordinal ranking or numeric ranges, considering the quality of available data and information and how best to maintain transparency and clarity.
- Apply the draft criteria to a number of example adaptation responses to test out the approach and identify any hurdles or information gaps that will need to be overcome.

2. Hold a meeting to evaluate adaptation responses using selected criteria:

- Present proposed evaluation criteria and the approach to applying them
- As a group apply the evaluation criteria to a number of example adaptation responses and discuss how the criteria work and if they need to be adjusted.
- Discuss how and if to prioritize or narrow the adaptation responses to be evaluated based on expected project outcomes, resources available, the collective and individual needs of the working group, the type of vulnerability addressed or the timing and magnitude of the potential consequences.

3. **Adjust evaluation criteria based on working group input:**
   - Evaluate adaptation responses (all or a sub-set) using selected criteria.
   - Summarize outcomes of the evaluation and share with working group members.

Step VI. Opportunities for Implementation

Develop recommendations for advancing high priority adaptation responses and further collaborations.

Resources needs/time requirements:

Project Team (Project Lead, 1 or 2 Project Associates):

- Develop recommendations for high priority adaptation responses; plan for / follow up after Working Group meeting; follow-up meetings with Working Group members.

Working Group:

- Attend one 3-hour meeting; additional small-group, or one-on-one meetings with project team as needed.

Program Communications:

- Assist development of communications materials for project outcomes.
- Program Logistics & Coordination.
- Meeting coordination; posting to website.

Deliverables and outcomes:

- Outcomes are summarized and communicated to support the working group in implementing adaptation responses and making the case for continued participation in collaborative adaptation planning.
- A set of recommendations for advancing high priority adaptation responses that require shared, coordinated action.
- Working group members launch new efforts and collaborations that will have a “life of their own”.

Tasks:

1. **Identify actions that are ready for implementation and those that are ready but lack funding**
2. **Identify actions from the adaptation responses that need further refinement or feasibility assessments, changes in governance or regulations, or the addition of new partners and participants**

3. **Craft a set of recommendations for advancing and funding actions that are ready to be implemented**
4. **Review actions that are not ready for implementation, and identify those that are most in need of immediate further collaboration**
5. **Hold one-on-one discussions with working group members and stakeholders to hear their ideas on what next steps are needed**
6. **Hold a meeting(s) to present and obtain input on opportunities for implementation and further collaboration:**
   - Present recommendations for advancing and funding "ready to go" adaptation responses and actions.
   - Discuss if there are next steps that project participants can take either individually or collectively to initiate ready to go actions, including getting buy-in from decision makers, and what next steps need to be taken for those that need further consideration.
   - Confirm next steps, discuss who will lead them, and determine a schedule and roadmap for their initiation.
7. **Finalize and share with working group members recommendations for advancing and funding "ready to go" adaptation responses, and for initiating additional assessments, feasibility studies, new efforts, or further collaborations**
8. **Follow up with those identified to lead any next steps to support them in the initiation of these efforts, including facilitating further collaborations, setting up meetings, connecting stakeholders directly, etc.**

San Francisco Bay Conservation and Development Commission
455 Golden Gate Avenue, Suite 10600, San Francisco, California 94102 tel 415 352 3600 fax 415 352 3606

California State Senate Committee on Environmental Quality
Oakland City Hall, City Council Chamber, 3rd Floor
1 Frank H. Ogawa Plaza
Oakland, California

May 29, 2015

Bay Area Regional Adaptation Efforts to Climate Change Impacts
Testimony of R. Zachary Wasserman, Chair
San Francisco Bay Conservation and Development Commission

Chair Wieckowski:

Thank you very much for holding this important hearing on regional climate change adaptation in my hometown of Oakland. I am Zack Wasserman. Governor Jerry Brown appointed me Chair of BCDC a little over three years ago. I am honored to give this testimony to a Committee whose Chair is a former BCDC Commissioner! Larry Goldzband, BCDC's Executive Director, accompanies me today.

BCDC is celebrating its 50th Anniversary this September. Since that time, BCDC has exercised direct regulatory authority over projects that propose to fill, or extract materials from, the Bay and has authority to maximize public access impacts within the Bay's 100-foot shoreline band. BCDC has approved projects worth billions of dollars, and we are proud of the Commission's record and commitment to work closely with all applicants – private and public – from a project's initial stages to ensure that they comply with state law. We continue to do so while we reassess how we can and should live with the Bay as it grows due to rising sea level. I have attached our much longer testimony before the Little Hoover Commission in late 2013 that describes in more detail BCDC's history, jurisdiction, authority, and regulatory and planning actions regarding rising sea level.

Since the passage of AB 2094 in 2008, BCDC has been the State agency responsible for leading the Bay Area's preparedness for, and resilience to, rising sea level, tides, and storm surge due to climate change. You will remember BCDC's efforts to amend the Bay Plan a few years ago to require project vulnerability assessments and adaptation measures such as resilient design, and the controversy that ensued. BCDC substantially revised its original plan to gain the support of local governments, the private sector, and the environmental community. Our policies now require projects to be resilient to rising sea level through at least mid-century – and beyond, given the project's expected life. Just as important, the amendments directed that a regional adaptation strategy be developed by the Bay Area's regional agencies.

Before I detail how BCDC is leading a collaboration of state, regional, and local government agencies to create and implement a regional adaptation and resilience strategy, I want to set the context in which adaptation is being discussed by BCDC and its collaborators.

Successful adaptation planning and implementation require all levels of government to act collaboratively with all public and private property owners within our jurisdiction and beyond who are affected by rising sea level. In some ways, this can be more complex than mitigation due to a host of governance issues, including local land use prerogatives and existing property rights. Complicating this task is our inability to forecast the extent to which our lives will change due to a rising Bay because we cannot fully predict that future. But I do commend Marin County's attempt, with its partners, to visualize what could happen to the shoreline off Mill Valley. A description of this effort is attached to my testimony.

To accomplish these challenges, and others, I think of our efforts as the vanguard of a five- to ten-year campaign to educate the public about three things: what we can do to adapt to rising sea level; what we should do considering reasonable priorities and unforeseen consequences; and, just as important, how we can fund successful adaptation strategies. At least five facts make this campaign very complex:

1. **Assets are Networked:** Individual assets such as highways, mass transit systems, railroads, airports, seaports, and wastewater treatment plants should be rehabilitated, adapted, or changed on a coordinated, not piecemeal basis. Passengers can't get to SFO without using 101 or BART, goods cannot be shipped from the Port of Oakland without using a truck or a rail car to get them there, and both wastewater treatment plants and endangered species need the Bay. These assets form a complex interwoven network that is only as strong as its weakest link and will only work together in the face of rising sea level if the entire network is analyzed and planned holistically and at a large enough scale. I have attached to my written testimony a third handout that demonstrates how the Bay Area's highway network is at risk and in need of complex and difficult community-based adaptation planning.

2. **Collaboration is Challenging:** Large-scale planning can succeed only when all public sector asset holders collaborate well with willing private sector and NGO partners, which is difficult, time-consuming, and expensive. We have been working with our Bay Area partners on adaptation for a few years, but the private sector, in general, is not yet at the table.

3. **Assets at Risk are Place-Based:** The assets I have spoken of so far are place- based and fixed, both literally and economically. They are expensive to buy, to replace, and to move.

4. **Underserved Communities Must be Part of any Solution:** Our discussion of assets and actions must include the most important asset of all – the public. Communities of interest, including underserved communities who have not taken part in many land use decision processes and too often do not have a voice that is heard, must be invited and encouraged to participate actively and constructively in this collaborative process and not be left behind.

5. **Time is a Valuable Asset:** We cannot plan now for the next hundred years. But we can and must plan for the next fifty years, and ensure that our decisions do not foreclose our children's, and their children's, options long after we depart.

The Governor's recent Executive Order is an excellent start to ensure that all of us in the Resources Agency and within state government collaborate internally and externally on our adaptation planning efforts. Now, I would like to talk briefly about the ways in which BCDC is fulfilling the Governor's directive.

1. **Adapting to Rising Tides (ART):** BCDC's groundbreaking ART program is a collaborative approach that assesses a community's vulnerabilities to rising sea level and works with local governments and special districts, businesses, residents, and other stakeholders to develop and implement a variety of adaptation approaches. This "retail" approach to adaptation planning is complex, time-consuming, expensive, **and critical**; it will require $12M to $15M over four years to complete the process regionwide. These community-led planning efforts are necessary to address multiple networked challenges in the densely developed shoreline areas and to strengthen networked infrastructure across multiple jurisdictions. The fourth attachment to this testimony is a summary of how stakeholders in Hayward have successfully developed a variety of such strategies. BCDC is now creating a "Help Desk" to disseminate our work to other jurisdictions. BCDC is

actively seeking funds within the Administration to implement ART throughout the nine-county Bay Area. Last year, the Legislature considered SB 1184 by Senator Hancock, which would have provided funding for ART, but it was held in the Appropriations Committee.

2. **Working Groups on Rising Sea Level and Bay Fill Policies:** BCDC has created two Commissioner-led working groups to advance our adaptation efforts. The Rising Sea Level Working Group is learning more about how adapt to an uncertain future and how to communicate about adaptation to further the campaign I spoke of earlier. The Bay Fills Working Group is working alongside a multi-stakeholder technical advisory group and BCDC staff to determine whether and/or how BCDC should revise its existing Bay fill policies that were conceived when the Bay was rapidly shrinking in the 1960s. Now that the Bay is growing, issues that will come to the forefront include where and how best to use natural and manmade structures and how to evaluate such projects that are "fill" under state law.

3. **Bay Area Regional Collaborative (BARC):** State and regional government agencies must work closely and cooperatively with local governments on adaptation issues. BARC, formerly known as the Joint Policy Committee, is now primarily devoted to climate change issues. ABAG, MTC, and BCDC are working together on adaptation issues both formally and informally through BARC, most notably with the Coastal Conservancy, as well, to develop the new "sustainability" chapter of the upcoming 2017 Sustainable Communities Strategy. Local elected officials form the vast majority of BARC Commissioners, and constantly ensure that the agencies collaborate with local governments on the ground.

4. **Natural Resources Agency:** The Natural Resources Agency is leading adaptation initiatives across the State government. The Ocean Protection Council is aggressively and appropriately ensuring that the State's coastal managers, including BCDC, collaborate on adaptation issues. Publication of "Safeguarding California," which identifies adaptation and risk management strategies, is one example of internal Administration coordination, collaboration, and partnership. In September, the Agency will release implementation action plans for the nine sectors identified in Safeguarding California to highlight successes and address gaps in adaptation efforts so far. While each of our challenges is different based upon the places that we regulate or manage, we continue to learn from, and provide guidance to, each other.

5. **Alliance for Climate Resilience (ACR):** BCDC is an original member of ACR, which includes state, regional, and local government representatives, the new Climate Readiness Institute formed by the University of California and Stanford, and philanthropists and environmental justice advocates. Our Commissioners expect that any successful regional adaptation strategy must not put underserved communities who are currently at risk from inundation at any further risk and, instead, must listen to their representatives and account for how those communities prosper in the future.

Let me finish by commenting on SB 246, legislation introduced by Senator Wieckowski to legislatively mandate a "Climate Action Team" headed by the CalEPA Secretary. The Commission has directed staff to work with your office to determine how this could best work, especially in light of the need to "thread the needle" between managing the Administration's collective work while recognizing that successful adaptation requires on-the-ground planning

across jurisdictions. We believe that there is room for discussion and we look forward to working with you as the State moves forward with the active involvement of the Legislature and the leadership of the Governor.

This completes my testimony, Mr. Chairman, and we look forward to answering your questions.

SAN FRANCISCO BAY CONSERVATION AND DEVELOPMENT COMMISSION
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R. Zachary Wasserman, Chair
San Francisco Bay Conservation and Development Commission

Testimony Before the
Milton Marks Commission on California State Government Organization and Economy
(Little Hoover Commission)

Public Hearing on California Climate Change Adaptation Strategies
October 24, 2013
State Capitol, Room 437

The San Francisco Bay Conservation and Development Commission (BCDC or the Commission) appreciates the opportunity to present information to the Milton Marks Commission on California State Government Organization and Economy (LHC) on the subject of climate change adaptation strategies. Your hearing could not be more timely.

Rising sea level (RSL) is a fact. According to the Nation's oldest continually operating self-recording tidal observation station, located near the Golden Gate Bridge in San Francisco Bay, the Bay has risen by over seven inches during the past century. BCDC Commissioners never have questioned the need to plan for a rising Bay.

It may seem a puzzle, then, that BCDC was created almost fifty years ago as the State's response to development pressures that threated to shrink the Bay into merely a nice-sized river. After years of protecting the Bay against almost unbridled growth, BCDC began to analyze climate change and RSL in relation to the Bay during the 1980s and published "*Sea Level Rise: Predictions and Implications for San Francisco Bay"* in December 1987. Two decades later, BCDC released a set of "inundation maps" prepared by BCDC staff based on United States Geological Survey (USGS) data that caused local, national, and international excitement, interest, and consternation. They showed, quite dramatically, the results of projected RSL both within BCDC's jurisdiction

and inland. BCDC recognized then, as now, that planning for climate change and RSL is critical to the long-term safety, wellbeing, and vitality of the Bay Area's communities, natural resources, and economy. Therefore, BCDC is developing and implementing a multi-dimensional program to address RSL and its affects in the San Francisco Bay Area that is based upon community participation, local government capacity building, voluntary cooperation, and the Commission's regulatory responsibilities. Sustained Institutional support for programs that rely upon community participation and voluntary cooperation can only strengthen the Bay Area's ultimate resiliency in the face of climate change.

THE CONTEXT

The Bay's shoreline is approximately half the length of the California coastline. The Bay is approximately 550 square miles, which is larger than all but nine cities in the United States. It is almost 20% larger than the City of Los Angeles and is larger than the combined dimensions of San Diego and San Jose. Nine counties and over 40 cities touch Bay waters.

The San Francisco Bay is the largest estuary on the west coast. It is biologically diverse, and it includes unparalleled marshes and mudflats along the shoreline that provide food and shelter to fish and wildlife and account for 77% of California's remaining perennial estuarine wetlands. It is home to over 1,000 species of animals, including endemic, threatened, and endangered species. It is a critical stopover on the Pacific Flyway and hosts more wintering shorebirds than any other estuary on the west coast outside of Alaska. Its diversity of key habitats and production of environmental benefits such as flood protection, water quality maintenance, nutrient filtration and cycling, and carbon sequestration compelled the international community to designate San Francisco Bay in late 2012 as a "Wetland of International Importance."

The Bay also helps provide a high quality of life for residents. It supports the world's 19th largest economy. The Bay shoreline hosts two major international airports and 40% of California's petroleum refinery capacity. The Oakland seaport is the Nation's fifth largest and moves a startlingly large portion of California's crops to market. Considerable commerce takes place on the water and in the shoreline band on a daily basis. The diversity of watercraft that appears on the Bay at any one time rivals that of any port.

With unparalleled recreational opportunities and beautiful scenery, San Francisco Bay is one of the world's greatest tourist destinations. Its beauty and its contributions to such a high quality of life help make the Bay Area one of the country's most desirable places in which to live. The Bay is inextricably woven into each resident's sense of place, culture, and community. The Bay is a dynamic and interconnected system whose value is crucial to the region's environmental, economic, and social prosperity. BCDC's mission is "to protect and enhance San Francisco Bay and to encourage the Bay's responsible and productive use for this and future generations."

BCDC MISSION AND ACCOMPLISHMENTS

BCDC has two ongoing primary functions: to maximize feasible public access to the Bay consistent with authorized projects; and, to minimize Bay fill. The Commission recognizes that the most important word in Bay Conservation and Development Commission is "and." BCDC does not, and cannot, unilaterally oppose development – indeed, BCDC has approved billions of dollars of capital investment in its jurisdiction. Bay fill has required mitigation, however, and the Bay is larger today than it was fifty years ago due to BCDC's efforts and those of other agencies and stakeholders. Mitigation has included removing fill in other Bay locations, breaching levees, and

creating and restoring wetlands. BCDC also has required public access on over 100 miles of the Bay shoreline and is an active partner of the Bay Trail project. BCDC's role is to ensure that appropriate development can take place that respects the need to conserve the Bay's natural resources, and to do so without superseding the role of local governments.

BCDC HISTORY, JURISDICTION, AND AUTHORITY

In 1965, California enacted the McAteer-Petris Act, which designated the San Francisco Bay as a State-protected resource and established BCDC. Twenty-seven members sit on the Commission. They represent a wide variety of public, private, and nonprofit sector interests. The Act is the key legal provision in California state law to prevent indiscriminate Bay fill. Concurrently, BCDC has permitting responsibility to ensure that appropriate and environmentally sound development provides public benefits and economic development for the entire region. BCDC was not created to obviate or supersede the authority of cities, counties, and special districts that are located along the Bay and its shoreline. Instead, its role is to view the Bay as an entire system, which is impossible for more narrowly focused governmental bodies. BCDC was the State's first regional coastal management agency. Throughout its history, BCDC has learned that its most notable successes are produced by coordinating, collaborating, and/or partnering with governments at all levels and with a wide variety of other stakeholders. This cooperation is vital given that BCDC's jurisdiction extends 100 feet into the Bay shoreline from mean high tide for purposes of public access – now and into the future.

BCDC's initial San Francisco Bay Plan was approved in 1968 and BCDC was made permanent one year later. The Bay Plan is updated regularly to ensure the responsible use of the Bay and its shoreline and address new issues as the Bay Area changes. The

Plan includes policies on issues critical to the Bay, ranging from port activities and public access to urban development and transportation. The Bay Plan maps the entire Bay and designates areas for water-related purposes such as ports, industry, public recreation, airports, and wildlife refuges.

In 1977, California expanded the Commission's authority to provide special protection for the Suisun Marsh. The Marsh is the "mixing zone" that connects the Bay with the Delta. It is the largest contiguous brackish marsh on the west coast of North America; more than 10% of California's remaining wetlands and more than 300 species, including 80% of the State's commercial salmon fishery, are found in the marsh. Therefore, BCDC has a great incentive to work closely with the organizations and interests that are associated with the current Bay Delta Conservation Plan. The environmental, economic, and social connections between and among the Bay, the Suisun Marsh, and the Delta should be understood as assets to all residents of the greater Bay Area and California, and they are all subject to climate change.

BCDC is the federally designated state coastal management agency for the San Francisco Bay segment of the California coastal zone. In this role, BCDC ensures that federal projects and activities are consistent with the State statutes and regulations. BCDC is the Nation's oldest coastal zone management agency. ***(A summary description of BCDC can be found in Appendix 1.)***

BAY PRODUCTIVITY

San Francisco Bay's marshes and associated transitional areas provide invaluable habitat, recreational, and aesthetic values. In addition, they can play a critical role in protecting the shoreline from a rising Bay. The first attack of rising water will occur during storms and extreme wave events when the added water elevation from RSL will

provide more power and thrust to waves pounding the shoreline. Wetlands and associated mudflats attenuate the power of incoming waves and protect the areas behind them. Therefore, less shoreline protection will be required for areas where wetlands are present, at least in the near and medium-term. (BCDC's Corte Madera Shoreline study with USGS and other researchers addresses this benefit and is discussed on page 27.)

The San Francisco Bay is where the tidal salt waters of the Pacific Ocean mix with the fresh water from the Sierra Nevada that flows through the Sacramento and San Joaquin Rivers to form the San Francisco Bay Delta estuary. Historically, the Sierra watershed and local Bay watersheds have provided sediment to form and sustain tidal marshes. The ability of wetlands to create this "sponge" affect will be reduced by rising Bay levels, both through potential drowning and through erosion caused by increasing wave energy. Therefore, the Bay's wetlands need a constant replenishment of watershed sediments that can feed marshes and help them to adapt to rising waters. Unfortunately, sediment concentration in Bay waters has decreased over the past decades, for many reasons. How can this issue be addressed?

Regional Sediment Management (RSM): Regular dredging to maintain channels and berthing areas is crucial for maritime commerce and recreational boating in the Bay. Without it, major ports (including the Port of Oakland) would become silted in and unusable. This would end the Bay's status as a major Pacific Rim port, recreational boating would founder, and the region's economy would suffer. Fortunately, most of the sediments dredged from Bay channels can be used to help restore and maintain Bay wetlands (known as "beneficial reuse"). Examples of this "win-win" are the Sonoma Baylands near the mouth of the Petaluma River in Sonoma County, the Montezuma Wetlands along the Carquinez Strait, the Suisun Marsh in Solano County, Bair Island in Redwood City, and the Hamilton Wetlands on the former Hamilton Army Airfield in

Novato, Marin County. These projects have beneficially reused millions of cubic yards of material dredged from Bay navigational projects to create over a thousand acres of wetlands.

This beneficial reuse of dredged materials supports the productivity of wetlands in the face of rising waters and protects the productivity of shoreline areas behind them, as well as the productivity of the ports and harbors from which the material is dredged. Expansion of this benefit must be a major component of the Bay Area's climate change strategy. That is why BCDC is a founding member of the Long Term Management Strategy (LTMS) for dredging and disposal in the Bay region, along with the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, the San Francisco Bay Regional Water Quality Control Board and the San Francisco Estuary Partnership. LTMS is charged with maintaining Bay channels in an economically and environmentally sound manner, and maximizing the beneficial use of Bay sediments. LTMS will be a key player to further regional sediment management and help the region and its wetlands adapt to a rising Bay.

In addition to reusing dredged material, understanding and managing more globally the flux of sediments into, within and through the Bay should be a key part of regional adaption. For example, flood control projects have a major impact on the movement of sediments from Bay tributaries. BCDC is working with a myriad agencies to better assess how to maximize the benefits of dredging, flood control, and other activities affecting sediment flows, and contribute to adaptation to RSL.

RSM Advocacy: BCDC has initiated an advocacy strategy development plan aimed at increasing federal funding for beneficial reuse and other Bay-centered environmental and economic strategies. Along with the State Coastal Conservancy, Save the Bay, the Bay Planning Coalition, and the Bay Institute – with help from the

USACE, SFEP, and the USEPA – BCDC plans to increase national recognition that the Bay is a resource no less valuable than the Chesapeake Bay or the Great Lakes and merits similar funding and program attention. Creating a Bay-wide advocacy group that includes regulators, funders, environmentalists, private sector interests, and the scientific community is a start.

CHALLENGES AND OPPORTUNITIES

How can the State and its governmental subdivisions create a public consensus around where a new public shoreline will grow and exist and what public benefits it will spawn or eliminate? What templates are available for local, subregional, regional, and State agencies to prepare their stakeholders for the major changes that will alter how California will look and work during the next 25, 50, or 100 years? How can the public become engaged in this discussion? For example, despite a quarter-century of warnings, less than half of Bay Area residents are prepared for a major earthquake and it required 24 years for the Bay Area and the State to decide whether to build a new eastern span of the Bay Bridge, design it, and then build it. The magnitude of this slow post-Loma Prieta response does not inspire confidence that governments alone can prepare the public to make and/or accept decisions about how to adapt to this "slow moving emergency" of rising sea level. So, all levels of government must be smarter, more aggressive, and more creative in meeting this challenge.

How can governments build and maintain planning and implementation capacity on the community, local, subregional, and regional levels? Capacity building requires sustained funding, greater levels of expertise, the willingness to prioritize projects, and recognizing that local planning processes must become part and parcel of larger planning efforts. The number and diversity of public agencies involved in such planning is astounding. Many in local government view regional agencies as necessary evils to

ward off; larger and more inclusive planning efforts may be viewed by some as an attempt to dilute local *de facto* and *de jure* authority. How can those feelings be transformed into more positive responses? Building local capacity takes money, time, effort, and recognition that the world – and California – is changing in uncertain ways. Part of BCDC's challenge is to enlist local governments in seeing capacity building as an opportunity and not simply a burden.

Given such uncertainty, what governance structures and policies can embody new types of cost/benefit analyses that reflect the uncertainties surrounding RSL and future climate change and reflect the values and benefits inherent in natural resources? Absent structures and clear guidance, local governments will have a convenient excuse for not planning well, or to want to address these issues, if at all. As LHC's academic panel discussed in August, government's basic cost/benefit analysis techniques do not work well in this scenario. Typically, they encourage one-size-fits-all solutions – the exact opposite of what is required in local, subregional, and regional adaptation planning. Developing new structures and policies to address these regional issues requires difficult, iterative discussions between representatives of the State, regional entities, and local governments.

What is the best time to implement change? While much of the State's economy may be at risk due to climate change, time gives us options. In other words, the State does not have to fix everything now, or by 2017. Instead, conducting the kind of difficult and productive discussions noted above during the next few years might actually preserve valuable policy options, especially because it is likely to take at least five years to develop a region wide strategy, even with increased funding for planning throughout the Bay Area.

BCDC Rising Sea Level Working Group: Under the direction of BCDC Chair Wasserman, a group of eight Commissioners is regularly and informally engaging with regional stakeholders to gather information about their efforts to confront RSL. In July, the Working Group met with representatives from Chevron, Union Pacific, Kaiser, Pacific Gas and Electric Company, and San Francisco International Airport to learn how they are planning to deal with a rising Bay. In August, the Working Group met with representatives from BART, the Capitol Corridor Rail Service, Caltrans, East Bay MUD, and the Port of Oakland. In October, the group met with representatives of the Bay Area Council, the Bay Planning Coalition, the Silicon Valley Leadership Group, the East Bay Economic Development Alliance, and the San Francisco Chamber of Commerce to discuss their stakeholders' preparations for a rising Bay. Next month, the Working Group is scheduled to meet with representatives of the insurance industry. The group is a key outreach mechanism for the Commission in its effort to develop the Resilient Shorelines regional strategy and its other climate program elements.

CONCLUSIONS AND RECOMMENDATIONS

1. *Land use decisions should continue to be made on the local level and fit into a Bay Area-wide response strategy. Concurrently, the State should create a more sustainable and robust integrated statewide process that provides incentives to local and regional governments to plan for RSL both as individual government entities and as members of subregional and regional collaboratives (and avoid mandating that they do so).* Decisions to develop new infrastructure or alter existing infrastructure to respond to RSL must result from processes that include meaningful participation by representatives of the communities affected. The vast differences within and among the extensive coastal and Bay shorelines throughout California should temper any inclination to adopt a comprehensive statewide plan to account for every inch of possible shoreline protection or

development. In addition, the Bay Area public – and likely the public throughout the State – is unaware of what changes to current governmental structures and authorities may need to occur for local, subregional, and regional planning to account for RSL. While BCDC's work with a wide variety of governmental, nonprofit, and private sector collaborators in the Bay Area is bringing us closer to understanding what those changes could be, at best it is premature to alter the current land use policymaking landscape.

2. *Such an integrated statewide process must include clear and consistent guidance to local and regional governments regarding a wide variety of issues, including data that informs and supports local decision-making processes.* These include: how to best use forecasts and work within the framework of uncertainty; the need for vulnerability analyses; the permission to plan for and finance both strategic development and strategic retreat; and, a variety of other technical requirements to understand how the landscape will change during the next century. Special care should be taken to ensure that communities are precluded from putting one another at risk. Any statewide "adaptation" strategy should look outward from Sacramento and reflect the groundbreaking policy and planning work occurring in coastal and shoreline communities. It must reflect thoughtful local, subregional, and regional input from the public, private, and nonprofit sectors throughout the State.

3. *The State should support a wide variety of on-the-ground community-based resilience programs that exemplify best practices, provide necessary and useful policy information for a region's SB 375 sustainability program, and measure and monitor results.* The results of these programs should inform the State's adaptation strategy. Special attention should be paid to inventorying best practices and providing incentives to local, subregional, and regional

governments to adopt them. Competitions and other efforts to promote innovative solutions to policy, design, and engineering challenges should be encouraged.

4. *Frameworks for regional collaboration, such as that authorized in the current SB 792 (DeSaulnier), should be rewarded.* The Bay Area's Joint Policy Committee (JPC) consists of the Association of Bay Area Governments (ABAG), the Metropolitan Transportation Commission (MTC), the Bay Area Air Quality Management Board (BAAQMD), and BCDC. Executive Directors and staff, the JPC's leadership team, and the complete body (with five representatives from each agency) meet regularly together and separately. The JPC is charged to ensure cohesive and collaborative relationships, promote policy alignment among the agencies, coordinate the development of a regional economic development strategy, and respond to challenges emanating from climate change and RSL. (Unfortunately, BCDC has not been able to convince the Administration that the Commission should co-locate with its three agency partners in the new JPC Headquarters building so that the four agencies' planners, regulatory, and enforcement personnel work together even more cooperatively than they do now.) The State also should provide incentives for statewide collaboratives, e.g., the Alliance of Regional Collaboratives for Climate Adaptation (ARCCCA), whose purpose are to share best practices and inform policymaking throughout various regions. In addition, the State should encourage creative policymaking collaborative processes among all levels of government that reflect state, local, and regional needs and values.

5. *That statewide integrated process should spur a constructive policy discussion among all levels of government regarding jurisdictional issues.* Questions to be answered include: what is the future of "the public trust" given RSL; should BCDC

and other entities continue to use the definition of "mean high tide" to define jurisdiction in 35-50 years; and, should different governments decide what science is "best" for their communities? The State should initiate multi-level discussions about how both environmental protection and economic growth can occur in spite of, or due to, RSL. Finally, the state must ensure that communities that do not touch the Bay but whose residents are inextricably linked to its commerce and environmental benefits are part of this discussion; their ways of life are at risk, as well, from climate-related challenges such as changing temperatures, increased wildfires, and flooding.

6. *The State should undertake an active advocacy role in Washington, D.C. on behalf of local, regional, and statewide projects that demonstrably improve shoreline and coastal resilience, including LTMS dredging projects.* The State should inventory and prioritize legislative and regulatory vehicles, propose a wide range of monetary and nonmonetary assistance, and use the weight of the California House and Senate delegations to assist local RSL and climate change adaptation efforts.

7. *The State, in conjunction with regional agencies and collaboratives, should undertake an extensive public education campaign about the probable effects of climate change.* It should offer residents non-threatening information about what might occur, how different levels of government are planning for its ramifications, and how communities can discuss policy options. BCDC has not sought an expansion of its authority or jurisdiction because neither the Commission's stakeholders nor the Commission are ready to propose or accept such a change. Like BCDC, the State should not propose to expand the authority of its agencies at this point because such an expansion likely would preclude a thoughtful discussion of options.

CURRENT BCDC CLIMATE CHANGE ACTIVITIES

The Commission's climate change activities include three different types of programs. Each is based on the policy assumption that adaptation planning and shoreline resilience is best planned on the local level with assistance from subregional, regional, and/or state and federal entities.

1. Adopted Policies, Case Studies, and Adaptation Projects

2011 Bay Plan Amendments: In 1989, the Commission amended the findings and policies in the Bay Plan to address RSL when making permit decisions and to provide policy advice to local governments. Twenty years later, BCDC staff prepared a vulnerability assessment, "*Living With A Rising Bay: Vulnerability And Adaptation In San Francisco Bay And On the Shoreline*," that evaluated:

1. Key Bay systems, both in the natural and the built environment, the stressors they faced, and potential impacts due to RSL and coastal flooding;
2. The sensitivity of those systems to those impacts; and,
3. Those systems' adaptability.

The USGS research on RSL in the Bay Area was integral to this assessment. So was an analysis of the socioeconomic impacts of that potential inundation by the Pacific Institute. The results showed that approximately 180,000 acres of shoreline are vulnerable to flooding following a 16-inch rise in sea level, and more than 213,000 acres following a 55-inch rise in sea level. This potentially affects over 250,000 Bay Area residents. The replacement value of the resources at risk is about $62 billion. The area vulnerable to inundation with a 16-inch RSL roughly corresponds to today's 100-year floodplain. Simply put, myriad Bay Area communities will be under water unless BCDC

and our stakeholders can plan and implement effective adaptation strategies. The maps of this analysis were released in April 2009. ***("Living With a Rising Bay" and the associated maps can be found in Appendix 2.)***

From April 2009 through October 6, 2011, when BCDC voted on the Bay Plan Amendments that resulted from this analysis, the Commission held almost forty public hearings, workshops, and meetings centered on its analysis and suggested regulatory language to protect the Bay and Bay Area communities. The staff's proposed amendments generated considerable controversy; representatives of the business community and many local governments were concerned that the Commission proposed to expand its jurisdiction into low lying areas beyond 100 feet above mean high tide. After a series of difficult and complex negotiations regarding BCDC's regulatory authority, the Commission voted 24-0 to amend the *San Francisco Bay Plan* to require permittees to address climate change in their development plans. The revisions to the Bay Plan create a climate change policy section that:

1. Incorporates science-based RSL projection ranges for use in the permitting process;
2. Calls for developing a long-term regional strategy to address RSL, storm activity, and other Bay-related impacts of climate change in a way that protects the shoreline and the Bay, and allows for appropriate, well-planned development that responds to the impacts of climate change and future RSL;
3. Calls for collaboration with the JPC and other agencies to integrate regional mitigation and adaptation strategies and adaptation responses of multiple government agencies, to analyze and support equity issues, and to support research that provides useful climate change information and tools;
4. Provides recommendations and requirements to guide planning and permitting of development in areas vulnerable to RSL; and

5. Includes policies that promote wetland protection, creation, enhancement, and migration.

The amendments also modified the Bay Plan by amending:

1. The findings and policies on tidal marshes and tidal flats to ensure that buffer zones are incorporated into restoration projects where feasible and sediment issues related to sustaining tidal marshes are addressed;
2. The policies on shoreline protection to address protection from future flooding; and,
3. Public access policies so that such access is sited, designed, and managed to avoid significant adverse impacts from RSL and ensure long-term maintenance of public access areas through site-specific adaptive management strategies.

(The entire text of the Bay Plan Amendments can be found in Appendix 3.)

Implementation of Bay Plan Amendments: BCDC's Climate Policy Implementation project, which commences in October 2013 with funding from the National Oceanographic and Atmospheric Administration (NOAA), will enable BCDC permit applicants, BCDC staff, Commissioners, and the public to better understand and comply with BCDC's new climate policies as embodied in the Bay Plan Amendments. BCDC will develop guidance around the following elements of the policies:

1. Risk assessments – whether one is required and how to address flood risks;
2. Fill designed to prevent flooding – how fill can be placed in ways so that it does not violate other BCDC policies;
3. Designing shoreline protection – how to design projects such as levees and seawalls to withstand projected RSL and be integrated with adjacent protection;
4. Preserving public access – how to design and maintain such access to avoid flood damage or provide equivalent access;

5. Ecosystem protection and restoration – to be resilient and provide space for marsh migration as sea level rises; and,
6. Preserving undeveloped areas --- to encourage conservation and habitat enhancement in areas vulnerable to future flooding.

BCDC will conduct a public outreach effort, establish a stakeholder advisory panel, host public workshops, and post material on BCDC's website (including summary translations in non-English languages) to garner as much useful information as possible prior to the publication of the guidance and vet draft language. In addition, this project will leverage several tools that have been developed recently by NOAA and PRBO Conservation Science to assist with projecting shoreline change. This project also will leverage BCDC's groundbreaking "Adapting to Rising Tides" (ART) Pilot Project, the Innovative Wetlands Adaptation Strategies Study, the Head of Tide Study, and the Regional Sediment Management Study.

Project Review: BCDC has reviewed proposed projects in the Bay and along the shoreline in light of the Bay Plan Amendments since Fall 2011. Two permitted projects demonstrate, in part, how BCDC is implementing the policies:

Port of Redwood City: The Port's application to replace several of its wharves and associated backland in San Mateo County in Spring 2012 was the first permit BCDC reviewed using its newly adopted climate change regulations. The Port's facility receives bulk cement, sand, and gravel aggregate. The area upland of the wharves contains related infrastructure and is protected from flooding by a berm and unengineered fill.

BCDC's climate change policies require that new major projects in the Bay be resilient to mid-century (or for the life of the project, if less). Each must have a feasible plan to be resilient to the end of century, as well. The Port's project's lifespan is approximately 60 years, and the Port's vulnerability assessment (using California Ocean Protection Council data) concluded that sea level might rise an additional 1.53 feet by 2060. Under that scenario, the project would be resilient to the rising Bay for the life of the project. In addition, BCDC's policies also require that "[a]dequate measures should be provided to prevent damage from sea level rise and storm activity that may occur on fill or near the shoreline over the expected life of a project…. New projects on fill or near the shoreline should…be built so the bottom floor level of structures will be above a 100-year flood elevation *that takes future sea level rise into account* for the expected life of the project." Therefore, the Port combined its RSL estimate with a 100-year flood level of +11.2 feet MLLW and designed the project to withstand water levels of up to +12.7 feet MLLW by 2060. BCDC held a public hearing on the project, found that the project was consistent with the Bay Plan policies, and approved it in May 2012. ***(A project summary and staff recommendation can be found in Appendix 4.)***

Phoenix Commons (Oakland): In September 2013, BCDC approved a major permit application for a senior co-housing project along the Alameda shoreline called "Phoenix Commons." The project is a four-story, 41-unit facility with a private patio adjacent to a 27- to 32-foot-wide public shoreline promenade, a 2,522-square-foot pier largely over the Bay that will provide an additional public access area, and a 650 square-foot floating dock for private use by the facility's residents.

While the Redwood City Port project is a maritime use and Phoenix Commons is a residential use, another major difference between the two projects is that the only portion of the Phoenix Commons project in the Bay is a pile-supported deck over the Alameda estuary. To comply with the BCDC climate change policies, the Applicant

provided RSL projections that showed the impact of a rising Bay over time on the public promenade. The applicant's analysis concluded that the public promenade's elevation would remain above flood elevations given a projected 16-inch sea level rise at mid-century. Using an end-of-century projection of 55-inches, however, the public promenade will be inundated by approximately one foot of Bay water during high tide flood events. Although the pier will be inundated by end of century, its useful life is expected to be much shorter than 87 years. Most important, the senior housing facility is at a similar elevation as the pier and will be vulnerable to flooding due to end-of-century RSL (its useful life likely will last far beyond the pier's). However, when a proposed project is located in the shoreline band (as opposed to in or over Bay tidal waters), BCDC can deny an application only if it does not provide maximum feasible public access consistent with the project or is inconsistent with a Bay Plan priority land use designation. This project is not within such a designation. Further, BCDC has no authority or policies regarding RSL outside of its jurisdiction. BCDC concluded that it is infeasible for the Applicant to modify the pier to withstand projected RSL because it will be connected to adjacent public access. Also, BCDC and the Applicant recognized that this infill project and its neighbors ultimately would have to be protected by a comprehensive and integrated RSL strategy rather than by actions of each property owner constructing protection independently in an uncoordinated manner. Further, BCDC has no jurisdiction or policies regarding RSL outside its jurisdiction. Therefore, the Phoenix Commons project is consistent with the new climate change policies, and BCDC approved the project in September 2013. ***(A project summary and staff recommendation can be found in Appendix 5.)***

BCDC's climate change policies are not intended to be comprehensive or to be a substitute for regional governance and adaptation strategies. Instead, they are intended to ensure that major new projects will address such vulnerabilities while the region is preparing and implementing a comprehensive approach to this challenge.

ART (Adapting to Rising Tides) Pilot Project: BCDC, in partnership with NOAA and with assistance from ICLEI Local Governments for Sustainability, MTC, and the California Department of Transportation (Caltrans), is working with Bay Area communities in a groundbreaking way to increase their preparedness and resilience to RSL and storm events while protecting critical ecosystem and community services.

ART is a community-based collaborative planning effort that addresses two questions:

1. *How will climate change impacts of RSL and storm events affect the future of Bay Area communities, infrastructure, ecosystems and economy; and,*
2. *What strategies can BCDC and its stakeholders pursue, both locally and regionally, to reduce and manage these risks?*

ART is being conducted in a portion of the Alameda County shoreline, from Emeryville to Union City. This subregion was selected based on local community and stakeholder interest and capacity, its diverse shoreline features, and the presence of regionally significant transportation infrastructure. Phase 1 of ART included forming ART's Subregional Working Group, comprised of representatives from staff at local, county, regional, state and federal agencies that work in the subregion, and some private interests with investments in the study area. The ART Working Group is composed of local government staff, park, flood and water district staff, airport, utility, and other regional agency staffs, and federal partners. The Project Management Team defined project goals and objectives, developed communications strategies, identified important assets along the shoreline, and selected climate scenarios and impacts associated with RSL and storm events. ART's second phase assessed the subregion's vulnerability and its risks, beginning with characterizing the existing conditions of assets in twelve categories. This analysis set the stage for a comprehensive evaluation of the

vulnerability of the assets in the subregion, including transportation, community land use, parks and recreation, contaminated lands, structural and non-structural shorelines, the Port of Oakland, Oakland International Airport, stormwater/wastewater, hazardous waste sites and pipelines.

The ART project team also considered the capacity of existing institutions to carry out adaptation efforts. Climate change presents serious challenges for the municipalities, agencies, community organizations, business interests, and many other institutions that will play a part in planning for resilience. However, the Bay Area's vulnerability may be greatly reduced if robust and thoughtful adaptation strategies are put to work. Such an effort will require coordination, cooperation, and partnership across different sectors and jurisdictional lines, and among a variety of organizations. In some instances, new programs, policies, and institutional arrangements also will be required.

ART's "Adapting Governance" white paper examines the factors that may help or hinder Bay Area institutions as they work to foster resilience to climate change. Current institutional arrangements, decision-making processes, and laws and regulations need to be reviewed in light of the challenges presented by RSL and storm events. The paper identifies three overarching governance challenges: uncertainty; complexity; and, resource constraints. With those challenges in mind and using ART's vulnerability and risk assessment as a foundation, ART developed a portfolio of possible adaptation responses to address the subregion's vulnerabilities. These are starting points for further adaption planning that will need to occur at multiple scales in the region. Indeed, the next steps of ART involve working with partners throughout the Bay Area to utilize the tools, resources, and lessons learned from the ART pilot project to assist resilience planning efforts that address specific sectors, neighborhoods and assets, as well as the broader resilience planning that is underway in the region. BCDC's

Commission meeting on October 17, 2013 was an actual ART workshop at which BCDC Commissioners, Alternates, and various other governmental, nonprofit, and private sector staff worked with ART Working Group members and members of the public on resilience issues. The ART project is evolving into the ART program of local assistance to apply the methods developed and lessons learned from the ART project throughout the region. ***(More information on the ART Project can be found in a separate binder titled Appendix 6.)***

2. Formal and Informal Policy Collaborations

Joint Policy Committee: Pursuant to AB 2094 (2008), BCDC is a full member of the JPC, which has two climate change goals – reducing regional greenhouse gas emissions and encouraging climate change adaptation. In May 2011, the JPC adopted a strategic work program to further Bay Area economic development and climate/energy resilience. In part, the program will inform the region of potential climate change impacts and provide guidance on adaptation measures to increase the region's resilience. ***(A copy of that work plan can be found in Appendix 7.)***

BCDC's Bay Plan Amendments recommend that BCDC collaborate with the JPC and other agencies and interested parties to prepare a regional strategy to adapt to a rising Bay. After almost a year of careful consideration, the JPC agreed to take a lead role in preparing a regional strategy for adaptation to climate change.

Sustainable Communities Strategy: Under SB 792 (pending, by Senator DeSaulnier), the four JPC member agencies would be responsible for the development of the second and third sustainable communities strategies required by SB 375. Although MTC and ABAG took the lead in formulating the first SCS, BCDC staff served on the *ad hoc* Committee, participated in its development, and ensured that agency

partners integrated adaptation considerations into the SCS, particularly for infill development areas that may be vulnerable to future RSL. BCDC staff played a lead role in crafting the vulnerability assessment and conceptual adaptation strategies in the Plan Bay Area EIR. ***(A copy of the amended SB 792 can be found in Appendix 8.)***

Local Government Adaptation Assistance Program: BCDC has taken the lead in developing an adaptation assistance program (AAP) to provide information and resources to local and regional governments, thus assisting them in planning for and adapting to the impacts of a changing climate. The AAP builds capacity within local governments to assess climate change issues and to plan for and implement adaptation strategies. BCDC's outreach efforts focus on addressing the needs of land use planning, public works departments, park and open space districts, flood control districts, and wastewater authorities, as well as resource-based managers. The AAP is supported by the JPC through its Regional Agency Climate Protection Program. The long-term goal of the AAP is to help communities adopt coordinated plans to make their communities more resilient to climate change impacts.

BCDC has identified five broad program components to accomplish these AAP objectives:

(1) Build partnerships that cut across jurisdictional boundaries;
(2) Perform public outreach to build community and institutional support for adaptation planning;
(3) Educate planners and managers about adaptation planning;
(4) Create a "one-stop shop" website and information clearinghouse; and,
(5) Develop and disseminate strategies to improve the region's resilience and adaptive capacity.

During the past five years, AAP efforts have focused on the first three components successfully. BCDC, with ABAG, the San Francisco Bay National Estuarine Research Reserve (SF Bay NERR), BAAQMD, NOAA, Office of National Marine Sanctuaries, ICLEI, and the Center for Ocean Solution at Stanford University, have held five workshops and a weeklong training for local governments that focused on adaptation. ***(A copy of case studies can be found in Appendix 9.)***

Bay Area Ecosystem Climate Change Consortium (BAECCC): BAECCC (pronounced "bake") is sponsored by the Coastal Conservancy and funded by the Gordon and Betty Moore Foundation. Its purpose is to advance the use and acceptance of nature-based solutions to climate change and RSL. BCDC staff serves on the steering committee. BAECCC is leading the Baylands Ecosystem Habitat Goals Update, which is producing a set of far-reaching management recommendations to restore and maintain these nature-based approaches to a rising Bay. Simply put, healthy ecosystems make the region more resilient to climate change and restoring ecosystems is a cost-effective strategy to make the Bay Area more resilient to the impacts of climate change. Natural ecosystem processes to sequester carbon, reduce flood impacts, and moderate climate extremes must be part of any far-reaching approach to making the Bay Area more resilient to climate change.

BCDC/State Coastal Conservancy/ABAG Partnership: The State Coastal Conservancy, ABAG, and BCDC are formally exploring ways to better coordinate, collaborate and partner on their various climate change related projects and programs. In part, this effort is focused on advancing the regional Resilient Shorelines initiative, called for in the recent Bay Plan Amendments, which ABAG and BCDC lead as part of the JPC. Current and future BCDC/ABAG/Conservancy collaborative projects include:

1. Integrating ABAG's regional Earthquake and Hazards Program into the ART Pilot Project work in Alameda and Marin Counties;

2. Developing with MTC, BART, and Caltrans adaptation strategies extending the ART project into key locations in Alameda County, including the Bay Bridge Toll Plaza, the Coliseum area, the Highway 92 Corridor and Toll Plaza, and/or other priority sites;
3. Conducting a region-wide assessment of the affects of a rising Bay on Priority Development Areas; and,
4. Integrating ABAG's housing vulnerability and infrastructure interdependency projects with the Resilient Shorelines initiative; and,

Regional Sediment Management: Bay sediment dynamics relentlessly affect the locations of tidal flats and marshes, habitat variability, and the productivity of Bay waters. Understanding sediment dynamics can help to more accurately forecast the impact of RSL and climate change. Sediments can feed tidal flats and wetlands to maintain their elevation in the tidal frame while minimizing erosion and inundation. Decreases in local or regional sediment supply can exacerbate erosion and inundation. BCDC and its partners, including the San Francisco Bay Regional Water Quality Control Board, the U. S. Environmental Protection Agency (USEPA), the U.S. Army Corps of Engineers, State Coastal Conservancy, San Francisco Estuary Institute, USGS, and local flood control agencies, are practicing regional sediment management to manage sediments within the context of the entire Bay system, including sediment sources, movement and sinks within the system, and sediment exchange with the ocean. ***(A staff report and presentation describing regional sediment management can be found in Appendix 10.)***

Dutch Partnership: BCDC has taken advantage of the Netherlands' experience in protecting low-lying areas from flooding. BCDC and Dutch staff compared and contrasted the two geographies, conducted technical research, and modeled the impact of RSL on the Bay. The analysis showed that tidal elevations due to a rising Bay largely

will be linear across the Bay and tidal velocities and wave heights within the Bay likely will increase. The team analyzed a range of shoreline typologies for adaptation purposes, identified potential adaptation measures, developed a decision-making matrix for their use, and identified differences in governance with respect to adaptation between the Netherlands and the Bay Area.

The partnership's final report, "*San Francisco Bay: Preparing for the Next Level*," was well received at a symposium on September 21, 2009. BCDC's partnership with the Dutch is continuing through its participation in the Delta Alliance, an international organization whose mission is to improve the resilience of four of the world's largest deltas in Indonesia, Vietnam, the Netherlands, and California. BCDC is leading the partnership in the Bay Area with the Port of San Francisco, other City Departments, and private property owners. The project will focus on the Mission Creek Area of San Francisco starting in Fall 2013. The project will include a high level vulnerability assessment and develop a suite of adaptation strategies.

3. Research and Innovation

Rising Tides Competition: Grappling with the realities of a rising Bay will require planners to approve a new suite of shoreline design concepts. BCDC's "Rising Tides" competition sought architectural and engineering responses to various design challenges, including; how do we build in an area that is dry now, but that may be wet in the future?; how do we retrofit existing shoreline infrastructure such as shipping ports, highways, airports, power plants and wastewater treatment plants?; can we imagine a different shoreline configuration or settlement pattern that allows temporary inundation from extreme storm events?; and, how can we provide flood protection inland of marshes without drowning the wetland when the water rises? In partnership

with the American Institute of Architects (San Francisco Chapter) and NOAA, BCDC sought a wide variety of submissions to address issues in estuarine environments.

Design proposals ranged from practical and pragmatic to aggressively imaginative and speculative. The best ideas could be transferred to other estuaries and expanded on traditional design solutions, such as seawalls and levees, or offered entirely new perspectives. Ideas addressed RSL for particular shoreline elements or structures, and larger issues related to a site, a neighborhood, commercial districts, public infrastructure, transportation systems or an entire watershed. Many integrated "green building" principles with resilient designs.

BCDC received more than 130 entries from around the world. An independent judging panel chose the six winning entries. Thousands of people viewed them at San Francisco's Ferry Building and the Commission curated the posters as a traveling exhibit in various public spaces to raise awareness about RSL and the need to adapt.

Innovative Wetland Adaptation Strategies: The "*Innovative Wetland Adaptation Techniques in Lower Corte Madera Creek Watershed"* project is one of the first analyses to examine how to reduce the vulnerability of tidal wetlands to a rising Bay. BCDC and USEPA undertook the study to better understand the flood control and wave attenuation benefits of tidal wetlands, the vulnerability of tidal wetlands to RSL, and potential strategies to improve the resiliency of tidal wetlands. The research team of BCDC, USEPA, USGS, the University of San Francisco, the Marin County Flood Control District, and private consultants has collected and analyzed data to evaluate the current flood and wave attenuation benefits of the tidal marsh system and to evaluate the sensitivity of the system to rising sea level. Staff will develop a conceptual adaptation

strategy for nature-based resiliency based on the data collection and the modeling results. ***(A non-scientific discussion of the project and its possible benefits can be found in Appendix 11.)***

Head of Tide: Head of Tide is the space of high ecological importance where freshwater flowing down tributaries to the Bay meets tidal currents flooding upstream from the Bay. Many Bay cities were located originally where freshwater met navigable Bay waters. RSL will shift head of tide upstream, which will increase flood risks. However, Head of Tide for Bay tributaries is not mapped and the flooding risks have not been evaluated. BCDC's Head of Tide study will establish a protocol to determine the location of the zone within which Head of Tide is located and will develop a protocol to evaluate changes due to RSL.

Climate Ready Estuary Pilot*:** The USEPA and BCDC conducted a pilot project to assess key vulnerabilities of the San Francisco estuary system to climate change. The assessment took advantage of significant work underway in the region, particularly on RSL, to support analysis of climate drivers and ecosystem effects. The project identified known stressors and potential climate change impacts on the Bay, and then synthesized experts' opinions to address uncertainties due to insufficient technical information. USEPA staff has prepared a report that describes the results of the analysis and the utility of the process to studying climate change impacts, which will be released after internal USEPA review. ***(A copy of the Executive Summary of the Final Report can be found in Appendix 12.)

The OWLS are coming.
Are you ready?

Preparing for Change Along Our Shores

Ribbon Cutting
May 21st
Thursday, 10 AM
the Mill Valley-Sausalito Multi-Use Path at Almonte

Sea level rise is impacting us **HERE** in Marin County **NOW**. It is up to all of **US** to protect the bayside communities that we love.

Join the OWL Team and Here-Now-Us:
The County of Marin, Supervisor Kate Sears, Climate Access, FEMA, Owlized, Autodesk, VIPs, friends and neighbors

Come take a look through this high tech viewer for a sea level rise virtual reality experience. See what higher tide levels mean along the Richardson's Bay shoreline now, what it could mean in the near future and see some possible responses to meet the challenge of living with sea level rise. Join us as we engage in the conversation about sea level rise and adaptation planning: www.Here-Now-Us.org and @HereNowUs #OWLMarin and "Like" us on Facebook!
Hosted viewings will be held on 5/20 and 5/22 from 10 AM to 4 PM, on the hour —no appointment necessary.
For more information, please contact Leslie Alden: 415-473-7862 or email at LAlden@marincounty.org

HERE -NOW-US *is a public-private-community project to test and promote community engagement on climate change risks*

CALENDAR ITEM
119

A	Statewide	04/23/15
		J. Deleon
		S. Pemberton
S	Statewide	K. Keen

STAFF REPORT ON THE CALIFORNIA STATE LANDS COMMISSION STAFF'S ACTIVITIES TO ADDRESS SEA LEVEL RISE

OVERVIEW:

As sea levels continue to rise, California's coastline will change, which will have a number of significant consequences for sovereign public trust lands, resources, and assets. This staff report provides background information about the potential impacts of sea-level rise on the public trust lands and resources under the State Lands Commission's (Commission) jurisdiction. It also provides an update about how the Commission and its staff have been addressing sea-level rise in its planning, leasing, and regulatory actions.

BACKGROUND:

The Commission serves the people of California by managing and protecting over 4 million acres of sovereign land, including the beds of California's navigable rivers, lakes and streams, and the State's tide and submerged lands. The Commission's jurisdiction extends along the State's 1,100+ miles of coastline and offshore islands, from the ordinary high water mark, as measured by the mean high tide line (except where there is fill or artificial accretion), to three miles offshore. The Commission also exercises oversight authority over sovereign public trust lands granted in trust by the Legislature to approximately 80 local jurisdictions.

Except for those locations where the boundary has been permanently fixed by either a court decision or an agreement with the Commission, the landward boundary of most sovereign public trust land is what is referred to as an "ambulatory boundary" because it moves with the ebb and flow of the tide. As previously mentioned, the boundary between state-owned sovereign land and private uplands is generally based on the location of the ordinary high water mark, as measured by the mean high tide line (except where there has been fill or artificial accretion). As a practical matter, this means that sea-level rise will likely affect the boundaries between sovereign public trust lands and privately owned uplands. Other sea-level rise impacts that could potentially affect the Commission's jurisdiction include an increase in applications to build new seawalls and protective structures, applications to maintain and repair existing

protective structures, and various changes in the characteristics of coastal marshes, wetlands, and lagoons.

The Commission employs a variety of management tools to protect the State's resources and accomplish its goals and objectives, including the resolution of boundaries between public and private lands, surface and mineral leases, cooperative management agreements, and, when necessary, litigation to enforce the protections of the Public Trust Doctrine, the State's property rights, and environmental quality laws. Through its boundary and title settlements, the Commission secures and protects the public's access rights to public lands within its jurisdiction and preserves resource areas that provide irreplaceable natural habitats for wildlife, vegetation, and unique biological communities.

Because sovereign lands are extensive, contain varied natural and cultural resources, and are home to various endangered species, their management requires a wide variety of programs and expertise. State lands are used by public and private entities for many purposes, including wetland restoration; water-dependent recreation; open space; ports; harbors; marinas; pipelines; industrial wharves; recreational piers and docks; marine terminals; dredging; timber harvesting; grazing; mining of sand, gravel, and precious metals; shoreline protective structures; and development and extraction of oil, gas, and geothermal resources. When considering lease applications and proposals for the use, occupation, or development of the State's public trust lands and resources, the Commission ensures that any approved use or project is both consistent with the common law Public Trust Doctrine and in the State's best interests.

The common law Public Trust Doctrine is integral to the Commission's work and especially important in the context of sea-level rise. The public's right to use and access California's waterways for commerce, navigation, fishing, boating, water-oriented recreation, and environmental preservation is protected by the Public Trust Doctrine. The Public Trust Doctrine ensures that title to sovereign land is held by the State in trust for the people of the State, who are the beneficiaries of the trust and entitled to access and use these lands. Sea-level rise will potentially limit the public's right to access these lands, as well as the protection of resources. The Commission has a fiduciary duty to the State and to the public to protect and preserve the State's trust assets. As such, a large part of the Commission's efforts to address sea-level rise have and will continue to focus on protecting public access and the public's property rights and interests in these public trust lands and resources.

According to a recent study by the National Research Council (NRC 2012), tide gauge measurements show that global sea level rose by an average of about 1.7 ± 0.5 millimeters per year (mm/yr) over the last century. However, the rate of sea-level rise has increased to about 3.1 ± 0.7 mm/yr during the last two to three decades. The NRC report assesses future global sea-level rise and future sea-level rise along the coasts of California, Oregon, and Washington. The rate of sea-level change is not uniform

around the world, nor is it the same in every place along the west coast of the United States. In California, the presence of a major plate tectonic boundary at Cape Mendocino causes the coastline to behave in different ways on either side of the feature. The NRC report accounts for those differences, as well as the major contributors to global sea-level rise (i.e. oceanic thermal expansion and the melting of glaciers and ice sheets). The NRC report also accounts for the atmospheric and oceanic variables that affect rates of sea-level rise in individual coastal regions. Thus, the NRC projects different values for future sea-level rise on either side of Cape Mendocino.

Relative to the year 2000, the NRC projects that sea level could rise along the California coast south of Cape Mendocino by 5 to 24 inches by the year 2050 and 17 to 66 inches by 2100. From Cape Mendocino to Puget Sound in the north, sea level is projected to change by -1 to +19 inches by 2050 and 4 to 56 inches by 2100. However, these figures do not account for the fact that the coast of northern California, Oregon, and Washington will one day undergo the next big subduction zone earthquake, which might cause some coastal areas to immediately subside and local sea level to suddenly rise by at least one meter.

There are numerous threats to California's coastal and bay communities and infrastructure from sea-level rise. Vast state-owned lands and resources under the Commission's jurisdiction will be affected by rising sea levels. Because of their nature and location, these lands and infrastructure are already vulnerable to natural hazards, including storms and extreme high tides. While some of these lands remain in a natural state, significant portions have been developed pursuant to leases issued by the Commission or through legislative grants to local jurisdictions. Future sea-level rise is expected to compound the effects of natural hazards on existing coastal and bay structures and will likely reduce or eliminate public access along the coastline in some areas.

The Commission, as a land and resource trust manager, has significant influence over on-the-ground development and uses of public trust lands that will be affected by sea-level rise. As discussed below, Commission staff is collaborating with federal, state, and local agencies to plan for and mitigate the impacts of sea-level rise on the lands and natural resources under its jurisdiction.

ADDRESSING SEA-LEVEL RISE:

INTERNAL ACTIVITIES

In 2009, the Commission issued a report entitled: *A Report on Sea Level Rise Preparedness* (http://www.slc.ca.gov/Reports/SEA_LEVEL_Report.pdf).[1] The report includes the results of a survey, which assessed whether trustees of legislatively-granted lands and the Commission's lessees had considered the potential impacts of sea-level rise. Based on survey responses, the Commission adopted recommendations from the report to improve sea-level rise preparedness. The recommendations that Commission staff are implementing include:

1) Update the Commission's lease application to incorporate sea-level rise considerations;
2) Include sea-level rise considerations in jurisdictional determinations;
3) Require boundary line agreements and title settlements to include a provision stating that the public trust easement will move with submergence or when subject to the ebb and flow of the tide;
4) Address the effects of sea-level rise on any relevant resource categories of a proposed project in the Commission's California Environmental Quality Act documents and in comment letters; and
5) Require all marine oil terminals to consider sea-level rise projections over the remaining life of the terminal.

In 2013, AB 691 (Muratuschi), Chapter 592, Statutes of 2013, was enacted to address sea-level rise impacts on granted public trust lands. Granted public trust lands include some of the State's most significant contributors to local, state, and national economies, including the ports of Los Angeles, Long Beach, San Diego, San Francisco, and Oakland. AB 691 requires local trustees of granted public trust lands with annual gross public trust revenues exceeding $250,000 to prepare and submit to the Commission an assessment of how they propose to address sea-level rise, including impacts on existing facilities and future development. Assessments must be submitted to the Commission by July 1, 2019. Later this year, grantees will receive letters offering assistance with AB 691 compliance.

In 2014, Commission staff participated in the Assembly Select Committee on Sea-Level Rise and the California Economy hearings. The Select Committee consulted many stakeholders to analyze the impacts of sea-level rise on coastal agriculture, fishing, aquaculture, tourism, and ports. The Select Committee also reviewed the authority of

[1] An update to the Report was provided to the Commission at its December 10, 2010 meeting; http://archives.slc.ca.gov/Meeting_Summaries/2010_Documents/12-10-10/Items_and_Exhibits/49.pdf

certain state agencies to address those issues. The Commission's Executive Officer provided testimony to the Select Committee on how the Commission and staff have been addressing sea-level rise and the threat to public trust lands and resources under the Commission's jurisdiction.

Current efforts to improve the Commission's consideration of sea-level rise issues in its decision-making include a revised surface leasing application that poses new questions regarding the impacts of sea-level rise. The questions will serve as a guide for applicants who propose new development or improvements to existing development to assess the impacts of future sea-level rise on their proposed projects. Applicants will also be asked to identify project design alternatives and/or adaptation measures to avoid impacts to coastal resources and structures, as well as minimize risk to proposed projects during their life expectancies. The information gained from these application questions will help the Commission develop appropriate and effective lease terms to address and adapt to sea-level rise, including terms to protect and enhance public access and recreational opportunities to the State's public trust lands, as well as protect the State against hazard and liability risks associated with sea-level rise.

In addition, staff is designing a webpage to serve as a resource for applicants who must respond to the sea-level rise questions. The webpage will include statewide tools, maps, datasets, and other relevant information. It will be continually updated and will also serve as a resource for the public and legislative grantees subject to the requirements of AB 691.

COLLABORATION AND PARTNERSHIP

The Commission staff is also addressing sea-level rise by contributing to statewide efforts to prepare and adapt. As a member of the State's Climate Action Team Coastal and Ocean Resources Working Group (CO-CAT),[2] Commission staff coordinated with other coastal and bay conservation and management agencies to review and provide recommendations for the *Safeguarding California: Reducing Climate Risk* (Safeguarding California Plan). Released in July 2014 by the California Natural Resources Agency, the Safeguarding California Plan is part of ongoing efforts to reduce impacts and prepare for risks associated with climate change by providing policy recommendations and guidance for decision-makers, including priority actions for protecting coastal communities and ocean and coastal ecosystems.

[2] The CO-CAT is a forum for senior-level staff from California state agencies with ocean and coastal resource management responsibilities to share information and coordinate on actions, including the implementation of the ocean and coastal resources chapter of the 2009 California Climate Adaptation Strategy and development of sea-level rise guidance.

The Commission is also a member of the State Coastal Leadership Group on Sea-Level Rise (Leadership Group). The Leadership Group includes the executive leaders of the Ocean Protection Council, State Lands Commission, California Coastal Commission, San Francisco Bay Conservation and Development Commission, and State Coastal Conservancy. The main focus of the Leadership Group is to develop and implement a coordinated approach for the State that leverages resources, expertise, and complementary agency missions to address sea-level rise. The Leadership Group is developing a shared definition/vision of resilience that can facilitate sea-level rise preparedness and is in the process of crafting an Action Plan that will identify and prioritize specific activities to interpret the Safeguarding California principles and accomplish successful resilience. After the Action Plan is finalized, staff will bring it to the Commission for its consideration.

Another way that the Commission collaborates to facilitate sea-level rise preparedness is through the California Collaborative on Coastal Resilience (Collaborative). The Collaborative, a subgroup of the Leadership Group, is focused on ways that state agencies can support local coastal jurisdictions in their efforts to prepare for sea-level rise. The Collaborative convened a workshop in March 2015 in Humboldt County to bring local stakeholders and partners, including tribes, together to discuss local adaptation projects, challenges, and how the State can be of assistance. This pilot project is helping the various agencies involved in improving collaboration among a diverse stakeholder group and providing ideas for how the State can help local governments be proactive in addressing sea-level rise.

CONCLUSION:

Sea-level rise, if unaddressed, will have catastrophic consequences for the State's millions of acres of sovereign lands, including limiting public access and ceding the State's property rights to private entities, particularly as the legal sovereign land boundary moves landward with the mean high tide, and the call to protect private property becomes increasingly urgent. Additionally, impacts from sea-level rise also pose significant risks to existing infrastructure located on public trust lands. The Commission and its staff are committed to being proactive, creative, and diligent to meet the challenges presented by climate change and rising sea levels. Through continued collaboration, commitment to science-based, comprehensive, and transparent policy development, and focused education efforts, the Commission and its staff will continue to protect and enhance the public's interests in the lands, resources, and assets under the Commission's jurisdiction as sea-level rises.

Sea Level Rise and the Public Trust Doctrine:
Moving Boundaries & Emerging Issues

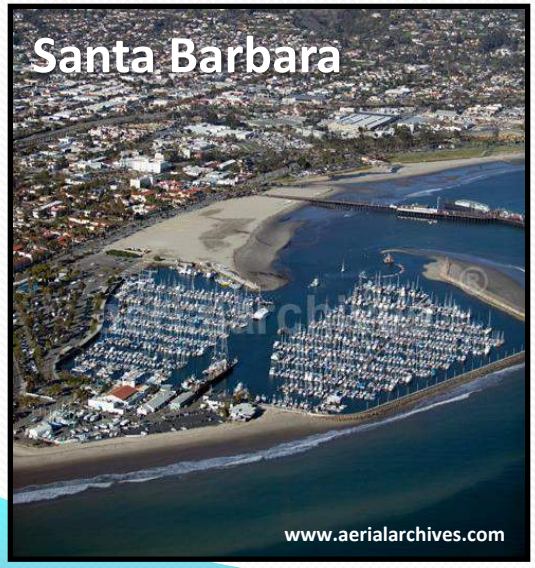
Jennifer Lucchesi

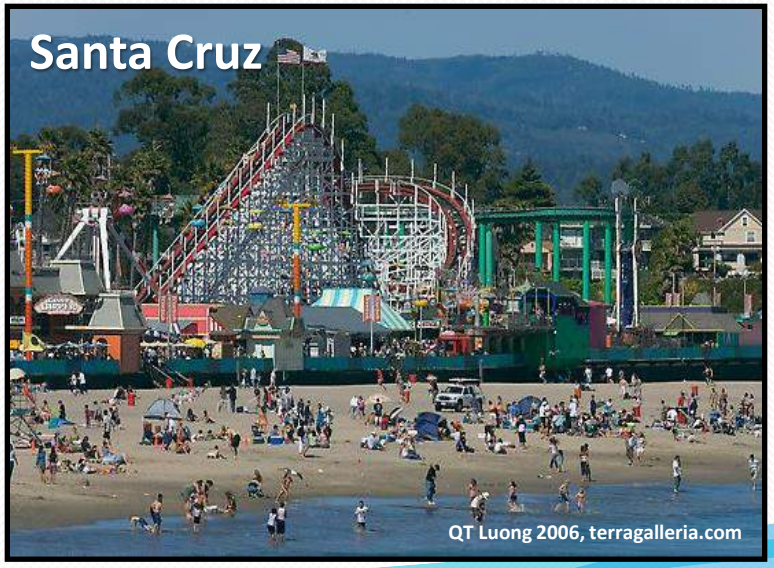
Executive Officer
California State Lands Commission

Coastal Symposium 15
May 27, 2015

California State Lands Commission

Three-Quarters of All Californians Live Near the Coast





California's Sovereign Lands

The Commission's jurisdiction is rooted in the **Public Trust Doctrine**. Tide and submerged lands and the beds of lakes, streams, and other navigable waterways are held in trust by the State of California for the benefit of the people of California.

- 4 million acres
- 120 rivers and sloughs
- 40 lakes
- Thousands of miles of non-coastal shorelines
- **1100 miles of coastline**
- **3 nautical miles offshore**

Jurisdiction and Management Responsibilities

Energy and Mineral Resources

MOTEMS

Oil Spill Prevention

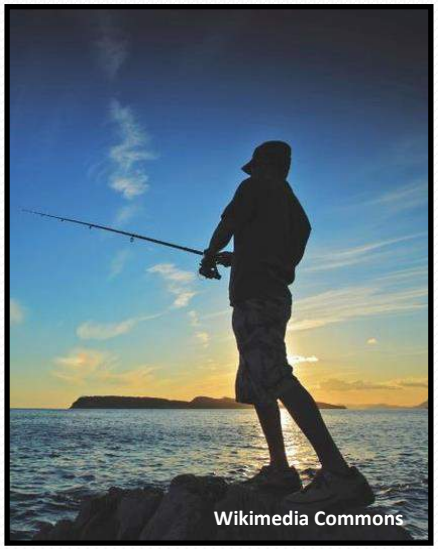
Marine Invasive Species Program

The CSLC as a "Land and Resource Trust Manager"

Mission:

The staff of the California State Lands Commission serves the people of California by providing stewardship of the lands, waterways, and resources entrusted to its care through economic development, protection, preservation, and restoration.

Public Trust Doctrine



The state's title to its tide and submerged lands is a title held in trust for the people of the state so that those citizens may enjoy the navigation of the waters, carry on commerce over them, and have liberty of fishing free from obstruction or interference from private parties.

Illinois Central R.R. Co. v. Illinois (1892) 146 U.S. 387, 452

Origins of the Public Trust Doctrine

Roman Civil Law

The air, the rivers, the sea and the seashore were incapable of private ownership; they were dedicated to the use of the public (Institutes of Justinian, 534 CE)

English Common Law

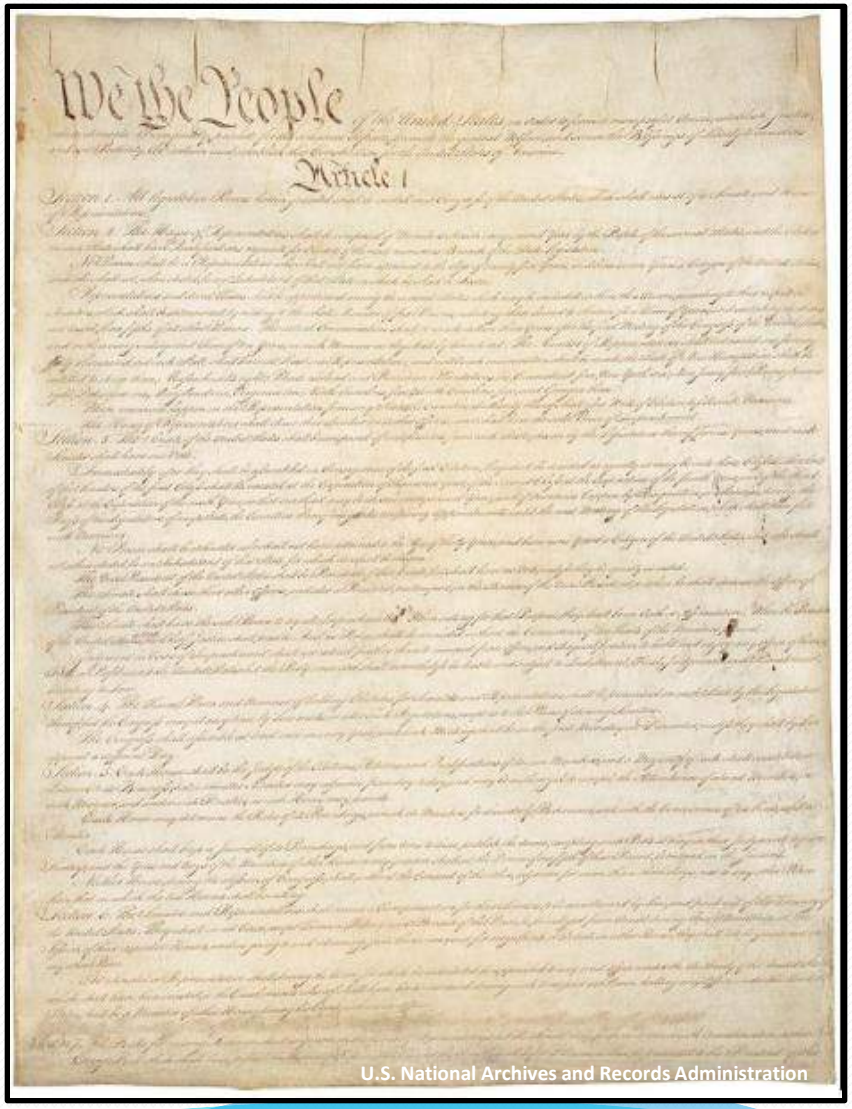
The sovereign held the tide and submerged lands, not in a proprietary capacity, but as trustee of a public trust for the benefit of the people of the realm (Magna Charta, 1215)

Origins of the Public Trust Doctrine in the U.S.

The precept that tide and submerged lands are unique and that the ruler of the people holds them in trust for the people was transplanted to the new world and when the U.S. broke free of the English sovereign; those former colonies became sovereign states.

- Post-American Revolution
  Martin v. Waddell (1842)

- Equal-Footing Doctrine
  Pollard's Lessee v. Hagan (1845)

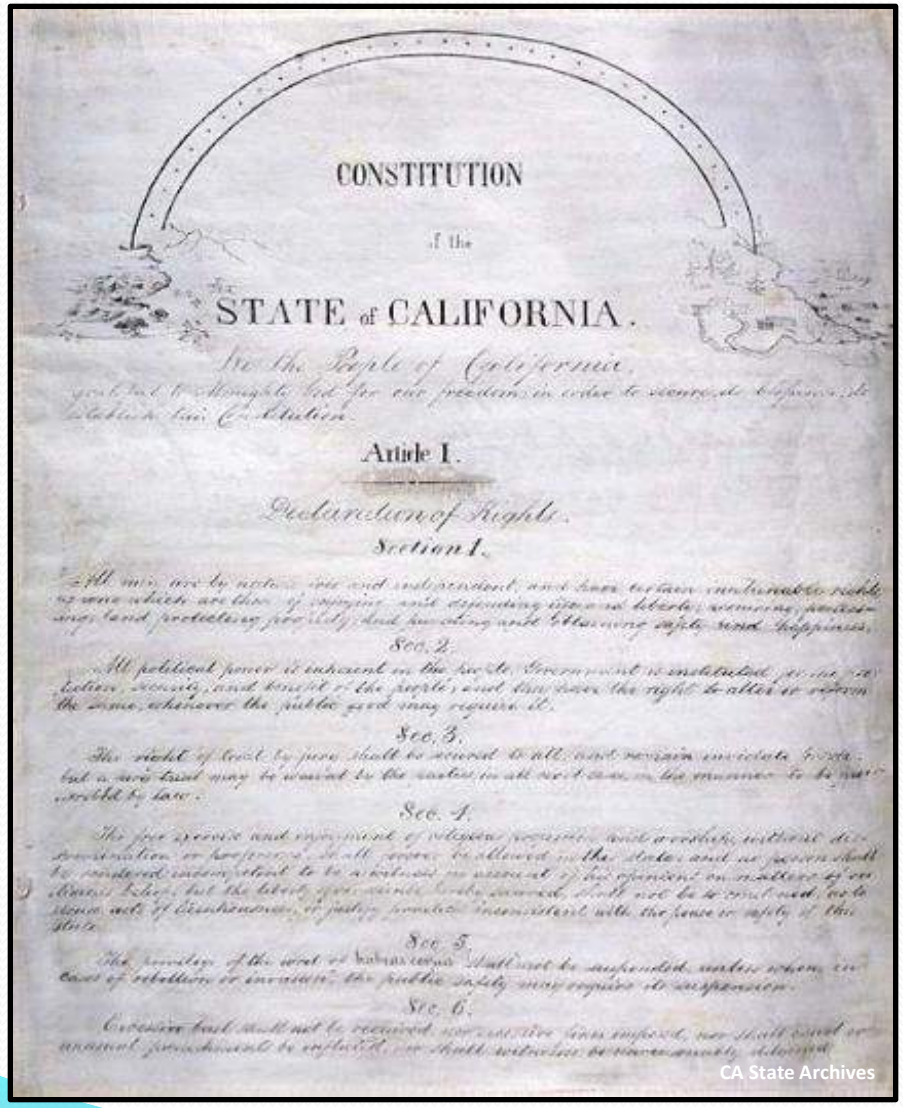


U.S. National Archives and Records Administration

Public Trust Doctrine: Limitations on State Powers

Illinois Central Railroad Co. v. Illinois (1892)

Public Trust Doctrine: California Constitution


CONSTITUTION

of the

STATE of CALIFORNIA.

We the People of California,

Article I.

Declaration of Rights.

Section 1.

Sec. 2.

Sec. 3.

Sec. 4.

Sec. 5.

Sec. 6.

CA State Archives

1879

- Article X, Section 3 – State prohibited from selling certain tidelands
- Article X, Section 4 – Public right of access to waterways guaranteed

1910

- Article 1, Section 25 – Public Right to Fish

Public Trust Doctrine: General Guidelines

- The primary use must be water-dependent or water-related.
- The use must directly promote or support uses authorized by the Public Trust Doctrine and if the trust is managed by a local or regional governmental entity, be authorized by the statutory trust grant.
- The use must accommodate or enhance the statewide public's enjoyment or benefit from the trust lands and not merely provide a local or municipal public benefit.


Don DeBold, Wikimedia Commons


© NOAA

California State Lands Commission

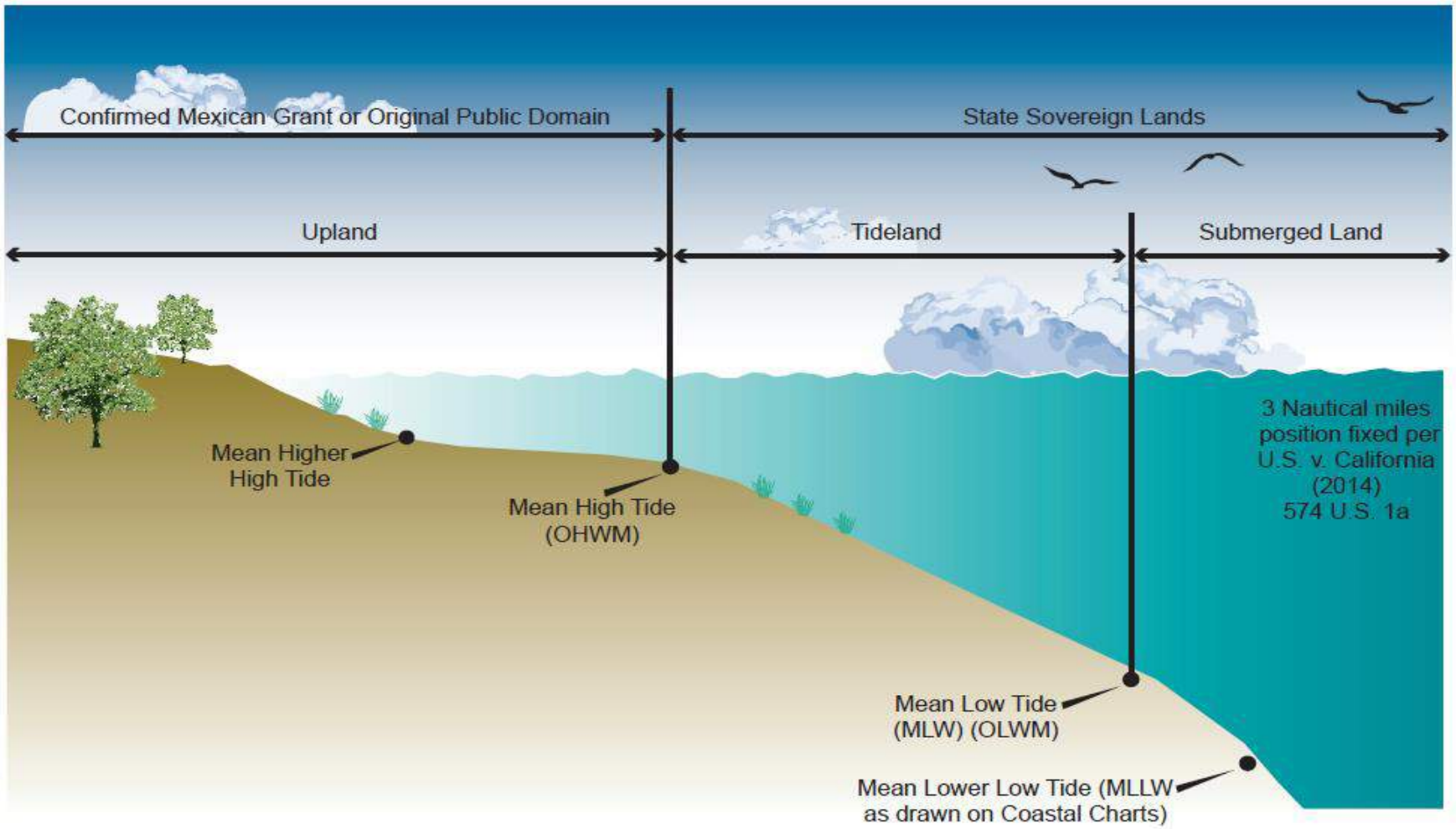
Public Trust Doctrine: Consistent/Inconsistent Uses

Consistent ⟷ **Inconsistent**

The Mean High Tide Line: An Ambulatory Boundary

- Sovereign lands are generally defined by reference to the ordinary high and/or low water marks of waterways, as measured by the mean high tide line, except where there has been fill or artificial accretion
- With sea level rise, the mean high tide line will shift landward
- Sea level rise will likely affect boundaries between State-owned sovereign land and private uplands

Water Boundaries and Ownership



General Land Title and Tide Line Cross Section Along the Pacific Ocean

California State Lands Commission

The Mean High Tide Line: Boundary Surveys


CA State Lands Commission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CA State Lands Commission


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CA State Lands Commission


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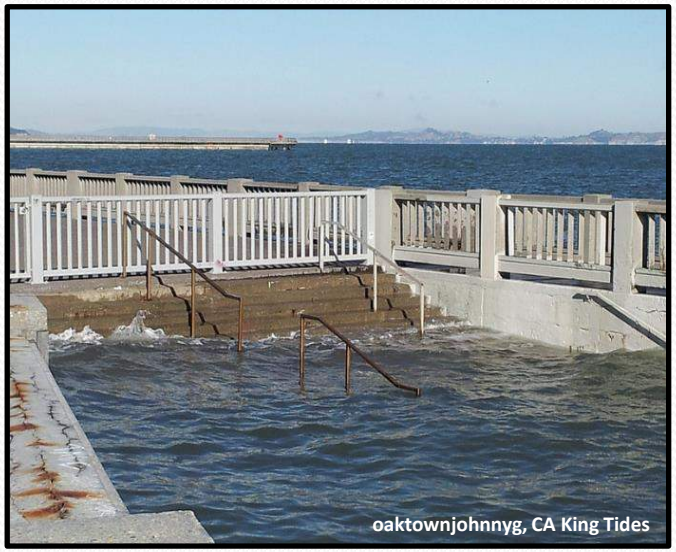
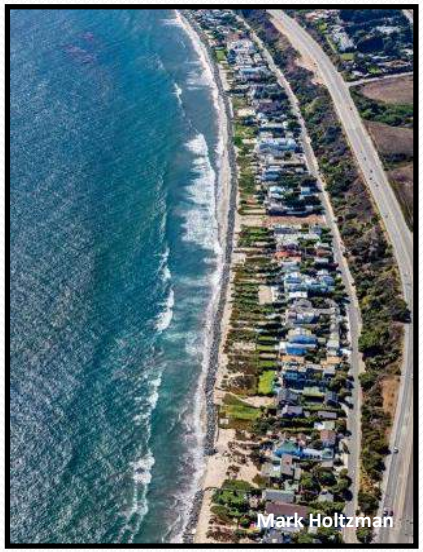
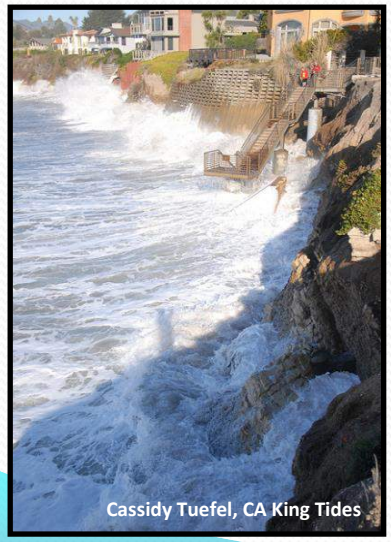
California State Lands Commission

Coastal Squeeze

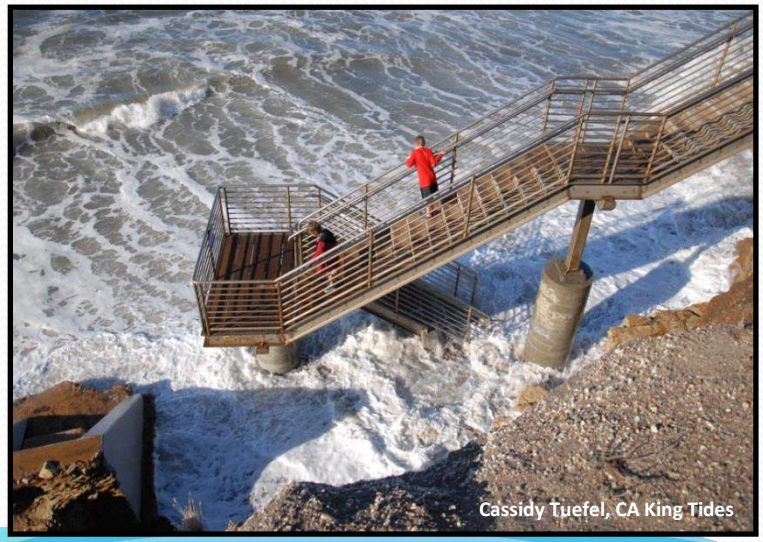

oaktownjohnnyg, CA King Tides


Dan Jarvis, CA King Tides


Mark Holtzman


Cassidy Tuefel, CA King Tides


USGS

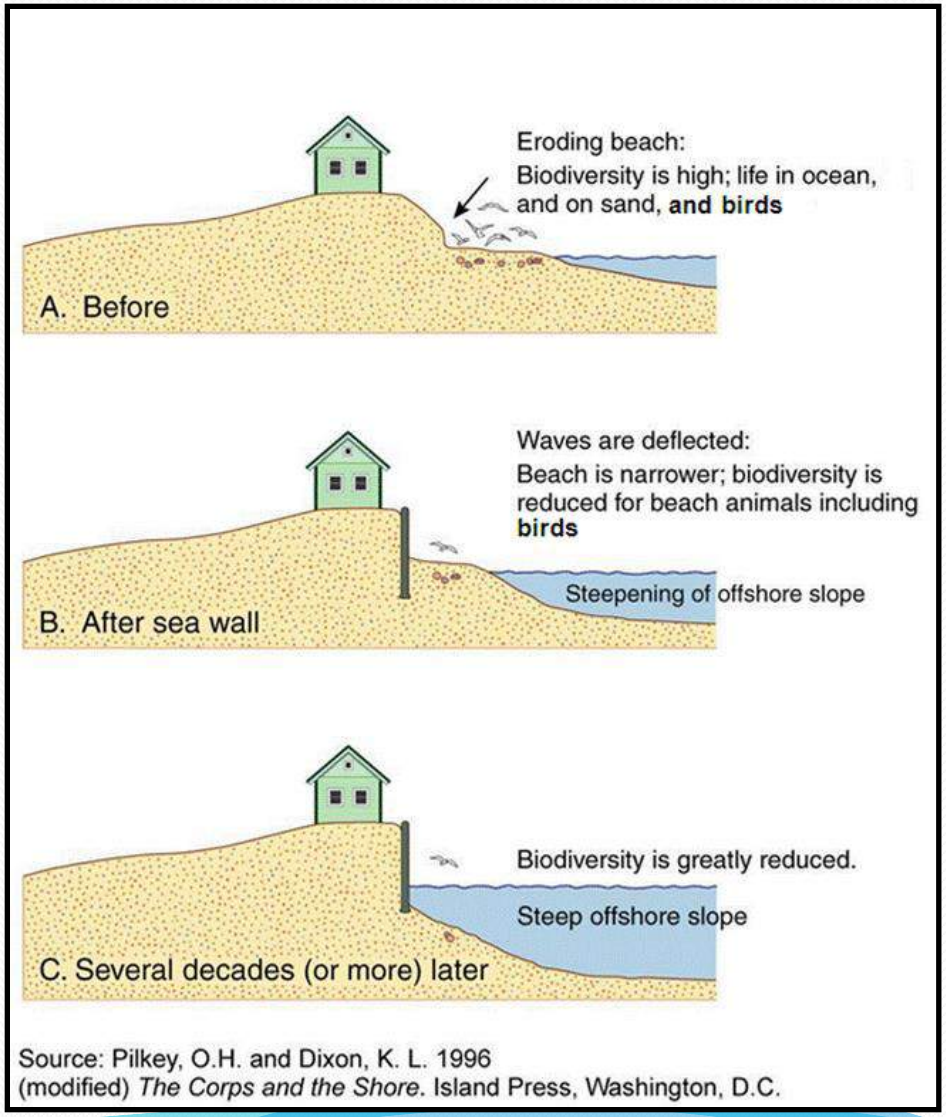

Cassidy Tuefel, CA King Tides

California State Lands Commission

Shoreline Protection Structures

Shoreline Protection Structures: Potential Impacts

- Visual Impacts
- Placement Loss
- Access Issues
- Reduction of Sand Supply from Armoring Cliffs
- Passive Erosion
- Active Erosion
- Biological Impacts
- Ecological Impacts



Source: Pilkey, O.H. and Dixon, K. L. 1996 (modified) *The Corps and the Shore*. Island Press, Washington, D.C.

Current and Future Impacts of Sea Level Rise

Broad Beach Coastline

Malibu, CA

1972

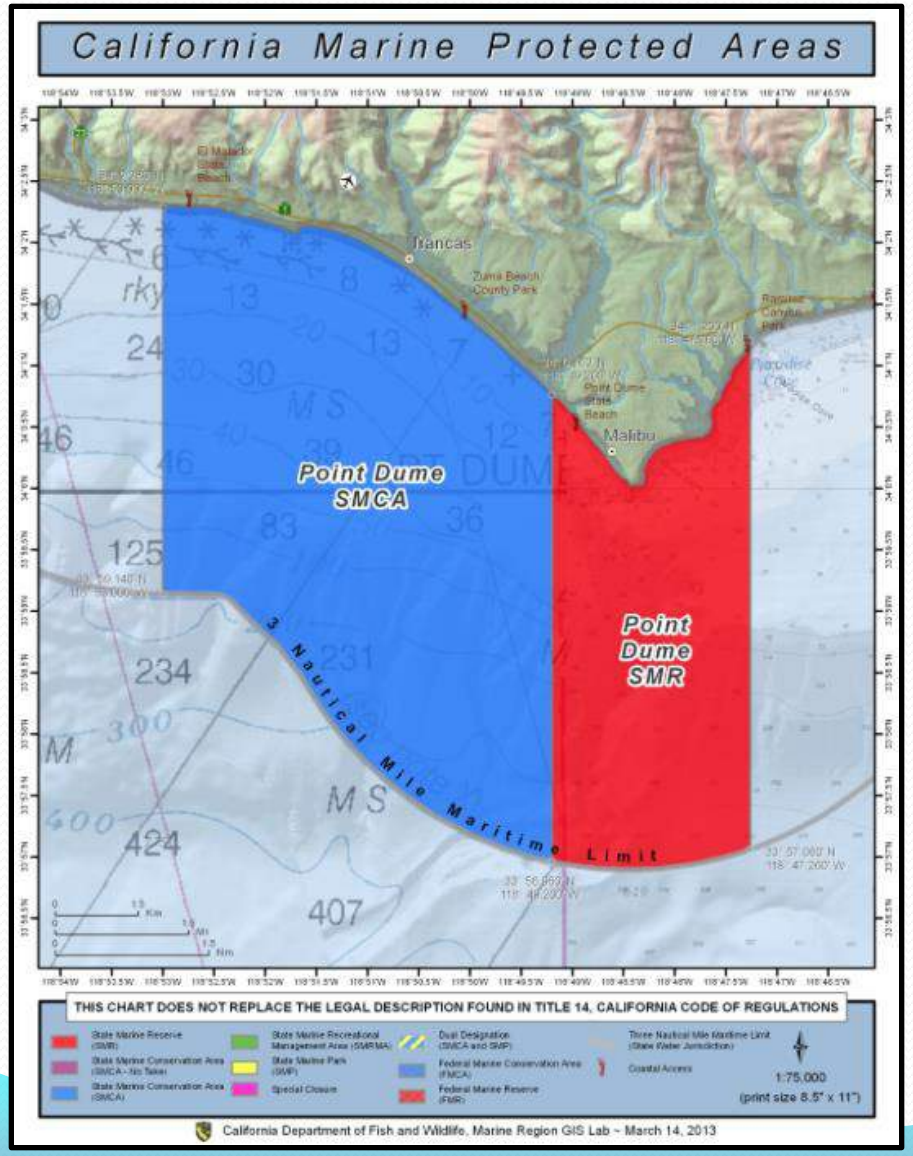
2013

California State Lands Commission

Broad Beach Coastline

California State Lands Commission

Broad Beach Coastline



California State Lands Commission

Threats to Coastal Communities, Infrastructure, and Ecosystems

California State Lands Commission

Hazards and Public Safety

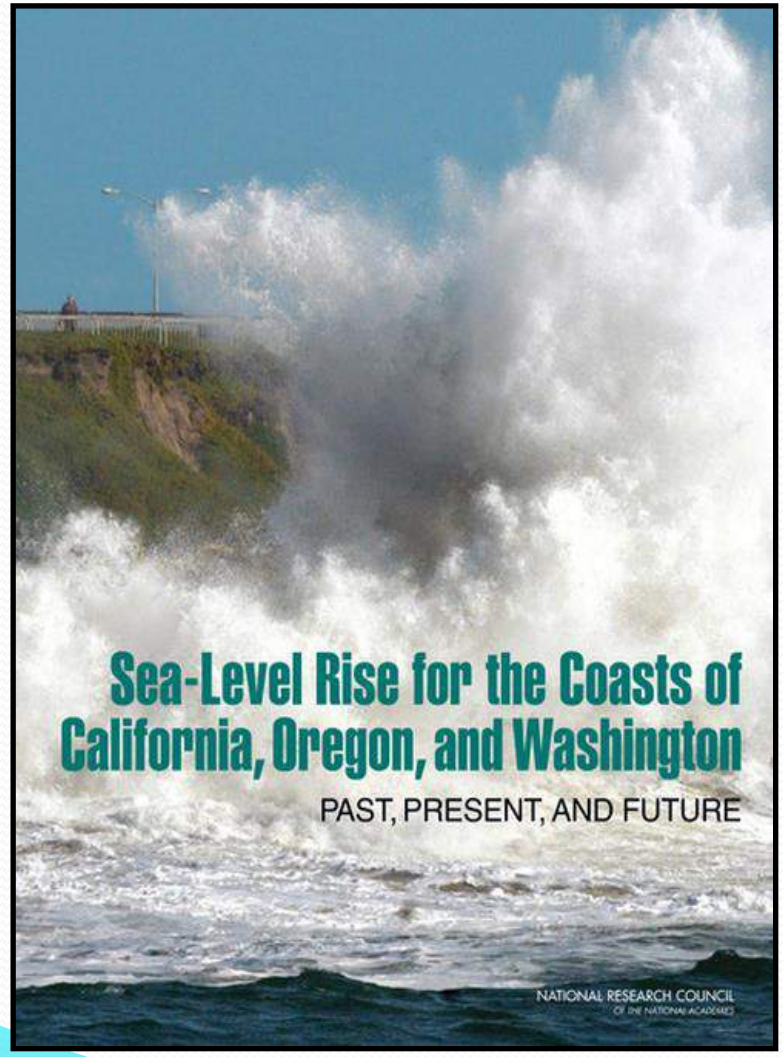

Jef Poskanzer, CA King Tides

Ron Rothbart, CA King Tides


Ron Rothbart, CA King Tides

Claire Fackler, CA King Tides

Current Practices to Address Sea Level Rise



National Research Council Report (2012)

Time Period	North of Cape Mendocino	South of Cape Mendocino
2000-2030	-4 to 23 cm (-1.57 to 9.06 in)	4 to 30 cm (1.57 to 11.81 in)
2000-2050	-3 to 48 cm (-1.18 to 18.90 in)	12 to 61 cm (4.72 to 24.02 in)
2000-2100	10 to 143 cm (3.94 to 56.30 in)	42 to 167 cm (16.54 to 65.75 in)

Current Practices to Address Sea Level Rise

Consideration of the Effects of Sea Level Rise included in CEQA Comment Letters

STATE OF CALIFORNIA — ARNOLD SCHWARZENEGGER, *Governor*

CALIFORNIA STATE LANDS COMMISSION
100 Howe Avenue, Suite 100-South
Sacramento, CA 95825-8202

PAUL D. THAYER, *Executive Officer*
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Relay Service From TDD Phone **1-800-735-2929**
from Voice Phone **1-800-735-2922**

Contact Phone: **(916) 574-1900**
Contact FAX: **(916) 574-1885**

February 27, 2009

File Ref: SCH #2009022030

Humboldt Bay Harbor, Recreation and Conservation District
Attn: David Hull
601 Startare Drive
P.O. Box 1030
Eureka, CA 95502-1030

Subject: Notice of Preparation of a Draft Environmental Impact Report (DEIR) for the Redwood Marine Terminal Modernization and Long-term Expansion Project, Eureka, Humboldt County

Dear Mr. Hull,

Staff of the California State Lands Commission (CSLC) has reviewed the Notice of Preparation (NOP) for the above referenced proposed project. Under the California Environmental Quality Act (CEQA), Humboldt Bay Harbor, Recreation and Conservation District (District) is the Lead Agency and the CSLC is a Trustee Agency, and potentially a Responsible Agency, for this project.

By way of background, the State of California acquired sovereign ownership of all tidelands and submerged lands and beds of navigable waterways upon its admission to the United States in 1850. The State holds these lands for the benefit of all the people of the State for statewide Public Trust purposes, which include waterborne commerce, navigation, fisheries, water-related recreation, habitat preservation, and open space. The landward boundaries of the State's sovereign and/or Pubic Trust interests in areas that are subject to tidal action are generally based upon the ordinary high water marks of these waterways as they last naturally existed. Both the Public Trust easement and fee-owned lands are under the jurisdiction of the CSLC.

The Redwood Marine Terminal Multipurpose Terminal Modernization project, as proposed, involves lands that have been legislatively granted to the Humboldt Bay Harbor Recreation and Conservation District pursuant to Chapter 1283, Statutes of 1970 and as amended, with minerals reserved; therefore, a lease from the CSLC will be required only if dredging is required for this project. However, any development, leases or franchises involving the granted lands must still be consistent with the terms of the legislative grant and the Public Trust easement.

The first phase of the proposed project involves the modernization of existing facilities that will enable the District to use the terminal for a variety of port-related uses.

MITIGATED NEGATIVE DECLARATION
PORT COSTA WHARF DECONSTRUCTION PROJECT
Final December 2013

Prepared by:
California State Lands Commission
100 Howe Avenue, Suite 100 South
Sacramento, California 95825

Applicant:
Phillips 66 Company
1380 San Pablo Avenue
Rodeo, California 94572

Consideration of the Effects of Sea Level Rise on the CSLC's Environmental Analyses

Current Practices to Address Sea Level Rise

Surface Leasing Application

e. If the project involves development, in an area subject to tidal action, provide a risk analysis, implications of failure, and adaptation strategies for addressing projected sea level rise of 16 inches by year 2050 and 55 inches by year 2100, relative to the projected life expectancy of the project. Adaptation strategies may include alternate project designs to prevent impacts.

f. What engineering standards are being relied on to address potential impacts from sea level rise on proposed or existing facilities throughout the life of the project?

California State Lands Commission
Land Management Division — Page 7 of 16 — Revised: 10/12/11

Part II, Section B, Subsection 1

Part III, Section B

Will the project involve:	Yes	Maybe	No
1. A change in existing features of any bays, tidelands, beaches, lakes, or hills, or substantial alteration of ground contours?	☐	☐	☐
2. A change in scenic views from existing residential areas or public lands or roads?	☐	☐	☐
3. A change in pattern, scale or character of the land use at or in the general area of the project?	☐	☐	☐
4. Impacts to plants or animals?	☐	☐	☐
5. The potential introduction or spread of non-native species?	☐	☐	☐
6. Any feature subject to sea level rise or other effects associated with climate change over the life of the project? If so, please explain in detail and address any planned adaptation strategies.	☐	☐	☐
7. Generation of solid or liquid waste or litter?	☐	☐	☐

California State Lands Commission
Land Management Division — Page 12 of 16 — Revised: 10/12/11

California State Lands Commission

Current Practices to Address Sea Level Rise

MOTEMs Regulations

Surface Lease Agreement

Language for Boundary Line and Title Settlement Agreements

Assembly Bill (AB) 691

- AB 691 (Muratsuchi), Chapter 592, Statutes of 2013
- Requires the State's trustees to assess the impacts of sea-level rise and propose how it will be addressed on granted public trust lands
- Includes existing/future development and tidal/submerged lands underlying the State's ports, harbors, and marinas
- Assessment due to the Commission no later than July 1, 2019


Bob Gingg, CA King Tides


www.portoflosangeles.org

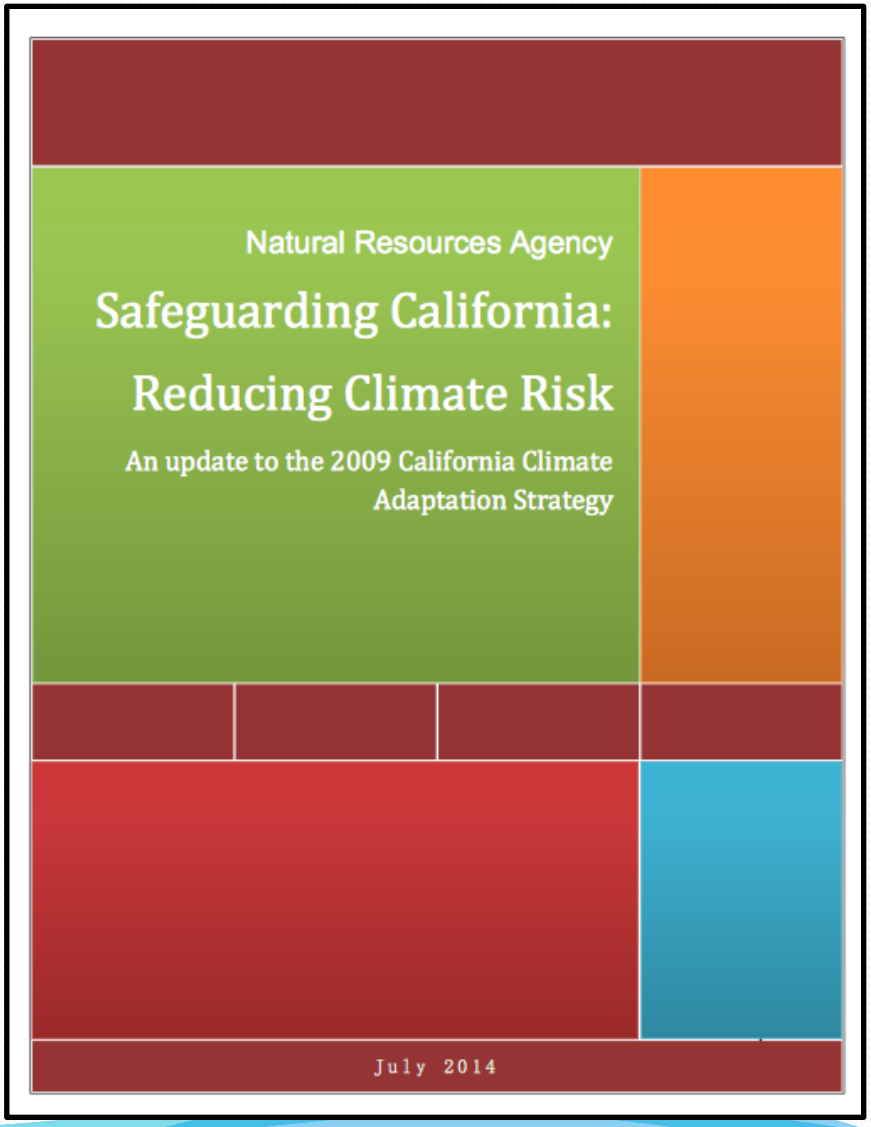
California State Lands Commission

CSLC Grantees Subject to AB 691

City of Alameda	Crescent City Harbor District	City of Morro Bay	Port San Luis Harbor District	San Mateo County
City of Avalon	City of Emeryville	Moss Landing Harbor District	City of Redondo Beach	City of Santa Barbara
City of Benecia (Marina)	City of Eureka	City of Newport Beach	Port of Redwood City	City of Santa Cruz
City of Berkeley	Humboldt Bay Harbor Rec.	Port of Oakland	City of San Diego	Santa Cruz Port District
City of Brisbane	City of Long Beach	City of Oceanside	Port of San Diego	City of Santa Monica
City of Carpinteria	City of Los Angeles (Port of LA)	Orange County	City and County of San Francisco	City of Sausalito
City of Crescent City	City of Manhattan Beach	City of Pittsburg	San Francisco Port District	City of Vallejo
	City of Monterey		San Mateo County Harbor District	

CO-CAT & Safeguarding CA Implementation Collaborative

- Coordinated with other agencies to review and provide recommendations for the Ocean and Coastal Ecosystems and Resources chapter in *Safeguarding California: Reducing Climate Risk* (July 2014)
- *Safeguarding California* provides policy recommendations and guidance for decision-makers
- Implementation Reports in Summer 2015 and 2016



State Coastal Leadership Group on Sea Level Rise


Jay McGill, CA King Tides


Jack Sutton, CA King Tides

- Facilitating a coordinated approach that leverages resources, expertise, and complementary agency missions to address sea-level rise
- Developing an Action Plan that will identify and prioritize specific activities to interpret the *Safeguarding California* principles and accomplish resilience

California Collaborative on Coastal Resilience

- Pilot project in Humboldt County focused on how the state can support the community in their efforts to prepare for sea-level rise
- Held a workshop in March 2015 to bring local stakeholders and partners together to discuss local adaptation projects, challenges, and how the state can help
- Developing a framework for how state agencies can best support local coastal jurisdictions in achieving their resilience goals

Current Efforts by CSLC Staff

Brant Ward, The Chronicle

Tito Son, CA King Tides

- Revising the Commission's Surface Leasing Application process to guide applicants assessing the impacts of future sea-level rise and climate change on their proposed projects
- Applicants will also be asked to identify project design alternatives and/or adaptation measures to avoid impacts and reduce risks
- Developing a companion webpage to serve as a resource

Questions? Comments?

CALIFORNIA STATE
LANDS COMMISSION

Thank you!

The Nature Conservancy
Protecting nature. Preserving life.®

The Nature Conservancy
California Program
201 Mission Street, 4th Floor
San Francisco, CA 94105-1832
Phone: (415) 777-0487 | nature.org/california | conserveca.org

REDUCING CLIMATE RISKS WITH NATURAL INFRASTRUCTURE

This report was prepared with the support of the California Landscape Conservation Cooperative (USFWS), the California Coastal Conservancy and Pacific Gas and Electric.

Coastal Conservancy
Pacific Gas and Electric Company®
CA LCC

"... recent assessments project alteration in the frequency, intensity, spatial extent or duration of weather and climate extremes, including climate and hydrometeorological events such as heat waves, heavy precipitation events, drought and tropical cyclones. ... New, improved or strengthened processes for anticipating and dealing with the adverse effects associated with weather and climate events will be needed in many areas."

—Intergovernmental Panel on Climate Change, 2012

Citation: IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Available at: http://ipcc-wg2.gov/SREX/

LEAD AUTHOR: Jim Downing
CO-AUTHORS: Louis Blumberg and Eric Hallstein

FRONT COVER PHOTOS: TOP LEFT: Sacramento River, California © *Geoffrey Fricker* **TOP RIGHT:** Water from San Francisco Bay overflows the Embarcadero, San Francisco © *Mike Filippoff/California King Tides Initiative* **BOTTOM:** Surf crashes into seawall in Pacifica, California © *Jack Sutton/California King Tides Initiative*

BACK COVER PHOTOS: TOP LEFT: Canada geese in the Yolo Bypass © *CanadaGeeseYWAfeliz* **TOP RIGHT:** Road damage due to flooding © *USFWS/Flickr via a Creative Commons license* **MIDDLE RIGHT:** Eroded cliffs in Pacifica, California © *DeanWmTaylor/Flickr via a Creative Commons license* **BOTTOM LEFT:** Cyclist avoids flooding in Marin County, California © *Yanna.B/California King Tides Initiative* **BOTTOM RIGHT:** Wetlands serve as a natural solution to flood protection © *Tom Mikkelsen/California King Tides Initiative*

Reducing Climate Risks with Natural Infrastructure

Over the past two centuries, efforts to control flooding have transformed California's natural landscape. Rivers have been dammed and constrained by levees, wetlands have been drained and shorelines have been fortified against erosion. These projects opened land to urban and agricultural development but at a huge and ongoing cost to fish, migratory birds and other wildlife throughout the state. Roughly 10 percent[1] of California's historic wetlands remain, nearly all major streams have been altered dramatically and more than 100 miles of the state's coastline have been armored with rock and concrete.[2]

Despite these measures—implemented at great expense—significant risks to people and property remain. Coastal erosion threatens homes from San Clemente to Santa Barbara to Pacifica. Along the shores of San Francisco Bay, at least $29 billion in property, including major business centers, is currently at risk from a 100-year flood.[3]

Climate change is expected to drive a combination of extreme weather and sea level rise that will increase the risk of flooding in California. The Intergovernmental Panel on Climate Change, the leading international body for the assessment of climate change, anticipates a significant increase in heavy precipitation events, translating to increased flood risk in many watersheds. The state Ocean Protection Council projects that sea level will rise five to 25 inches by 2050, and 17 to 66 inches by 2100.[4]

Already, the state's communities are considering how to respond to the growing risks. Much is at stake, as substantial resources likely will be devoted to protecting communities. For example, Louisiana recently adopted a $50 billion plan to prepare for rising sea levels and future storms.[5]

As California considers how to adapt to a changing climate, planners often focus on defensive infrastructure with a negative habitat impact: bigger levees, rock walls to protect coastlines or even giant sea gates.[6]

But California can follow a different path. With natural or "green" infrastructure that leverages natural processes to reduce risk to human lives, property and businesses, the state can build resilience to the coming changes while restoring natural habitats instead of degrading them.

1. *California Natural Resources Agency, 2010 State of the State's Wetland report. www.resources.ca.gov/ocean/SOSW_report.pdf*
2. *Lesley Ewing, California Coastal Commission, pers. comm, 11 Sept 2013. Figure is 102 miles of 1,073 total miles of ocean coastline.102 miles is the total linear distance of armoring on coastland, and does not include offshore structures such as breakwaters.*
3. *Heberger et al, 2012. The Impacts of Sea Level Rise on the San Francisco Bay. California Energy Commission Report 500-2012-014. http://www.energy.ca.gov/2012publications/CEC-500-2012-014/CEC-500-2012-014.pdf. Page 20: estimated $29 billion in property currently at risk, replacement value of buildings and contents in 2000 dollars.*
4. *California Ocean Protection Council, 2013 State of California Sea-Level Risk Guidance Document. http://www.opc.ca.gov/webmaster/ftp/pdf/docs/2013_SLR_Guidance_Update_FINAL1.pdf*
5. *State of Louisiana, 2012 Coastal Master Plan. http://www.coastalmasterplan.louisiana.gov/*
6. *http://www.scientificamerican.com/article.cfm?id=tidal-gate-across-san-francisco-bay-proposed-to-manage-sea-level-rise*

"Green" or "natural" infrastructure can include a range of strategies. Some projects focus on preserving existing natural systems, while others are highly engineered, combining green techniques with more traditional "gray" approaches.

This report evaluates nine green infrastructure case studies in California. Each improves flood or coastal protection, provides habitat and preserves or restores the natural dynamics between water and land. We review the available data on the costs and benefits of each case and, where possible, compare this information with the costs and benefits of a gray alternative at the same site. We also present information on the sources of funding for each project. Notably, public dollars have provided essential support to the partnerships that have made these natural infrastructure projects possible.

What is a "100-year" flood?

Climate change and FEMA flood risk estimates

Estimates of flood risk in this report are based on standard Federal Emergency Management Agency (FEMA) analyses using historic precipitation, stream-flow and sea-level data. A 100-year flood has a 1 percent chance of occurring in any given year, based on past experience. Notably, these estimates have not been updated to reflect the effect of climate change on flood risk in California. Climate change is expected to increase flood risks in the future. A 2013 federal study,[7] for instance, estimates that the total land area subject to 100-year river floods nationwide will increase 45 percent by 2100, with climate change responsible for 70 percent of that increase.

PHOTO: Flooded city street © *Don Becker, USGS/Flickr via a Creative Commons license*

7. *AECOM, The Impact of Climate Change and Population Growth on the National Flood Insurance Program through 2100. Report prepared for the Federal Insurance and Mitigation Administration and the Federal Emergency Management Agency. June 2013. Available at: http://www.aecom.com/deployedfiles/Internet/News/Sustainability/FEMA%20Climate%20Change%20Report/Climate_Change_Report_AECOM_2013-06-11.pdf*

Natural Infrastructure: Nine Cases, Multiple Approaches

Green infrastructure project approaches range from the preservation of natural systems to combinations of ecological restoration and engineered structures.

Preservation*
Protects existing ecology and river/coastal processes
Example: Conservation of floodplain maintains natural flood protection

Restoration*
Restores natural ecology and river/coastal processes
Example: Wetland restoration provides flood protection and habitat

Structure + Nature
Combines levees or other structures with restored natural systems
Example: Setback levee and floodplain restoration provide risk reduction as well as habitat

Structure Alone
Builds defenses with a neutral or negative impact on natural systems
Example: Armored seawall or levee reduces risk but does not provide habitat and may alter natural erosion and sedimentation processes

Case Studies	Preservation	Restoration	Structure + Nature	Structure Alone
1. Hamilton City Setback Levee Habitat Restoration			✔	
2. Napa River—Napa Creek Flood Protection Project		✔	✔	✔
3. Yolo Bypass			✔	
4. Santa Clara River Floodplain Protection Program	✔			
5. Surfers Point Managed Retreat		✔		
6. Aramburu Island Coarse Beach Restoration		✔		
7. The SF Bay Living Shorelines: Nearshore Linkages Project		✔		
8. The Horizontal Levee Concept		✔	✔	
9. Monterey Bay Coastal Erosion Mitigation Alternatives Study[8] (concept only)	✔			

* "Preservation" is the protection of existing landscapes and land-water interactions, while "Restoration" typically involves actions such as earth moving, revegetation and ongoing monitoring and management designed to create healthy, diverse and sustainable ecosystems similar to what would exist in the absence of human disturbance.

8. *Managed retreat only.*

FIVE LESSONS

Done right and under the right conditions, green infrastructure can reduce risks to people and property as effectively as traditional "gray" infrastructure can, while potentially providing a number of additional benefits.

1. Green infrastructure can provide cost-effective flood and coastal protection.

In many cases, green infrastructure provides the same level of risk reduction at a lower cost than gray infrastructure because green projects take advantage of the protection provided inherently by natural systems. For instance, tidal wetlands reduce the size and erosive power of waves along the shoreline of an estuary, while floodplains can divert, hold and slow floodwaters, reducing risks to downstream communities. Preserving or restoring wetlands, floodplains and other natural systems can be less costly than building and maintaining structures of rock, steel and concrete. When other benefits—such as the provision of wildlife habitat or ecosystem services like improved water quality—are considered as well, the advantage of green projects can be even greater. Another factor influencing cost-effectiveness is implementation time; green projects, in particular those that primarily involve the protection of an existing natural system, can potentially be completed more quickly than alternatives requiring major construction.

2. Green infrastructure has been demonstrated successfully in a wide variety of settings.

Projects from the Central Valley to the Napa River to the mountains and coasts of southern California illustrate the breadth of designs that are being used to address risks in a range of geographies.

3. Green infrastructure can be designed to adapt to changing conditions.

Given adequate amounts of space and sediment, natural floodplains, beaches and shorelines can adapt to altered river flows and sea levels and continue to support healthy ecosystems. Well-designed green infrastructure projects can have the same flexibility.

4. Green infrastructure provides multiple benefits.

Each case examined for this report provides benefits beyond flood or coastal protection. These benefits include: habitat for fish, migratory birds and other wildlife; increased productivity from farms and fisheries; carbon sequestration; improved water quality; temporary water storage by wetlands and floodplains; recharge of aquifers; support for recreational activities including bird watching, surfing and fishing; increased property values; and jobs and economic activity supported by fisheries, recreation and conservation.

5. Green infrastructure can inspire strong local support.

Green projects tend to provide attractive and highly valued community amenities, such as restored river channels, river parkways, and beaches. This factor is critical for raising local funds, which is often a prerequisite for obtaining government and other outside project funding. As an example: In 1995 a $115 million[9] "gray" Napa River flood protection proposal from the Army Corps of Engineers was rejected amidst strong local opposition. Two years later, Napa County voters approved a local sales tax increase to fund a "Living River" design, despite its higher projected cost of $163 million.

PHOTO: Oxnard industrial drain wetlands © *Carey Batha/TNC*

9. Throughout the report, cost figures are presented in dollars in the year referenced.

MAP: © The Nature Conservancy

Case Studies 1–9

The nine case studies, seven completed or under way and two conceptual projects, represent a range of geographic settings and illustrate the variety of ways that nature-based infrastructure can be used to mitigate the effects of extreme weather and rising sea levels.

CASE STUDY 1:

Hamilton City Setback Levee and Habitat Restoration

Location: Six-mile stretch of the Sacramento River at Hamilton City

Summary: A 6.8-mile setback levee on the Sacramento River will provide flood protection while reconnecting the river to 1,500 acres of its historic floodplain and restoring 1,361 acres of riparian habitat.

Estimated Cost: $52 million (2013 estimate)

Vulnerability Addressed: The community of Hamilton City and surrounding farmlands are poorly protected from floods by a substandard private levee along the Sacramento River built in the early 20th century. Six times since 1983, floods have forced residents of Hamilton City to evacuate, imposing a major burden on a community where median household income in 2011 was less than $30,000.[10,11] The current levee protecting the community has only a 10 percent chance of withstanding a 75-year flood event. The portion of the new setback levee that will protect Hamilton City will have a 90 percent chance of passing such an event, reducing expected flood damage by $577,000 annually (2004 estimate).

THE PROJECT: As early as 1975, the Army Corps of Engineers drafted plans for a modern levee to protect Hamilton City. But because the value of the land and homes in need of protection was much lower than the cost of building the levee, the Corps could not justify the project on benefit-cost grounds.

By 2003, however, changes in Corps planning policies[12] allowed the benefits of flood protection *and* habitat restoration to be considered in project cost-benefit analyses. These rules favor the most cost-effective combination of flood protection and habitat restoration. A new feasibility study[13] for the Hamilton City site determined that a setback levee (see map on facing page) would best meet these objectives and deliver benefits greater than the project cost, meaning the project could proceed. The Hamilton City project was the first in the nation to be approved by the Corps under the new multiple-benefit rules.[14]

During the project analysis, the option of upgrading the existing private levee was considered and discarded because it would involve extensive and costly rock armoring for erosion protection (and no habitat benefit). By contrast, the setback levee will be separated from the main river channel by floodplain and will require only limited rock armoring. Taking advantage of the natural function of the floodplain reduces the construction cost of the setback levee, in addition to providing a large habitat benefit.

The acreage to be restored by the project is mostly agricultural. Because the land is close to the river and not well protected by the current levee, it is subject to waterlogging, flooding and erosion. The setback levee will reconnect this land to the river's natural floodplain while providing flood protection to the higher-quality farmland further from the river. The Nature Conservancy has led the acquisition of the floodplain land, valued at roughly $12 million (actual dollars spent through 2013).

10. *U.S. Army Corps of Engineers, 2004. Hamilton City Flood Damage Reduction and Ecosystem Restoration, California. Final Feasibility Report and Environmental Impact Statement / Environmental Impact Report.*

11. *http://www.city-data.com/city/Hamilton-City-California.html*

12. *U.S. Army Corps of Engineers, 2003. Engineering Circular 1105-2-404. http://planning.usace.army.mil/toolbox/library/ECs/EC1105-2-404.pdf*

13. *U.S. Army Corps of Engineers and the Reclamation Board of the State of California, 2004. Hamilton City Flood Damage Reduction and Ecosystem Restoration, California, Final Feasibility Report and Environmental Impact Statement / Environmental Impact Report. Online at: bit.ly/1bhLy8p*

14. *Plain, Todd, 2011. "Corps' first multi-benefit project moves forward at Hamilton City." Army Corps of Engineers Web site, April 25, 2011. http://www.army.mil/article/55499/*

STATUS: The Corps and state regulators have approved the project. In March 2014, Congress appropriated funding to begin implementation.

FUNDERS: The U.S. Army Corps of Engineers, the California Department of Water Resources, Reclamation District 2140, Hamilton City Citizens In Action, and The Nature Conservancy

FOR MORE INFORMATION:
Ryan Luster, The Nature Conservancy,
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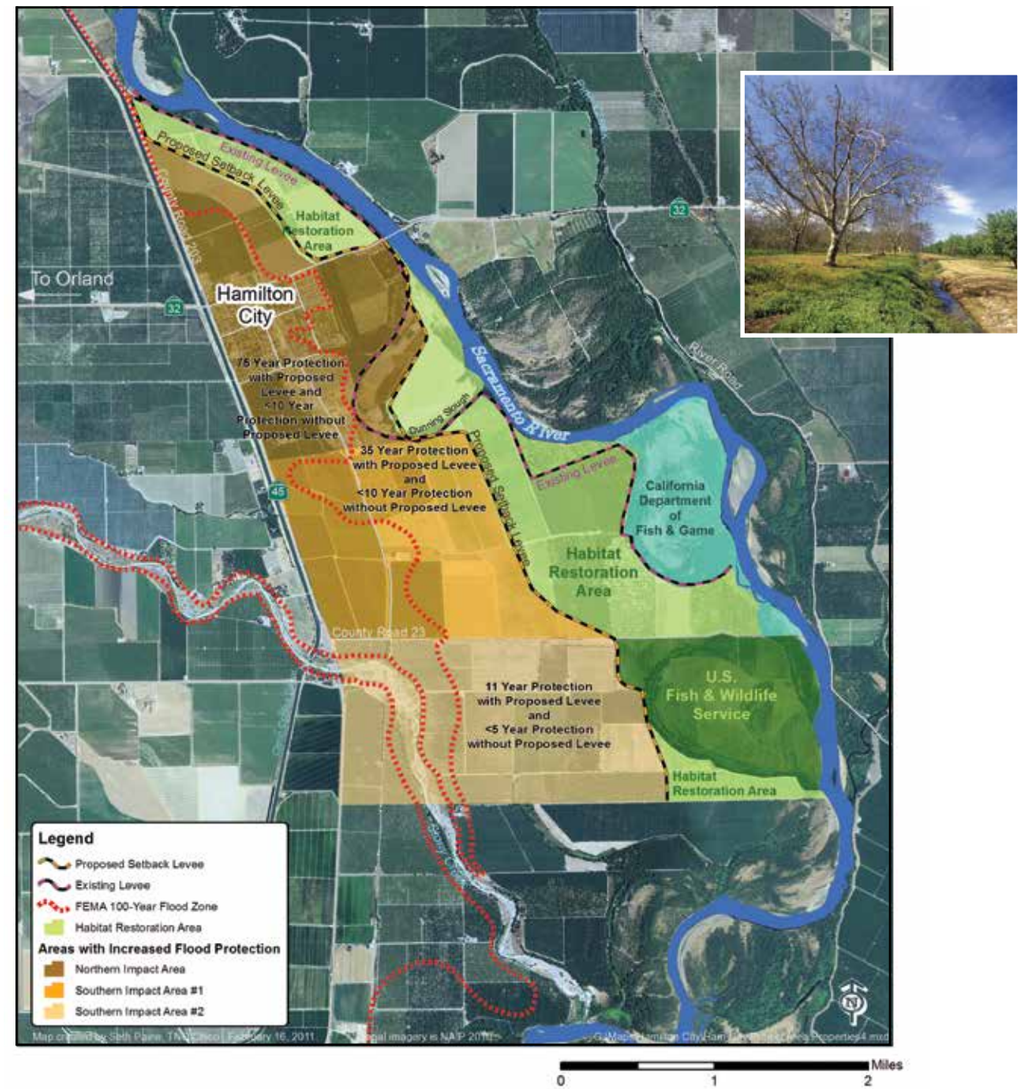
Hamilton City Flood Damage Reduction and Ecosystem Restoration Project



MAP: The new setback levee will reconnect the Sacramento River to its historic floodplain, protecting Hamilton City and making room for the restoration of 1,361 acres of river-connected habitat. © *The Nature Conservancy* **INSET:** Flood-prone land near Hamilton City will be restored to floodplain habitat. © *Grant Johnson*

CASE STUDY 2:

Napa River—Napa Creek Flood Protection Project

Location: Napa River from Trancas Road, Napa, to where Highway 29 crosses the river, as well as Napa Creek from the confluence to one mile upstream

Summary: A "Living River" plan of restoration and flood protection provides 100-year flood protection for the city of Napa, valued at $26 million annually; restores more than 900 acres of tidal wetlands and 135 acres of floodplain and associated habitat; and improves the aesthetics and visibility of the river for the community.[15]

Estimated Cost: $500 million[16]

Vulnerability Addressed: The Napa River and Napa Creek presented a severe flood risk to the City of Napa: From 1970 to 1998, flood damage totaled $542 million (actual damage valued in the year of each event). The 1986 flood alone, estimated to be a 50-year event, caused $100 million in damage (1986 dollars). The new project will provide protection from 100-year floods.

THE PROJECT: Congress authorized a flood control project for the Napa River in 1965. In 1975, the Army Corps of Engineers prepared a plan to deepen, straighten and armor the river channel, but local residents twice voted not to approve a sales tax increase to fund it. In 1995, the Corps presented a similar plan; it too was abandoned due to opposition from local groups as well as state water quality regulators.

From 1995 through 1997, local leaders, environmental and business groups, and state agencies worked with the Corps to draft a "Living River" plan that would yield 100-year flood protection through a combination of gray and green measures: restored floodplain areas as well as restored downstream wetlands to give the river room to spread out and provide wildlife habitat, combined with levees and rock and concrete structures where needed. The plan also added trails and a downtown riverfront promenade, turning the river into a community amenity.

The projected cost of the new plan was 42 percent higher than the Corps' 1995 proposed plan,[17] but the community was mobilized in favor of it. In November 1997, a two-thirds majority of Napa County voters approved a sales tax increase to provide the local share of the funds for the project.

STATUS: As of June 2013, the project is roughly 70 percent complete.

FUNDERS: Napa County (Measure A funds), the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, the California State Coastal Conservancy, and the California Department of Water Resources (Flood Control Subventions program).

FOR MORE INFORMATION:
Napa County Flood Control and Water Conservation District
tinyurl.com/m6nok3z

Rick Thomasser, Napa County Flood Control and Water Conservation District
richard.thomasser@countyofnapa.org

15. *http://www.countyofnapa.org/FloodDistrict/*
16. *2013 Napa County Flood Control and Water Conservation District estimate for total actual expenditures to date and projected future expenditures to complete the project.*
17. *U.S. Army Corps of Engineers, 1995. Napa River, California: Draft Supplemental General Design Memorandum/Environmental Impact Statement/Environmental Impact Report. Vol. 1. (the 1995 plan estimated cost was $115 million, compared with $168 million for the 1998 plan)*

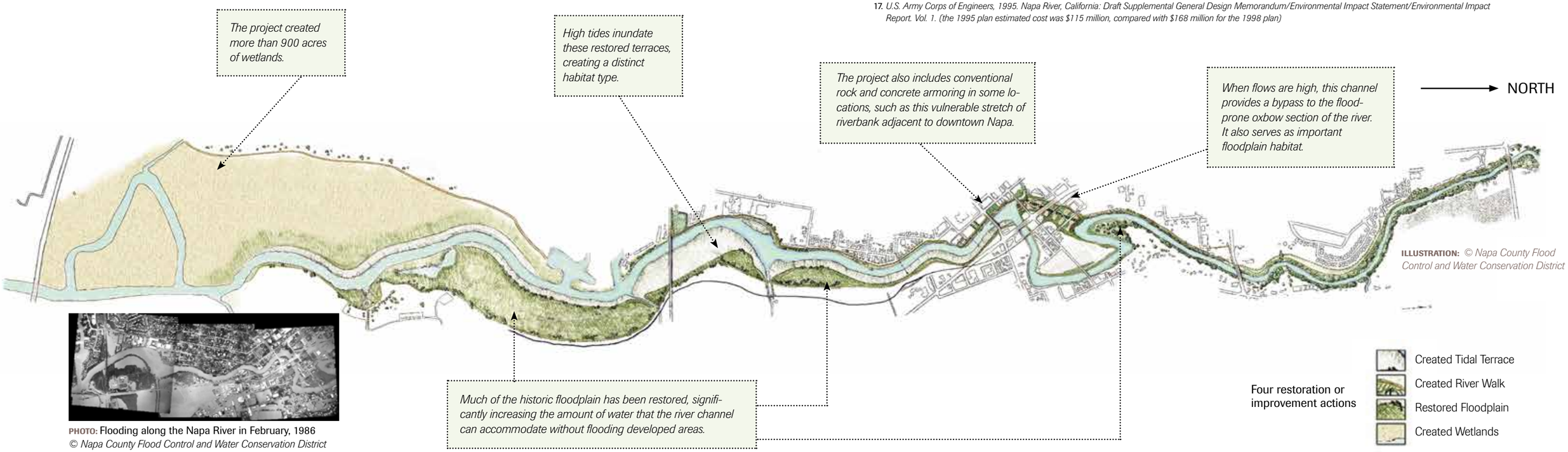


PHOTO: Flooding along the Napa River in February, 1986
© Napa County Flood Control and Water Conservation District

ILLUSTRATION: *© Napa County Flood Control and Water Conservation District*

CASE STUDY 3:

Yolo Bypass

Location: A 37-mile-long river bypass running north to south between the cities of Sacramento and Davis.

Summary: This 59,000-acre river bypass serves as a floodplain for the Sacramento River. It can convey 490,000 cubic feet of water per second, more than three times the capacity of the main Sacramento River channel as it passes downtown Sacramento.

Estimated Cost: Not available. The Yolo Bypass was part of the Sacramento River Flood Control Project, which had a reported cost in 1925 of $51 million.[18]

Vulnerability Addressed: In the 19th century, floods frequently inundated the city of Sacramento, much of which occupies the natural floodplain of the Sacramento and American rivers.

THE PROJECT: The Yolo Bypass is one of several elements of the Sacramento River Flood Control Project, which was federally authorized in 1917.[19]

When the river rises above a certain level, water flows over the Fremont Weir into the bypass. Adjustable flood gates at the Sacramento Bypass allow for additional diversions into the bypass if needed. At the downstream end of the bypass, water flows into the Sacramento–San Joaquin Delta.

The land in the bypass, which is under a mix of public and private ownership, is the largest contiguous area of river floodplain remaining in the Central Valley. The state Department of Water Resources holds flood easements that allow for the land to be inundated. The river rises high enough to crest the Fremont Weir and send water into the bypass in roughly 60 percent of all years.

The Yolo Bypass is an excellent example of the multiple benefits that a green infrastructure project can provide. Roughly two-thirds of the bypass land is farmed—crops include rice, tomatoes, corn, millet, wheat and safflower—or used for grazing livestock, generating as much as $50 million in agricultural revenue annually. An area of more than 16,000 acres makes up the Yolo Bypass Wildlife Area, which includes restored wetlands as well as uplands. The bypass provides thousands of acres of migratory bird habitat, which has substantial economic value: Elsewhere in the Central Valley, programs to incentivize bird-friendly management of agricultural land cost roughly $30 per acre annually.[20]

Inundation of the bypass also creates prime habitat for many native fish, including Sacramento splittail, Chinook salmon, sturgeon and lamprey. The nutrient-rich seasonal wetlands provide abundant food for juvenile fish as well as protection from predators. Non-native fish, which can be predators as well as competitors for food, are generally less prevalent in the bypass than in the main channel of the Sacramento River. Sacramento splittail spawn in the bypass, and multiple migratory species benefit by using it as an alternate route to and from the Delta.[21]

18. *The project was part of the Sacramento River Flood Control Project, which had a 1925 cost of $51 million but included many levee projects in addition to the bypass. Source: I19 U.S. Congress, Senate Document 23, 69th Congress, 1st Session (The Grant Report of the California Debris Commission January 5, 1925). The total flood control project cost included building 180 miles of bypass levees and 500 miles of river levees, and acquiring and clearing bypass areas.*

19. *California Department of Water Resources, 2012 Central Valley Flood Protection Plan. Pages 1–4.*

20. *From 2011 to 2013, Natural Resources Conservation Service contracts through the Waterbird Habitat Enhancement Program and the Migratory Bird Habitat Initiative totaled $8.7 million. These contracts covered 98,289 acres, typically for a duration of three years—or roughly $30 per acre per year. Data are from the NRCS ProTracts database, accessed August 2013.*

21. *Bay Delta Conservation Plan Draft Conservation Measure 2: Yolo Bypass Fisheries Enhancement, pages 3.4-29 to 3.4-56 in:http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/BDCP_Chapter_3_%E2%80%93_Conservation_Strategy_3-14-13.sflb.ashx.*

A "gray" alternative to the bypass would have been increased upstream reservoir storage for floodwaters. An analysis of the February 1986 flood found that during the 3-day peak, the bypass conveyed a total of 2.7 million acre-feet of water. During this period, upstream reservoirs were nearly full, meaning that roughly 2.7 million acre-feet of additional reservoir capacity would be needed to provide the same flood protection afforded by the bypass.

Controlling a flood of that size without the Yolo Bypass would require roughly doubling the amount of flood storage currently provided by upstream reservoirs[22]—something that is likely not feasible for several reasons, including a scarcity of dam sites, the high monetary and environmental costs of dam construction and popular opposition to new dams.

Replicating a project today on the scale of the Yolo Bypass would likely be very costly as well. However, major flood channel restoration projects planned for the Mississippi River in Louisiana indicate that such efforts are still feasible under the right conditions.

STATUS: A variety of modifications are being considered to optimize habitat conditions for fish species of concern. Changes may include altering the Fremont Weir to provide more control over the timing and duration of bypass inundation, and improving passage for migrating fish between the bypass and the Sacramento River.

FUNDERS: Federal government, state government, and local property owners; possibly others.[23]

FOR MORE INFORMATION:

California Department of Water Resources
Aquatic Ecology Section
water.ca.gov/aes/yolo/

Yolo Basin Foundation
yolobasin.org

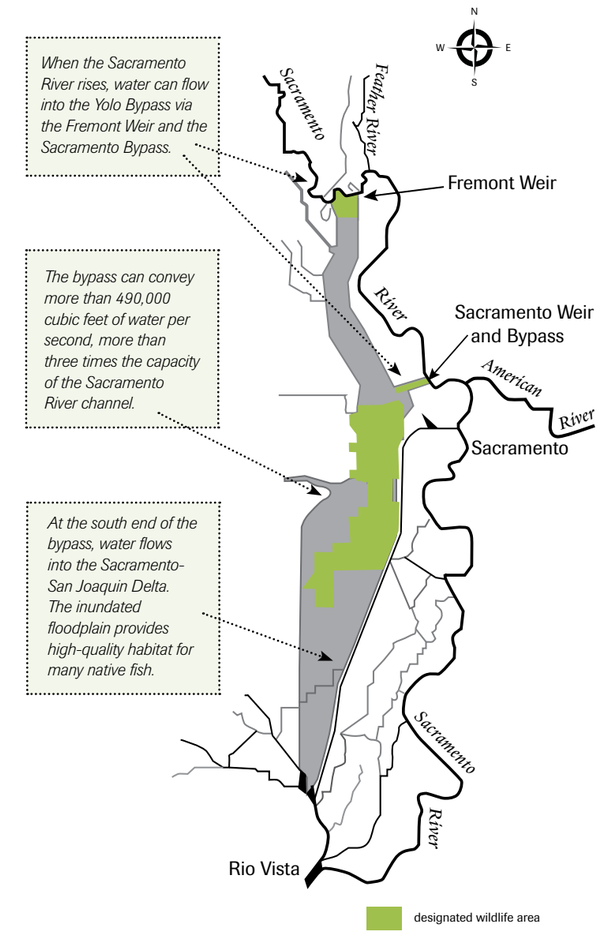


ILLUSTRATION: *© Redrawn from maps provided by the California Department of Water Resources and the California Department of Fish and Wildlife.*

22. *Opperman et al., 2011. Integrated floodplain-reservoir management as an ecosystem-based adaptation strategy to climate change. Paper for the AWRA 2011 Spring Specialty Conference. http://www.ecosystemcommons.org/sites/default/files/andrewwarner_floodplains_climate_change.pdf.*

23. *Barton, M. 1933. Data Relative to the Sacramento River Flood Control Project Legislation and Appropriations. Report for the California State Reclamation Board, March 15, 1933.*

CASE STUDY 4:

Santa Clara River Floodplain Protection Program

Location: Santa Clara River from the Ventura County line to the river mouth between the cities of Ventura and Oxnard

Summary: The project aims to preserve agricultural land in the 500-year floodplain of the Santa Clara River in Ventura County through the purchase of flood easements by The Nature Conservancy.

Estimated Cost: Easement costs and priorities are currently being evaluated.

Vulnerability Addressed: Protecting the river's floodplain from development allows flood waters to spread out over open space and farmland, reducing flood risk for downstream communities (see map on the facing page). According to a 2011 Ventura County study, if the river is leveed to allow for development in the floodplain, the risk to downstream communities would increase sharply. The estimated damage to these downstream communities from a 100-year flood would roughly double, from $182 million to $385 million. In a 500-year flood, the loss of the upstream floodplain would result in a tripling of damages, from $512 million to $1.56 billion.[24] New downstream levees could mitigate the increased risk, but at great cost—at least $300 million, according to a 2013 estimate.[25]

THE PROJECT: Though it flows through a region with significant urban and agricultural development, the Santa Clara River is one of the least altered rivers in southern California. Much of the river's natural floodplain is currently used for farming and has not been separated from the river by structural levees. However, residential development could eventually encroach on much of the floodplain and would likely be accompanied by new flood-protection levees along the river.

The Floodplain Protection Program aims to conserve the river's natural processes by purchasing easements on agricultural lands in the floodplain that will permanently protect the land from development, promote agriculture in a historic farming community and allow natural flooding to continue.

STATUS: Acquisition of flood easements for agricultural land is under way.

FUNDERS: The California Department of Water Resources (Integrated Regional Watershed Management grant program) and the Santa Clara River Trustee Council.

FOR MORE INFORMATION:

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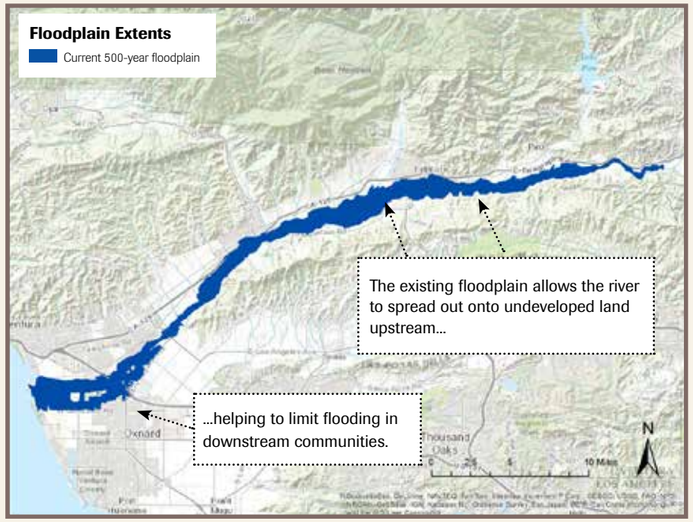
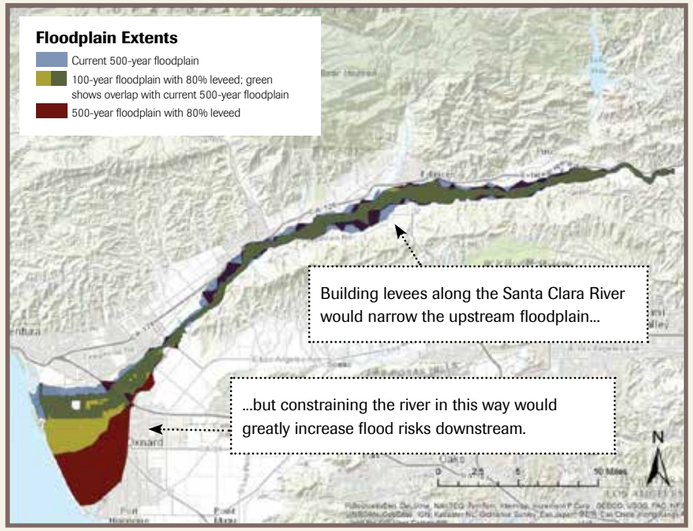
UCSB-TNC Santa Clara River Group Project
santaclararivergp.weebly.com

PHOTO: Santa Clara River © *Melinda Kelley*

24. *Ventura County Watershed Protection District, 2011. Hydraulic Impact Analysis of the Santa Clara River Floodplain Protection Program. http://www.water.ca.gov/irwm/grants/docs/Archives/Prop84/Submitted_Applications/P84_Round1_Implementation/County%20of%20Ventura/Att9_IG1_DReduc_2of2.PDF.*

25. *Watersheds Coalition of Ventura County Proposition 84 IRWMP Implementation Grant application, 2013. Page 9-5. http://portal.countyofventura.org/portal/page/portal/ceo/divisions/ira/WC/Prop84/Attachment%209%20Economic%20Analysis%20-%20Flood%20Damage%20Reduction%20Costs%20and%20Benefits.pdf.*





MAPS: © *Montgomery, J., L. Prahl, P. Schellenbarger and W. Wilkinson. 2013* Prioritization of Easements for Floodplain Conservation along the Santa Clara River. *Presentation of project results for the Master of Environmental Science & Management Program at the Bren School of Environmental Science and Management, University of California, Santa Barbara.*

The increased flood damages if the river is 80% leveed are estimated at $204 million for a 100-year flood and $1.04 billion for a 500-year flood. Conserving the existing floodplain avoids these increased risks.

CASE STUDY 5:

Surfers Point Managed Retreat

Location: Surfers Point, Ventura

Summary: The project relocated erosion-damaged infrastructure inland as an alternative to the construction of a seawall. Natural shoreline processes were restored by replacing a 65-foot-by-900-foot stretch of paved beachfront land with a cobble berm covered by vegetated dunes.

Cost: $4.5 million.[26] A concrete-and-rock seawall would have cost an estimated $5,000 to $10,000 per linear foot,[27] or $4.5 million to $9 million for the 900-foot length of the project.

Vulnerability Addressed: The project removes and relocates infrastructure at risk of erosion—a bike path and a portion of a parking lot—and replaces it with a cobble berm and sand dunes that will provide sustainable protection for remaining structures.

THE PROJECT: In 1992, winter storms eroded a new beachfront bike path, owned by the California Department of Parks and Recreation, and damaged the adjacent parking lot for the Ventura County Fairgrounds. Local officials proposed the construction of a seawall to stop further erosion.

A sea wall would have reduced the habitat and recreational value of the site and, by altering wave patterns, likely increased erosion rates on nearby beaches. As such, it was opposed by the Surfers Point Working Group, which includes members of local and state agencies, legislators, and non-governmental organizations.

After much discussion, the many parties with an interest in the site agreed on a "managed retreat" approach for the site. In 2001, a plan was developed to relocate an 1,800-foot section of pathway and a parking lot 65 feet inland. In the retreat zone, a cobble berm beneath dunes and native vegetation is engineered to be resilient to erosion while restoring habitat and preserving the site's value for surfers and other beachgoers. Construction on Phase 1, covering a 900-foot reach, was completed in 2011.

STATUS: The constructed berm and dunes have resisted erosion through two winters; monitoring is ongoing. Phase 2 of the project is on hold, due in part to a lack of funding.

FUNDERS: The California State Coastal Conservancy, the Federal Highway Administration, the City of Ventura, and the Coastal Impact Assistance Program of the U.S. Fish and Wildlife Service

FOR MORE INFORMATION:

NOAA Managed Retreat Case Studies
tinyurl.com/ccr2wjz

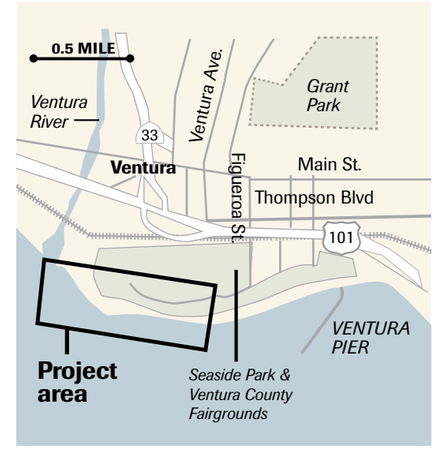
Ventura River Ecosystem blog
venturariver.org

Los Angeles Times 2011 article
tinyurl.com/mbeg9sg

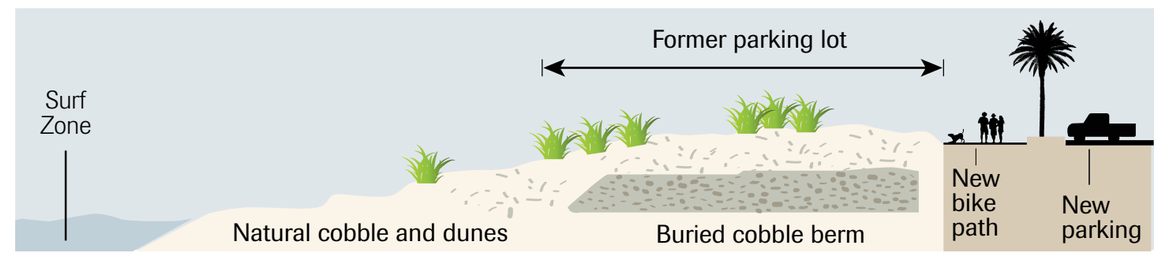
Paul Jenkin, Surfrider Foundation
pjenkin@surfrider.org

Joe McDermott, City of Ventura
jmcdermott@ci.ventura.ca.us

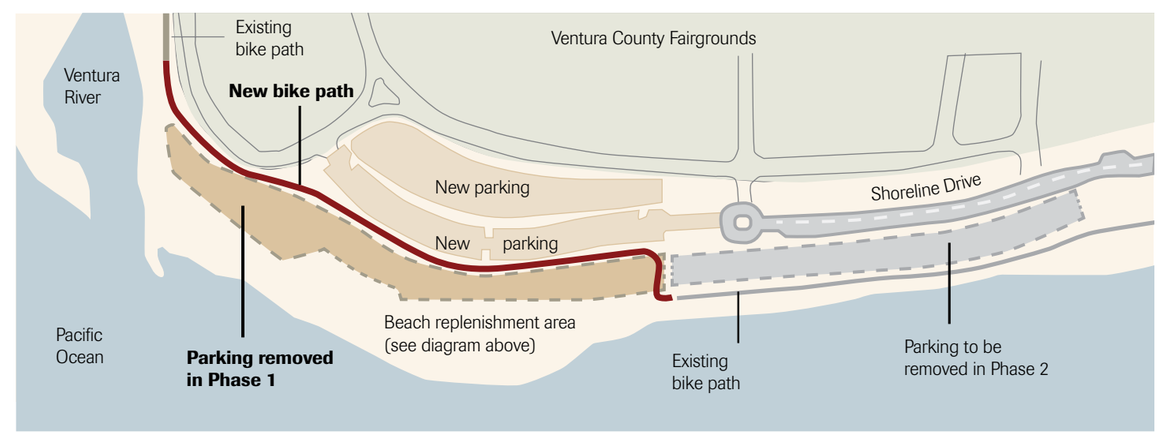
26. *2011 construction cost.*
27. *Bob Battalio, Principal Engineer, ESA PWA, pers. comm.*



Before project construction: Coastal erosion had destroyed a bike path and damaged a parking area for the Ventura County Fairgrounds.



Under the managed retreat plan, the bike path and parking lot were relocated inland (below). An eight-foot-thick berm of cobblestones beneath vegetated dunes was built in place of the parking lot (above), restoring habitat and beach processes while providing erosion protection.



Surfers Point Managed Retreat: Phase 1 Construction (completed 2011)

CASE STUDY 6:

Aramburu Island Coarse Beach Restoration

Location: Aramburu Island, on the Mill Valley shore, San Francisco Bay

Summary: A 500-meter-long resilient coarse beach of gravel and oyster shells was built in 2011 and 2012 on the bayward side of the 17-acre island in Richardson Bay.

Estimated Cost: Beach construction totaled roughly $500,000; with other restoration measures, the project cost totaled $2.6 million.

Vulnerability Addressed: Rising sea levels will increase shoreline erosion and strain tidal ecosystems.

THE PROJECT: Coarse gravel and cobble beaches occur naturally in many places along the Pacific coast and in San Francisco Bay. In appropriate sites, engineered beaches of this type can provide erosion protection that is as effective as the traditional alternative—rock armoring—but less expensive to build, while also offering habitat and aesthetic benefits.

Aramburu Island was created in the 1950s by the dumping of waste soil from dredging and upland excavation and was soon colonized by invasive vegetation. While birds and harbor seals used the island, habitat quality was generally low. In addition, fine sediment on the eastern shore of the island was exposed to waves from San Francisco Bay, and the island was eroding steadily. The Richardson Bay Audubon Center and Sanctuary and the County of Marin led a multifaceted restoration project, completed in 2012, that included an erosion-resistant coarse gravel beach as well as restoration of uplands and tidal wetlands to increase the island's resilience to sea level rise, enhance habitat for birds, harbor seals and rare salt marsh plants and establish native upland vegetation.

The beach slope and gravel type used for the beach restoration were selected based on observations of natural coarse beaches that exist at sites elsewhere in San Francisco Bay that have similar exposure to waves.

Building an erosion-resistant beach with gravel or cobbles can be significantly less expensive than installing riprap, due to lower materials costs and less need for heavy equipment during construction. For example, at Cape Lookout State Park on the Oregon coast, a 250-meter cobble berm and artificial sand dune coastal project was built in 2001 for $125,000, while the cost of a riprap revetment at the site was estimated at $500,000.[28/29]

STATUS: Construction on the Aramburu Island project was completed in 2012, with revegetation efforts scheduled to continue until 2015. The project is being monitored systematically, and results will inform the design of erosion-resistant restored shorelines elsewhere. Because few projects of this type have been built, pilot studies are needed to establish engineering parameters.

FUNDERS: The California Cleanup and Abatement Account, the Sewer Agency of Southern Marin, the National Fish and Wildlife Foundation, the Marin Community Foundation, Toyota Together Green, the National Association of Counties, the S.D. Bechtel, Jr. Foundation, and the Mary Crocker Foundation

FOR MORE INFORMATION:

Richardson Bay Audubon
tinyurl.com/kouyg6j

Initial 2010 Project Study
bit.ly/1dQwHcR

Rachel Spadafore, Richardson Bay Audubon Center & Sanctuary
rspadafore@audubon.org

28. *Komar, Paul, 2007. The Design of Stable and Aesthetic Beach Fills: Learning From Nature. Coastal Sediments '07 (Proceedings of the Sixth International Symposium and Science of Coastal Sediment Process, New Orleans, May 13–17, 2007). http://ascelibrary.org/doi/pdf/10.1061/40926(239)32.*

29. *Allan, J.C. et al., 2006. The use of Passive Integrated Transponder tags to trace cobble transport in a mixed sand-and-gravel beach on the high-energy Oregon coast, USA. Marine Geology 232. 63–68.*

Pre-construction

Before construction (left), the eastern shore of Aramburu Island was eroding steadily and provided low-quality shoreline habitat. The coarse beach built in 2011 and 2012 (below), modeled after naturally occurring beaches elsewhere along San Francisco Bay, is more resilient to erosion and provides higher quality habitat.

Post-construction

PHOTOS: *© Richardson Bay Audubon Center & Sanctuary*

CASE STUDY 7:

The San Francisco Bay Living Shorelines: Nearshore Linkages Project

Location: Shorelines of San Rafael and Hayward

Summary: A variety of designs for engineered oyster habitat and restored eelgrass beds are being evaluated at two sites in San Francisco Bay.

Estimated Cost: Construction costs for a one-acre pilot site in 2012 were roughly $300,000. No detailed estimates are available for larger-scale projects. Full-scale engineered oyster reef projects on the Gulf Coast have been constructed at costs as low as $1 million per linear mile.[30]

Vulnerability Addressed: Rising sea levels will increase shoreline erosion and strain subtidal ecosystems.

THE PROJECT: Engineered oyster reefs are being installed in many coastal and estuarine locations in the eastern United States and along the Gulf of Mexico to restore oyster habitat and also, in some cases, to attenuate wave energy to reduce erosion. The Living Shorelines: Nearshore Linkages Project, led by the California State Coastal Conservancy, is testing similar approaches in San Francisco Bay. The San Rafael Bay site is located on property owned by The Nature Conservancy.

The project evaluates several designs for constructed native Olympia oyster reefs as well as restored eelgrass beds, which provide complementary habitat. Eelgrass and native oyster beds were once widespread in San Francisco Bay. They were selected for restoration because together they provide a variety of habitat features that support many species of invertebrates, fish and waterbirds. The San Francisco Bay Subtidal Goals Project has set a restoration target of 8,000 acres of oyster habitat and 8,000 acres of eelgrass beds.

The Living Shorelines Project is designed to see if the two habitat types also increase sedimentation and reduce wave energy, both of which reduce erosion and may facilitate the migration of subtidal habitats and the protection of adjacent tidal marshes as sea level rises. These physical effects may reduce the need to armor the shoreline of the bay as sea level rises.

For erosion control, a typical gray alternative to these habitat-oriented approaches would be a rock breakwater. Costs of both the green and gray approaches can be expected to vary widely by site due to variation in sediment and wave conditions. These variations influence the type and quantity of rock or oyster reef material appropriate for the site as well as the complexity and expense of construction.

STATUS: Researchers are evaluating the pilot sites to assess the performance of each design and to measure wave attenuation. The results will inform the design of future projects.

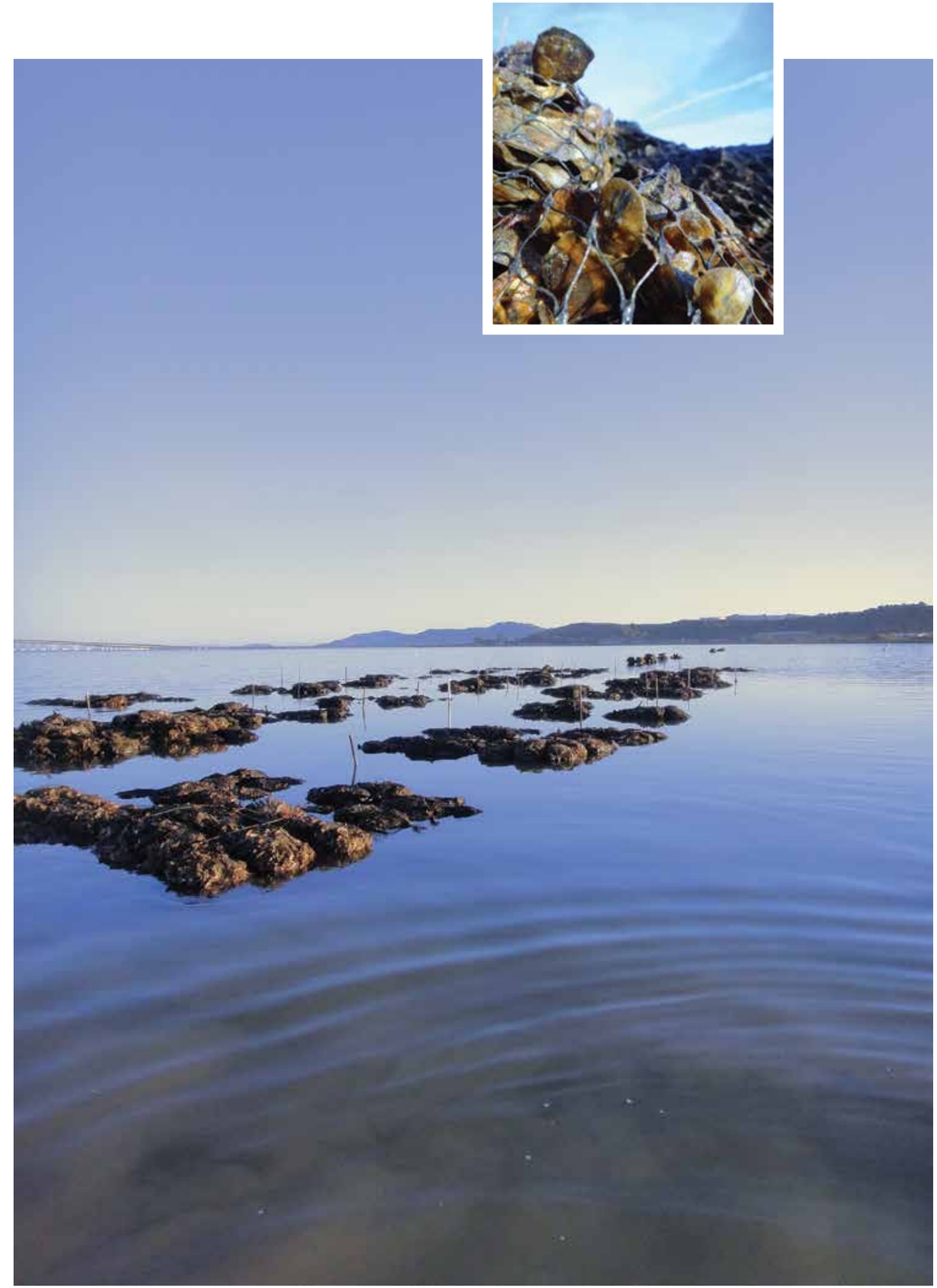
FUNDERS: The California Wildlife Conservation Board, the California State Coastal Conservancy, the San Francisco Estuary Partnership (U.S. Environmental Protection Agency), and NOAA Fisheries

FOR MORE INFORMATION:

Project Description
tinyurl.com/ljsfkev

San Francisco Bay Subtidal Habitat Goals Project
sfbaysubtidal.org

Marilyn Latta, Project Manager,
State Coastal Conservancy
mlatta@scc.ca.gov



OPPOSITE PAGE: The Living Shorelines: Nearshore Linkages project is testing several alternative designs for engineered oyster reefs in San Francisco Bay. The reefs reduce wave energy while providing habitat. © *California State Coastal Conservancy*

30. *Timm Kroeger and Jeff DeQuattro, The Nature Conservancy Alabama, pers. Comm.*

CASE STUDY 8:

The Horizontal Levee Concept

Location: Concept for San Francisco Bay

Summary: The Horizontal Levee concept integrates the natural flood risk reduction properties of tidal marshes into a shoreline management strategy. This strategy would meet marsh restoration and flood management objectives, while also addressing water quality issues in the bay.

Cost: Capitalizing on the capacity of tidal marshes to reduce the height of storm waves could reduce levee construction costs by 50 percent.

Vulnerability Addressed: In San Francisco Bay, rising sea levels threaten to overwhelm the flood protection capacity of existing levees and drown tidal marshes. Wastewater treatment infrastructure is particularly at risk.

THE CONCEPT: The Horizontal Levee strategy envisions abandoning existing bayshore levees (bayward of the constructed salt ponds that exist along much of the eastern shoreline of the bay) in favor of smaller inland levees behind restored tidal marsh (Figure 1). Because the restored marsh would substantially reduce wave energy, a smaller inland levee could provide the same level of flood protection as a large bayshore levee. The strategy would complement ongoing tidal marsh restoration efforts in San Francisco Bay begun in the 1980s while providing necessary flood protection for homes and businesses close to the shore.

Where appropriate for the bay's ecology and development, the Horizontal Levee concept could be extended to include additional multiple-benefit features (Figures 2 and 3). The tidal marsh could transition into gently sloping upland (potentially built using material dredged from local flood channels), which would facilitate landward migration of tidal habitats as sea level rises. These upland areas could also be used to address issues associated with the disposal of effluent from the many wastewater treatment plants along the shore of the bay. Treated effluent from these facilities could be used to irrigate native freshwater marsh vegetation, a strategy that would reduce the flow of nitrogen to the bay while also reducing the costs wastewater treatment plants incur to pump and discharge effluent.

The study compared the cost of the Horizontal Levee with upgrading existing levees, assuming 14 inches of sea level rise over 50 years. The study found that the cost of raising and maintaining an existing bayshore levee was twice that of the cost to build and maintain a smaller levee behind a roughly 150-foot-wide restored marsh. The reduced cost stems from the difference in size between the two levees, which translates into large savings on construction costs for the smaller levee. The study did not account for land acquisition costs or other complications associated with moving the levee inland; the assumption is that Horizontal Levee implementation would be coordinated with ongoing salt pond restoration efforts.

FUNDER: The Horizontal Levee study cited here was funded by The Bay Institute; the idea has been evolving for decades, through work funded by the Hayward Area Shoreline Planning Agency, the San Francisco Bay Conservation and Development Commission, and others.

FOR MORE INFORMATION:

2013 Horizontal Levee study for The Bay Institute
bay.org/publications/the-horizontal-levee

2013 Innovative Wetland Adaptation Techniques Project for the San Francisco Bay Conservation and Development Commission
tinyurl.com/kwnroqs

2010 Sea Level Rise study for the Hayward Area Shoreline Planning Agency
tinyurl.com/7jd8vza

The study found that the cost of raising and maintaining an existing bayshore levee was twice that of the cost to build and maintain a smaller levee behind a roughly 150-foot-wide restored marsh.

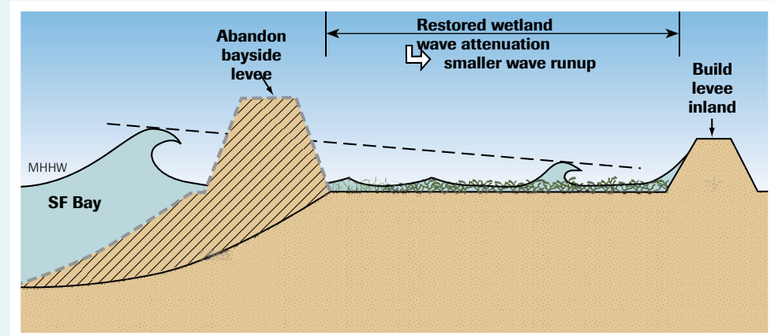


Figure 1: Tidal marshlands reduce wave energy substantially. Modeling results indicate that it would be cost-effective to abandon deteriorating bayshore levees in favor of smaller levees built landward of restored tidal marshes. This strategy would meet both ecological restoration and long-term flood risk management goals.

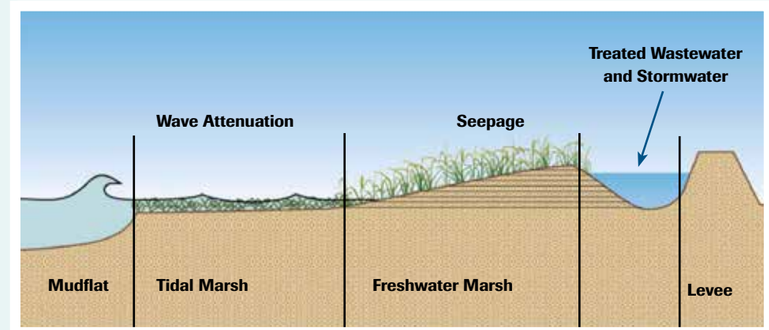


Figure 2

Figures 2 and 3: These illustrations show cross-sections of a conceptual, multiple-benefit Horizontal Levee design, showing four zones: 1) tidal mudflat habitat; 2) a tidal marsh, which attenuates waves in addition to providing habitat; 3) a sloping, vegetated freshwater habitat zone irrigated with treated wastewater and stormwater, which would help to address water quality issues associated with discharges into the bay; and 4) a flood risk management levee. As sea level rises, the sloping profile facilitates landward migration of tidal habitats.

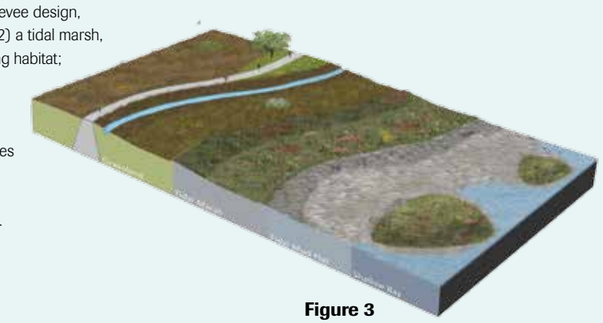


Figure 3

CASE STUDY 9:

Monterey Bay Coastal Erosion Mitigation Alternatives Study

Location: Southern Monterey Bay coast

Summary: An analysis[31] of the Monterey Bay coast compared the costs and benefits of revetments (rock armoring), off-shore breakwaters, managed retreat (acquiring easements to allow natural shoreline erosion to proceed), and other erosion mitigation alternatives. For one 4-mile coastal reach, the study found that a managed retreat approach would deliver habitat and recreation benefits nearly four times greater than project implementation costs. By contrast, the cost to build revetments or breakwaters at the same site would be much greater than the value of the benefits provided by either of those strategies.

Vulnerability Addressed: The southern Monterey Bay coastline is on average the most erosive sandy shore in California.[32] Sea level rise is expected to accelerate coastal erosion.[33]

THE STUDY: Options for mitigating coastal erosion influence habitat and recreation values and carry a wide range of economic costs. A 2012 study by ESA PWA for the Monterey Bay Sanctuary Foundation and the Southern Monterey Bay Coastal Erosion Working Group evaluated the costs and benefits of more than 20 potential strategies for responding to the high rate of erosion in Monterey Bay.

The chart below compares the net present value of the costs and benefits over 100 years of two engineered approaches—revetments and the combination of off-shore breakwaters and beach nourishment (sand addition)—as well as managed retreat (see illustration below) facilitated by the acquisition of easements that would allow for the erosion of coastal property. The figures shown are for a 4-mile section of coast near the towns of Marina and Seaside.

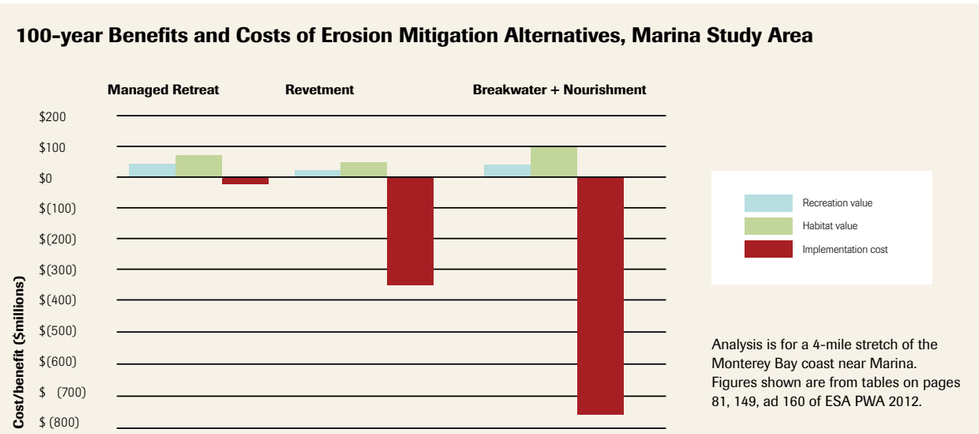


ILLUSTRATION: *© Data from ESA PWA 2012*

31. *ESA PWA 2012, Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay. Report prepared for the Monterey Bay Sanctuary Foundation and the Southern Monterey Bay Coastal Erosion Working Group. May 30, 2012. Available at http://montereybay.noaa.gov/research/techreports/tresapwa2012.html.*
32. *Hapke, C., D. Reid, B. Richmond, P. Ruggiero, and J. List, 2006, "National Assessment of Shoreline Change, Part 3: Historical Shoreline Change and Associated Land Loss Along Sandy Shorelines of the California Coast." Santa Cruz, California: U.S. Geological Survey Open-file Report 2006-1219, p.#79.*
33. *The analysis in this study is based on current rather than projected future erosion rates.*

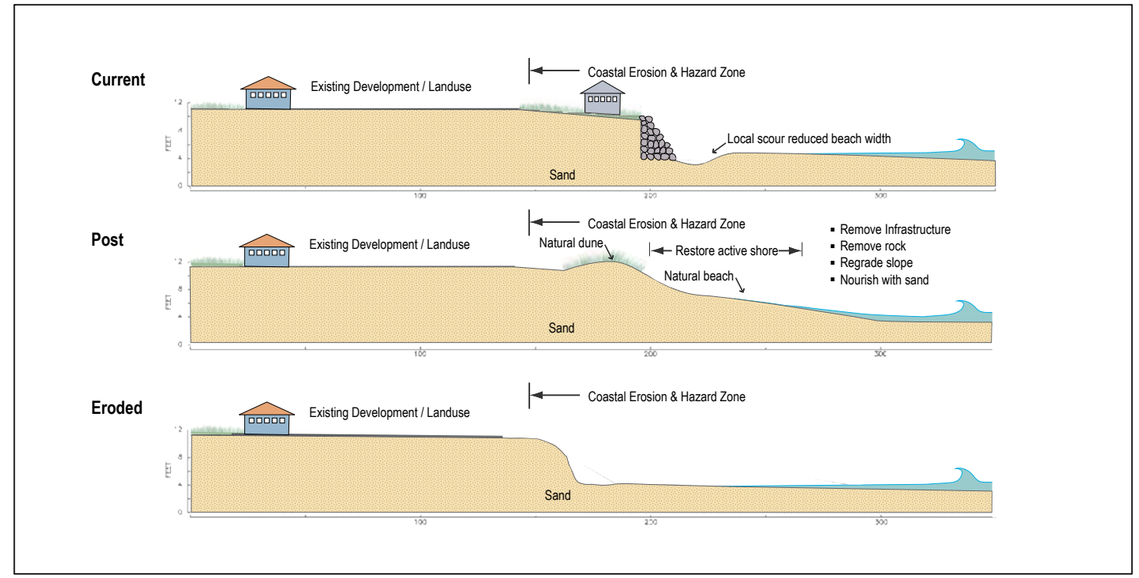


ILLUSTRATION: In appropriate locations, managed retreat can be a cost-effective way to preserve coastal habitat and recreation benefits on erosion-prone coastlines. *© ESA PWA*

The construction and maintenance costs of the engineered structures greatly exceed the easement cost of the land required for the managed retreat strategy. Habitat and recreation values are lowest for the rock revetment strategy, because it would result in the least amount of beach area. The breakwater option would be implemented with a beach nourishment program that would provide for a broad beach, so it provides greater habitat and recreation than managed retreat.

The study does not account for reductions in property tax revenue due to the loss of land to erosion. On the other hand, it does not account for increases in sales tax revenue associated with coastal recreation value.

FUNDERS: The California Coastal Sediment Management Workgroup (a partnership of the U.S. Army Corps of Engineers and the California Natural Resources Agency) and the Monterey Bay National Marine Sanctuary, under the direction of the marine sanctuary and the Association of Monterey Bay Area Governments

FOR MORE INFORMATION:
2012 ESA PWA Study
tinyurl.com/nxylahc

Conclusion

Green infrastructure is already working across California to protect communities from the effects of rising sea levels and more extreme weather. The case studies presented here illustrate that several key features of green infrastructure make it a competitive strategy for adapting to climate change in a wide range of settings:

Cost: By working *with* natural river and coastal processes instead of against them, green infrastructure designs can avoid the high capital costs of defensive strategies like rock armoring, can have lower long-term maintenance costs and can take less time to implement. In some cases, the cost savings for natural infrastructure can be quite significant.

Diversity: These projects have been developed successfully in a wide range of California climates, habitat types and topographies. In each case, attention to the workings of local natural systems has guided the green infrastructure design.

Flexibility: Many green infrastructure projects are designed with the capacity to adapt to changing river flow and sea level conditions.

Multiple Benefits: The natural systems at the heart of protective green infrastructure can also provide habitat, support recreation, improve water quality and deliver economic and other societal benefits.

Community Value: By conserving and restoring natural landscapes and habitats, green infrastructure projects tend to be popular with communities, which can be critical to raising project funds and building political support. Furthermore, green infrastructure projects often enhance existing restoration and conservation efforts.

By fostering the spread of green infrastructure, California can prepare for the effects of climate change while enhancing natural habitats and reducing flood risks for communities.

Recommendations

CONDUCT ECONOMIC ANALYSES: ***Project proponents should conduct rigorous economic analyses on current and future green infrastructure projects.***

Lack of information often complicates the economic comparison of green and gray options. For instance, the value of benefits provided has not been quantified for most projects; and detailed, publicly available comparisons of the costs and benefits of the gray alternative (that is, the project that was *not* built) to a green project often do not exist.

To better evaluate the economic case for green infrastructure, rigorous analyses are needed and should include the following elements:

- *A description*—including construction, permitting, mitigation, and long-term operations and maintenance cost estimates—of the most likely alternative gray infrastructure approach at the site that would provide equivalent risk reduction.
- *An assessment*—as quantitative as possible—of the value of ecosystem services provided by the green project and its gray alternative.
- *An analysis* of the costs and benefits of both projects.

STRENGTHEN PUBLIC SECTOR SUPPORT: ***Because of the multiple benefits of green infrastructure, federal, state, and local governments should provide policy support and facilitate research to advance the field.***

Policy support: State and federal policymakers should:

- Direct implementing agencies to consider green infrastructure alternatives for all coastal and flood protection projects
- Encourage the incorporation of natural flood protection processes, such as the reduction of storm wave height by tidal marshes, into flood-control infrastructure standards.

Research support:

- Research and pilot projects are needed to better understand the tradeoffs involved in green infrastructure strategies. For instance, the construction and monitoring of pilot projects is key to the development of engineering standards for coarse gravel and cobble beaches, a natural approach to coastal erosion protection. While modeling indicates that these approaches will be effective, empirical evidence under a variety of conditions is needed before such projects can be implemented on a large scale.

Funding support:

- Public dollars have been critical to the success of the projects presented in this report. Ongoing public investments in the testing and implementation of natural infrastructure strategies are needed to prepare society for the threats posed by the changing climate.

MAKE GREEN INFRASTRUCTURE A PART OF THE PLANNING PROCESS: ***Local planners should consider green infrastructure in climate adaptation planning.***

Where feasible, green infrastructure can be a cost-effective way to provide necessary flood and coastal protection while advancing other conservation, environmental quality, and recreational objectives. It should be evaluated alongside other options as local governments prepare for sea level rise and more extreme weather, for instance through the Local Coastal Plan update process. Planners should follow the Climate Smart Principles presented on the following page to effectively respond to climate change and implement green infrastructure projects.

Climate Smart Principles

These seven guidelines for planners and policymakers are derived from principles developed by Point Blue Conservation Science and the National Wildlife Federation.

1. **PLAN AHEAD TO REDUCE RISK FROM EXTREME EVENTS**
   Decision makers should avoid approving new projects or development in areas that would be at increased risk from climate change impacts, especially from extreme events like flood, wildfire, and sea level rise. Prevention is the easiest and cheapest strategy to safeguard Californians from the risks of extreme events exacerbated by climate change. The state should not make large capital expenditures without evaluating the potential risk posed by climate change. Local governments should make land use decisions that reduce the risk from climate change to people, private property, and natural resources.

2. **FOCUS ON FUTURE CONDITIONS, not past experience**
   Potential climate changes and their impacts should be considered in planning and projects over a meaningful time horizon, at least up to 2050. Longer-term planning can help agencies avoid mal-adaptation – taking actions that might work today but in the long run will inhibit or prevent future adaptation actions that arise as the climate changes. Planning should be based on a range of plausible future scenarios, including extreme ones, to address uncertainty in both near- and long-term time frames.

3. **PRIORITIZE NATURAL INFRASTRUCTURE over engineered actions where feasible**
   Agencies should establish a preference for natural infrastructure or nature-based responses to the maximum extent feasible. As illustrated in this report, natural infrastructure can be an effective, expedient, and cost-effective strategy for building climate resilience across a range of geographies and landscape types.

4. **COLLABORATE & COMMUNICATE ACROSS SECTORS**
   Identify activities that meet goals of multiple sectors, such as water and energy or forests and biodiversity; establish and engage diverse alliances to accelerate effective problem-solving, explicitly including disadvantaged communities, which are disproportionately vulnerable to climate impacts; share knowledge, communicate openly, convey hope; engage local communities and youth to instill a Climate Smart planning ethic.

5. **DESIGN AND GIVE PRIORITY TO ACTIONS THAT PRODUCE MULTIPLE BENEFITS**
   Adopt landscape or watershed scale analyses; focus on natural system function and services in addition to risk reduction including water and food security, habitat for fish and wildlife, recreation, jobs, and quality of life amenities.

6. **QUANTIFY THE GREENHOUSE GAS EMISSIONS REDUCED AND AVOIDED**
   Evaluate changes in carbon stocks and give preference to actions that help address the source of climate change – greenhouse gas emissions.

7. **EMPLOY ADAPTIVE AND FLEXIBLE APPROACHES**
   Be prepared to respond to changes in climate, ecology, and economics; use adaptive management frameworks that incorporate regular monitoring, learning, and reassessment.

8. **USE BEST AVAILABLE SCIENTIFIC INFORMATION AND TECHNICAL KNOW-HOW to make informed decisions now**
   Recognize that not making a decision is actually a decision with potentially important implications. Structured decision-making processes should be applied and documented.

"We're going to need to get prepared. And that's why this plan will also protect critical sectors of our economy and prepare the United States for the impacts of climate change that we cannot avoid. States and cities across the country are already taking it upon themselves to get ready... And we'll partner with communities seeking help to prepare for droughts and floods, reduce the risk of wildfires, protect the dunes and wetlands that pull double duty as green space and as natural storm barriers."

—President Barack Obama, June 25, 2013

FACT SHEET: Executive Order on Climate Preparedness—November 1, 2013
1.usa.gov/1dhWwOg

TOP PHOTO: A family picnics on the shore of a lake © *Pete Spiro*

California

CLIMATE CHANGE: Reducing Risk Now With Nature-based Solutions

The Nature Conservancy

Protecting nature. Preserving life.®

Nature holds some of the world's best and most practical solutions to climate change. Solutions that keep people and nature healthy, safe and secure.

Our planet is in a state of change. The past decade has been one of unprecedented extreme weather events, rapidly altering our world. In 2011 alone, the U.S. was hit by 14 extreme weather events causing damages exceeding one billion dollars each. Yet science tells us that drought, wildfire, rising temperatures, rising seas, floods, and erratic and extreme weather are only going to increase in both frequency and magnitude.

In California, we've witnessed sea levels slowly rising, potentially disrupting our coastal communities. We've seen an increase in temperature, wildfires and a loss of snow pack, a pattern that will lead to more extreme heat days, extensive droughts, and wildfires that threaten our water and food supplies and the ability of our state's agriculture industry to feed the nation.

NATURE: Our most powerful ally

But, there is hope. Reducing the effects of these impacts requires our action now, demanding that nature be incorporated into our planning as we prepare for and respond to our changing climate.

By protecting today the forests that store our water, floodplains that absorb overflowing rivers and wetlands that accommodate sea level rise, and by relying on nature's own built-in systems that are designed to absorb the impacts of extreme weather, we will reduce our risks and be better prepared to respond to our changing planet tomorrow.

There is an urgent need to conserve these critical landscapes now before it is too late to engage nature's safeguards that will help protect us.

HOW NATURE MINIMIZES OUR RISK:
Planning now to conserve and restore nature protects us all

» Restoring our floodplains and reconnecting our rivers protects people and farms from flooding—like the green infrastructure Yolo Bypass near Sacramento, a wetland during the rainy season and farmland in summer. It is a proven, cost-effective solution with the added benefit of creating desperately needed wildlife habitat.

» Coastal wetlands absorb fluctuating water levels and pounding wave energy, both predicted to affect more people as sea levels and storms increase. Restoring wetlands and conserving adjacent open space today will help ensure we have working wetlands and protect nearby communities in the future.

» Protecting and restoring California's forests safeguards our water supply and reduces the risk of catastrophic wildfire. With 65 percent of Californians getting some portion of their drinking water from water originating in the Sierra Nevada, preserving these forests is key. Proper forest management reduces the risk of catastrophic wildfire and protects our homes and livelihoods. Forested watersheds act as natural reservoirs, storing massive amounts of water and releasing it slowly downstream during increasingly hot and dry months.

» Trees, especially in urban forests, remove pollutants from the air and keep our cities cooler, lowering demand for energy consumption and improving the quality of our neighborhoods.

» Forests, rivers and other natural areas provide important habitat for wildlife, fish and plants that are threatened by increased temperatures and changes in rainfall, preserving biodiversity while providing access to nature and recreation for people.

» Forests, wetlands, oceans and other natural areas remove carbon dioxide from the atmosphere and store it for centuries, stabilizing the atmosphere and reducing the cause of global warming.

» Infectious disease often spreads when ecosystems are disrupted. Healthy, diverse ecosystems buffer human populations from the spread of Lyme, West Nile and other diseases.

Scientists predict that climate change will increase the severity and frequency of floods from heavily engineered river systems, mudslides from deforested hillsides and wildfires in drought-ridden landscapes. The Nature Conservancy is developing nature-based solutions to reduce the risks to people from climate change–driven extreme weather events:

» With our partners, we are creating the Coastal Resilience Ventura project to help decision-makers respond to the coastal impacts of climate change with an emphasis on nature-based approaches. Multiple factors (sea level rise, flooding and saline intrusion into ground water) and multiple land uses (high-value agriculture, urban areas and natural areas) converge in Ventura County, making it an ideal location for producing solutions that can protect local communities and nature, and can be exported globally.

» At the Santa Clara River, the Conservancy has protected more than 3,000 acres of floodplain that total over 13 miles of river, and 500 acres of coastal wetlands has been protected, important buffers against the impact of our changing climate.

» On Mt. Hamilton, less than an hour from downtown San Jose, the Conservancy has developed assessment tools and management plans to help wildlife and plants survive in a climate-changed future. Based on our scientific analyses, we are now conserving land to reduce the risk of flooding to the people downstream along the Pajaro River and land that will allow animals to move when climate change forces them out of their current habitat.

» Working closely with the citizens of Hamilton City, near Chico, we are partnering with the U.S. Army Corps of Engineers to replace its aging levee with one set further back from the Sacramento River, making the community safer from floods while adding 1,500 acres of scarce riverside habitat for the more than 50 threatened species that live in the area.

» The Conservancy helped to launch the Northern Sierra Partnership and produced a climate assessment for the region that identified management strategies to help protect the resources of the Sierra Nevada in a changing climate. The Partnership is working with local communities, businesses and landowners to protect valuable forest watersheds, keeping them healthy and providing water to the majority of Californians.

» Engaging state officials and agencies to advocate for landmark California climate policy, the Conservancy helped secure a role for forest conservation and biodiversity protection in the State's climate change program under AB 32 and in the California Climate Adaptation Strategy.

The Nature Conservancy

Protecting nature. Preserving life.®

To learn more, contact:
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Key lessons for incorporating natural infrastructure into regional climate adaptation planning

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ABSTRACT

Sea-level rise, potential changes in the intensity and frequency of storms, and consequent shoreline erosion and flooding will have increasing impacts on the economy and culture of coastal regions. A growing body of evidence suggests that coastal ecosystems—natural infrastructure—can play an important role in reducing the vulnerability of people and property to these impacts. To effectively inform climate adaptation planning, experts often struggle to develop relevant local and regional information at a scale that is appropriate for decision-making. In addition, institutional capacity and resource constraints often limit planners' ability to incorporate innovative, scientifically based approaches into planning. In this paper, we detail our collaborative process in two coastal California counties to account for the role of natural infrastructure in climate adaptation planning. We used an interdisciplinary team of scientists, economists, engineers, and law and policy experts and planners, and an iterative engagement process to (1) identify natural infrastructure that is geographically relevant to local jurisdictional planning units, (2) refine data and models to reflect regional processes, and (3) develop metrics likely to resonate within the local decision contexts. Using an open source decision-support tool, we demonstrated that protecting existing natural infrastructure—including coastal dunes and wetlands—could reduce the vulnerability of water resource-related structures, coastal populations, and farmland most exposed to coastal flooding and erosion. This information formed part of the rationale for priority climate adaptation projects the county governments are now pursuing. Our collaborative and iterative approach, as well as replicable use of an open source decision-support tool, facilitated inclusion of relevant natural infrastructure information into regional climate adaptation planning processes and products. This approach can be applied in diverse coastal climate adaptation planning contexts to locate and characterize the degree to which specific natural habitats can reduce vulnerability to sea-level rise and storms.

1. Introduction

Sea-level rise and extreme storm events will have significant consequences for the economy and culture of coastal regions through gradual inundation, and increased frequency of flooding and rates of erosion (Heberger et al., 2009; Griggs and Haddad, 2011; National Research Council, 2012). Sea-level rise also could lead to loss of coastal wetlands, dunes, and beaches, particularly if the shoreward migration of these natural habitats is blocked by development (Griggs, 2005; Kraus and Mcdougal, 2013; Berry et al., 2013). Prevailing responses to the risk of coastal flooding and erosion are engineered approaches (hereafter referred to as 'built'

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0964-5691/

infrastructure such as levees and seawalls, in contrast to 'natural' infrastructure such as dunes and coastal wetland). However, seawalls can be costly; in California capital costs for new seawalls average approximately $7 000 per linear foot and yearly maintenance costs average approximately 3% of construction costs (Heberger et al., 2009; King et al., 2010; ESA PWA et al., 2012). Further, built infrastructure may only address one part of a multidimensional problem. For example, built infrastructure designed to prevent future inundation may have indirect effects, such as loss of recreational beaches or fish nursery habitat due to seawall construction, and ultimately fail to address the long-term needs of human communities (Caldwell and Segall, 2007; Turner et al., 2010; Adger et al., 2011).

Natural infrastructure can play an important role in mitigating risks to coastal communities from climate change impacts. These habitats can protect communities from erosion and flooding by dissipating wave energy and stabilizing the shoreline (Millennium Ecosystem Assessment, 2005; Barbier et al., 2008; Everard et al., 2010; Gedan et al., 2010; Shepard et al., 2011; Pinsky et al., 2013) and in some cases can do so cost-effectively in comparison to built infrastructure approaches (ECA, 2009; Jones et al., 2012; Lowe et al., 2013; Lowe et al. (2013) estimated marsh restoration costs in the San Francisco Bay in California at approximately $10 000/acre). Unlike built infrastructure, natural infrastructure has the capacity to migrate upslope as sea level changes and even slow the relative rate of sea-level rise by accumulating sediments that allow the coastline to keep pace with rising waters (Reed, 1995; McKee et al., 2007; Kirwan and Temmerman, 2009; Gedan et al., 2010). In addition to coastal protection, natural infrastructure can provide multiple benefits to many different sectors of the community, including provision of fishery habitat, water quality regulation, and recreation values (Zedler and Kercher, 2005; Barbier et al., 2008; Everard et al., 2010).

A critical challenge lies in introducing feasible natural infrastructure strategies to decision-makers and planners at the regional and local scale. To include natural infrastructure in coastal planning, decision-makers seek to understand where and when habitats (alone, or in combination with built infrastructure) can provide adequate coastal flooding and erosion risk reduction. Scientists and other disciplinary experts can provide practical guidance and evidence to support planners and decision-makers in selecting this relatively under-utilized approach to climate preparedness, particularly where built infrastructure approaches might be more familiar and override other less-familiar options (Hart et al., 2012). Here we report on the engagement process and outcomes from a unique collaboration between an interdisciplinary academic team and county-level planners in California. This collaboration was designed to overcome the challenges associated with co-production of practical and transferable information for integrating natural infrastructure into regional climate adaptation planning in coastal California.

California is an ideal state in which to explore the role of natural infrastructure in climate adaptation planning because a) the effects of climate change, including sea-level rise, are already apparent (Caldwell et al., 2013); b) the existing policy framework—including the California Climate Change Adaptation Planning Guide (CNRA, 2012) and Integrated Regional Water Management plan requirements (CDWR 2011)—encourages adaptation planning; c) intact natural habitats still provide coastal protection from sea-level rise and storms as well as provide co-benefits such as improved fisheries habitat and recreational opportunities; and d) existing laws expressly protect these coastal habitats (California Coastal Act, 1976; California Endangered Species Act, 1984; Caldwell and Segall, 2007; Farber, 2008; Eichenberg et al., 2010; Peloso and Caldwell, 2011). However, it remains difficult to translate scientific information in a way that enables integration of natural infrastructure into climate adaptation plans for several reasons. First, these approaches are new and relatively untested compared to the more established practices that rely solely on built infrastructure (Hart et al., 2012; Rayner, 2005). Second, even with new knowledge and tools that help assess climate risk and potential contribution of natural infrastructure to coastal protection (Everard et al., 2010; Shepard et al., 2011; Pinsky et al., 2013; Jones et al., 2012; Arkema et al., 2013), there is a gap in how to translate and apply this information in practice at the regional and local level to real decision contexts.

Cash et al. (2003) proposed a framework for improving the effectiveness of translating scientific information into action that includes three key attributes that can be applied to the climate adaptation context: saliency, credibility, and legitimacy (Moser and Ekstrom, 2010; Lemos et al., 2012). Saliency refers to the responsiveness of the information to the policy context. Credibility refers to the perceived quality and validity of the information. Legitimacy refers to the perceived fairness of the process of producing the information (Cash et al., 2003). These three attributes are more likely present if there is iterative communication between scientists and planners that facilitates information flow and understanding (Cash et al., 2003). In addition, joint production of information using "boundary objects"— an interface that translates between the scientific and planning languages including decision-support tools or collaborative products such as maps, models or reports (Guston 2001; Clark et al., 2010)—can increase the presence of these three attributes. This interface increases saliency of the scientific information by engaging end-users early in the process, the credibility by incorporating multiple types of expertise in the process, and the legitimacy by providing increased access to the information production process (Cash et al., 2003; White et al., 2010; Guston, 2001).

We developed an interdisciplinary collaboration between planners and academic scientists, economists, engineers, spatial analysts, and law and policy experts focused on producing management-relevant science that can serve as evidence and guidance for translating and applying natural infrastructure approaches in integrated watershed planning conducted in the state of California. Our unique team used an iterative communication approach to facilitate translation of scientific information. We also used an open source decision-support tool as a "boundary object" to facilitate communication across groups, communicate scientific information using management-relevant metrics and scales, visualize analyses and outputs, and clarify goals in a format that is relevant to climate adaptation planning needs (Cash et al., 2003; White et al., 2010; Ekstrom et al., 2011). Utilizing a free, open-source tool also maximizes the replicability and transferability of our approach, allowing others to use the approach and tool tailored to local conditions, using local data, and embedded within local decision-making.

In this paper, we first provide background on the integrated water management planning process in California and regionally specific information on the Monterey Bay area, including habitats that provide coastal protection services and regional and state policy context. We then describe our collaborative approach to co-producing regionally relevant information on where protection of natural infrastructure could reduce vulnerability of people, farmland, and water-resources related structures in the Monterey Bay area and how that information is used in an integrated watershed planning context.

2. Integrated Regional Water Management planning in California

In 2002, the State of California implemented an Integrated Regional Water Management (IRWM) planning process to

encourage local, stakeholder-driven collaborative approaches to solving water resources challenges. A key driving force to encourage IRWM planning was the availability of funding for planning and implementation of integrated regional water management (CDWR, 2012). The IRWM planning process encourages fragmented jurisdictions and institutions to work together to reduce conflict and establish more sustainable water management (Lubell and Lippert, 2011), including a focus on a multi-benefit approach. In California, IRWM plans follow specific guidelines (CDWR, 2012) to outline collaborative strategies for water management. IRWM plans are required to include a prioritization scheme for projects submitted to the state for funding (CDWR, 2012).

In response to observed and potential future effects of climate change, the California Department of Water Resources revised IRWM Guidelines in 2010 to require a chapter in water management plans addressing adaptation and mitigation responses to climate change (CDWR, 2011). A guidance handbook developed by the Department of Water Resources outlines four steps for completing a climate change adaptation analysis: 1) assess vulnerability; 2) measure impacts; 3) develop and evaluate strategies; and 4) implement under uncertainty (CDWR, 2011). The state's multi-benefit approach, emphasis on sustainable water management, and requirements for a climate change vulnerability analysis provide opportunities for including natural infrastructure approaches to climate adaptation. Our case study focused on two IRWM planning regions, Greater Monterey County (Monterey) and Santa Cruz, both located in the Monterey Bay area in California (Fig. 1).

3. Introduction to the Monterey Bay Area case study

Coastal natural habitats within the Monterey and Santa Cruz IRWM regions include coastal dunes, kelp forests, and wetlands (Fig. 2). These habitats provide many ecosystem services relevant to regional water management such as water quality improvement, groundwater recharge, fish nursery habitat, and erosion and flood protection (Zedler and Kercher, 2005; Barbier et al., 2008; Defeo et al., 2009; Pinsky et al., 2013). These natural habitats also provide opportunities for recreation and tourism (Zedler and Kercher, 2005; Defeo et al., 2009), both of which are among the top three employment sectors in the Monterey and Santa Cruz IRWM regions (CA EDD, 2010).

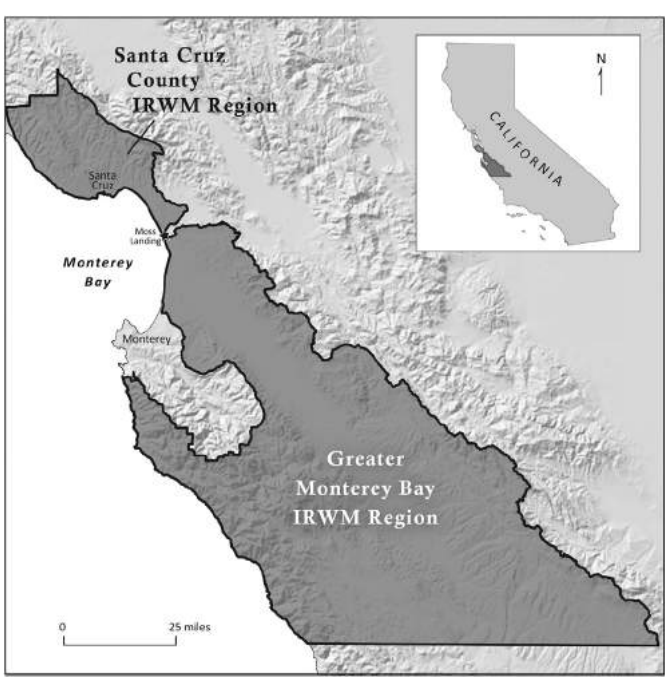

Fig. 1. Santa Cruz and Greater Monterey County Integrated Regional Water Management planning regions. Bold lines outline the two different regions.

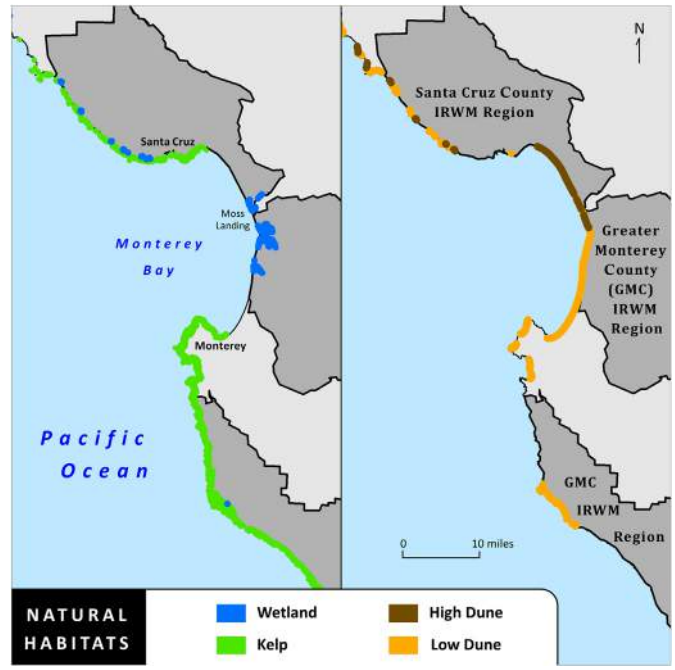

Fig. 2. Distribution of the coastal habitats used in the coastal vulnerability analysis in the Santa Cruz and Greater Monterey County IRWM planning regions. (Kelp was not included in the Santa Cruz vulnerability analysis – see text).

Sea-level rise could lead to loss of these habitats and the services they provide (Zedler and Kercher, 2005; King et al., 2010), particularly if development or built infrastructure blocks their migration upslope. Currently approximately 11% of California's coast is blocked from upslope migration by seawalls and revetments (Griggs, 2005). King et al. (2010) found that sea-level rise on California beaches backed by coastal armoring could result in the loss of 90% of existing beach area and $80 million in state and local recreation spending. In Santa Cruz County, Heberger et al. (2009) found that 17% of wetland habitat will be unable to migrate with sea-level rise due to existing development. They also found that while approximately 43% of wetlands not blocked by development may be able to migrate into land currently used as farmland and parks if the land is suitable for wetlands, loss of the farmland and parks would lead to economic losses for the region (Heberger et al., 2009).

The Monterey Bay region is addressing these concerns with several planning and climate initiatives through state and local governments, guided by legislation and policy guidance documents (Executive Order S-13-08, 2008, CDNR, 2009; CO CAT, 2010; Abeles et al., 2011; Atchison, 2011; CDWR, 2011; CNRA, 2012; ESA PWA et al., 2012). Below we outline how our collaborative work supports and furthers these efforts and provide information on where natural infrastructure adaptation strategies are being incorporated into planning in this region.

4. Incorporating natural infrastructure into regional vulnerability analysis

We used an approach similar to the analysis conducted by Arkema et al. (2013) which assessed vulnerability of coastal

communities to erosion and flooding at a national scale, and the value of natural habitats in protecting coastal regions from these hazards. Arkema et al. (2013) used the coastal vulnerability model in the InVEST (Integrated Valuation of Environmental Services and Tradeoffs) decision-support tool (Kareiva et al., 2011; Tallis et al., 2013; Arkema et al., 2013) to analyze physical vulnerability of coastal regions of the United States at a 1-km scale and examine how sea-level rise scenarios and removal of coastal protective habitats affected people and property (Arkema et al., 2013). This vulnerability model is similar in concept to the United States Geological Survey's qualitative Coastal Vulnerability Index (Thieler and Hammar-Klose, 2000), but the InVEST model also includes the documented role of natural habitats in reducing exposure of the coast to erosion and flooding and resultant changes in vulnerability of people and development (Arkema et al., 2013; Tallis et al., 2013).

We produced and integrated salient and credible information to estimate coastal vulnerability for the Monterey Bay region following the Arkema et al. (2013) analysis. The county planners helped define the appropriate scale, data, metrics, and visualization most useful for regional planning. Fig. 3 illustrates the components and iterative approach of the regional vulnerability analysis.

4.1. Coastal vulnerability model

The coastal vulnerability model in InVEST (Arkema et al., 2013; Tallis et al., 2013) is based on seven physical and biological characteristics of the region—geomorphology, natural habitats, relief, wave exposure, wind exposure, surge potential, and sea-level change—each ranked for its potential to increase or decrease exposure to erosion and flooding from ocean storms or sea-level rise (Fig. 4). To produce an overall hazard index of exposure to erosion and flooding, the coastline is divided into segments (of user-defined size) and, using input datasets for each of the biological and physical variables (Appendix A), the model generates absolute values for each of the variables (e.g., distance to shelf, average elevation in meters, wave power) for each coastal segment. The model then ranks each segment of coastline for each variable from very low exposure (Rank = 1) to very high exposure (Rank = 5) to erosion and flooding (Fig. 4). Ranks for geomorphology and habitats are absolute and depend on categorical variables. Ranks for the other five variables are relative and depend on the distribution of values for all coastline segments (Fig. 4). The model then estimates exposure to coastal hazards for each

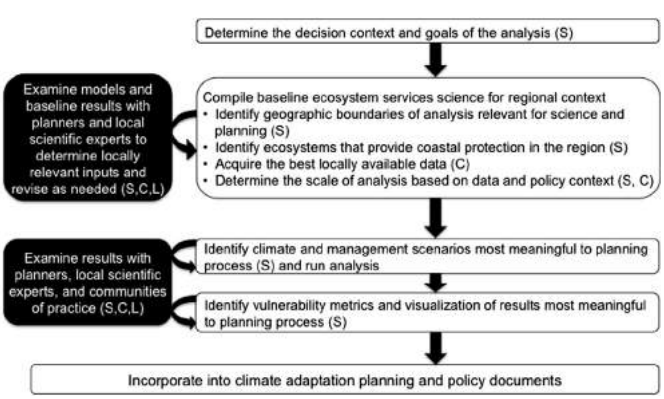

Fig. 3. Conceptual diagram outlining a regional approach for assessing vulnerability to coastal hazards that includes the ability of natural infrastructure to reduce vulnerability of people and development. Letters next to each action symbolize where saliency (S), credibility (C), and legitimacy (L) are enhanced within the process (Cash et al., 2003).

Exposure to Erosion and Flooding

Rank Variable	Very Low 1	Low 2	Moderate 3	High 4	Very High 5
Geomorphology	Rocky high cliff, **Cement armoring**	Medium cliff, Indented coast, **Wood armoring**	Low cliff, Alluvial plain	Cobble beach, Estuary, Lagoon, Bluff	Barrier beach, Sand beach
Natural Habitats		**High dune, Coastal wetland**	**Low dune**	**Kelp**	**No habitat**
Relief	1st Quantile	2nd Quantile	3rd Quantile	4th Quantile	5th Quantile
Wave Exposure	1st Quantile	2nd Quantile	3rd Quantile	4th Quantile	5th Quantile
Wind Exposure	1st Quantile	2nd Quantile	3rd Quantile	4th Quantile	5th Quantile
Surge Potential	1st Quantile	2nd Quantile	3rd Quantile	4th Quantile	5th Quantile
Sea Level Change	**Baseline**		**Moderate**		**Highest**
Long-term Erosion Rate	**Top 50% Accretion**	**Lower 50% Accretion**	**Null**	**Lower 50% Erosion**	**Top 50% Erosion**

Fig. 4. List of biophysical variables and ranking system for exposure to erosion and flooding used in the Santa Cruz and Greater Monterey County IRWM planning regions. Bold variables are those that were revised from the US-wide analysis by Arkema et al. (2013) for our regional analysis.

shoreline segment using a vulnerability index comprised of rank exposure values for each of the seven variables.[1]

4.2. Determining baseline exposure to erosion and flooding

As first steps in the regional vulnerability analysis our interdisciplinary team identified the key decisions to be informed, and relevant goals, timelines, and published guidelines (CDWR, 2011; CDWR, 2012). Initial scientific analyses calculated the level of shoreline protection that existing habitats provide based on their current distribution. The interdisciplinary team then used these baseline results to facilitate discussions with planners to refine model inputs for more specific scales, habitats, and data of interest. For example, in one early analysis, we used the entire Monterey Bay region to present the initial results to the planners and used these introductory discussions to ensure the analysis matched the specific boundaries of the Santa Cruz and Monterey IRWM planning regions. This iterative process enabled our interdisciplinary team to shift the focus of our analysis to match the criteria and policy language of the specific decision context and helped identify more refined regional data for our analysis.

We made several key modifications from the national scale analysis in Arkema et al. (2013) to make the analysis regionally relevant for IRWM planning based on iterative engagement between our interdisciplinary team and planners, as well as input from local experts. The coastal vulnerability model and the other models in the InVEST "toolbox" are open source and flexible and therefore can be modified to reflect local processes that may affect exposure to erosion and flooding. For example, the coastal vulnerability model is flexible in which habitats are included as candidates for coastal protection services. The Monterey analysis included kelp beds due to their documented ability to attenuate waves (Arkema et al., 2013; Pinsky et al., 2013). However, we removed giant kelp beds from the Santa Cruz analysis after extensive discussions with local experts because the specific type of kelp and the forcing conditions in this region were determined unlikely to affect long period wave attenuation in comparison to other regions. We also worked with local experts to determine that long-term erosion rates were an important determinant of coastal hazards in the region (Hapke et al., 2006). We therefore included long-term erosion rates provided by local coastal

[1] Vulnerability Index $= \sqrt{\frac{R_{\text{Habitats}} R_{\text{Geomorphology}} R_{\text{Relif}} R_{\text{SLR}} R_{\text{wind}} R_{\text{Waves}} R_{\text{Surge Potential}}}{7}}$, where R is rank, and subscripts for each rank indicate one of the seven variables. This is a version of the equation used in Arkema et al. (2013) which produces the same results but on a different scale.

engineering experts as another variable in the model by ranking erosion rates relative to the distribution across all segments (ESA PWA, 2014, Fig. 4; Appendix A). In addition, this region has relatively high-quality information on armoring, so we used a two-step process to account for those segments of shoreline where our data included human-made armoring structures (e.g., seawalls, riprap, revetments). First, we categorized structures as either concrete or wood. We then assigned a rank of 1 (lowest risk) to shoreline segments backed by concrete structures and a rank of 2 to those backed by wood structures. A final difference from the Arkema et al. (2013) analysis is that we analyzed the vulnerability of the two counties' coastlines at a finer scale resolution (50-m^2) to better reflect the data available in this region of California and to enhance the utility of the model outputs for local decision-making.

4.3. Identifying scenarios

In order to help characterize the protective role that natural habitats play in reducing exposure to erosion and flooding from sea-level rise and ocean storms, we conducted our analysis with the locally relevant input data described above with the habitats "present" (with their associated ranking) and again with the habitats "removed," setting all habitat segments to the lowest rank (5) (Fig. 4). We assumed that habitats "present" in these scenarios persisted. We compared these two scenarios, with and without habitats, to highlight areas where habitats are providing critical defense against coastal erosion and flooding. We used sea-level rise scenarios in consultation with the planners and in accordance with state climate change guidance (CDWR, 2011; CO-CAT, 2010). We explored the different sea-level rise projections in the Guidance (for example: year 2000 baseline sea levels; 0.4 m sea-level rise by 2050; and 1.4 m sea-level rise by 2100 (CO-CAT, 2010) by reflecting these three projections in the sea-level rise parameter of the vulnerability model as baseline (rank = 1), moderate (rank = 3) and high (rank = 5) respectively. In all, we explored six scenarios: the presence and absence of habitat for each of three sea-level rise projections (baseline, moderate, high).

Although there are several climate variables that may affect the ability of coastal and marine habitats to reduce risks from coastal flooding and erosion in California, our analysis focused on the direct effects of sea-level rise on the risk of coastal communities to erosion and flooding. On the California coast, sea-level rise is the most certain consequence of climate change and thus an important factor to include in our analysis. However, sea-level rise, ocean acidification, and changes to temperature and precipitation also are likely to affect the distribution and abundance of coastal and marine ecosystems (Fabry et al., 2008; National Research Council, 2012; Koch et al., 2013), thus affecting their ability to defend coastlines. The model does not predict migration or loss of habitat under the different sea-level rise scenarios, nor does it predict long- or short-term changes in shoreline position or configuration. Further work is needed to understand which habitats may be able (or unable) to adapt to change associated with several climate variables and how that is likely to affect nature-based climate adaptation planning.

4.4. Identifying and analyzing metrics

We determined the vulnerability metrics to use in our analysis through frequent discussions between the interdisciplinary team and planners and by referencing key guidance documents and previous plans (CDWR, 2011; 2nd Nature, 2013). Metrics included locations of water-resource related structures (e.g., water treatment facilities, sewer lines; data of locations only available for Santa Cruz IRWM region), agricultural land, and disadvantaged families, here defined as people below the poverty line from the 2010 U.S. Census data (Appendix A).

We analyzed the relationship between these metrics and the exposure of the coast to erosion and flooding using an approach similar to the analysis conducted by Arkema et al. (2013). First, we classified the 50-m^2 segments of coastline as highest, medium high, medium low or lowest vulnerability based on quartiles of the full distribution of vulnerability index values (across all coastline segments for all six scenarios). Then, we assessed the number of water-resource related structures (pumps, treatment plants, wells) within 1 km of the 50-m^2 segments of the coast with the highest exposure (top quartile of the vulnerability index values) to erosion and flooding for the Santa Cruz IRWM region. To assess the vulnerability of pipes we selected only the 50-m^2 segments with the highest exposure (top quartile) and determined the number of these segments within 1 km of pipes. To assess the vulnerability of farmland to coastal erosion and flooding, we selected the coastal segments with the highest exposure (top quartile) and determined the number of segments within 1 km distance of farmland. Finally, to assess the vulnerability of people and disadvantaged families to coastal erosion and flooding, we analyzed the average number of people and disadvantaged families associated with each 50-m^2 segment with the highest exposure (top quartile) within a 1 km distance of the coast (Arkema et al., 2013).

5. Vulnerability analysis for the Santa Cruz and Monterey IRWM regions

In this section we report on the results of the vulnerability analyses for the Monterey and Santa Cruz IRWM regions and discuss the challenges and successes of incorporating this information into climate adaptation decisions.

5.1. Coastal vulnerability results for the Greater Monterey County IRWM region

Nearly a tenth of the Monterey coastline is highly exposed (top quartile of the vulnerability index values) to coastal hazards, putting in harms way approximately 15% of the people and 10% of disadvantaged families on the Monterey coastline to flooding and erosion. The area of coastline most exposed to hazards will increase by more than 25% with the highest rise in sea level even with current habitats intact. This rise in sea level will also increase vulnerability of agricultural land, coastal populations, and disadvantaged families (Fig. 5).

Loss of coastal dunes, wetlands, and kelp forests would increase the exposure to erosion and flooding of more than three quarters of the Monterey County coastline (Fig. 2). In particular, without coastal habitats, the area of coastline with the highest exposure to hazards would increase by approximately 10%, putting at high risk an additional 25% of the people and disadvantaged families (Fig. 5). Rising seas exacerbate the problem of habitat loss, such that under the highest sea-level rise scenario with habitat loss over half of the disadvantaged families will be highly vulnerable to coastal hazards and the area of farmland most exposed to erosion and flooding will increase by more than 10% (Fig. 5). Loss of habitat has the biggest impact on vulnerability in the central-southern Monterey Bay coast stretching between the towns of Moss Landing to Monterey, where coastal dunes protect people and farmland from erosion and flooding. In this area, sand mining is accelerating erosion rates and reducing the resiliency of natural dune infrastructure (Thornton, 2006; ESA PWA, 2012).

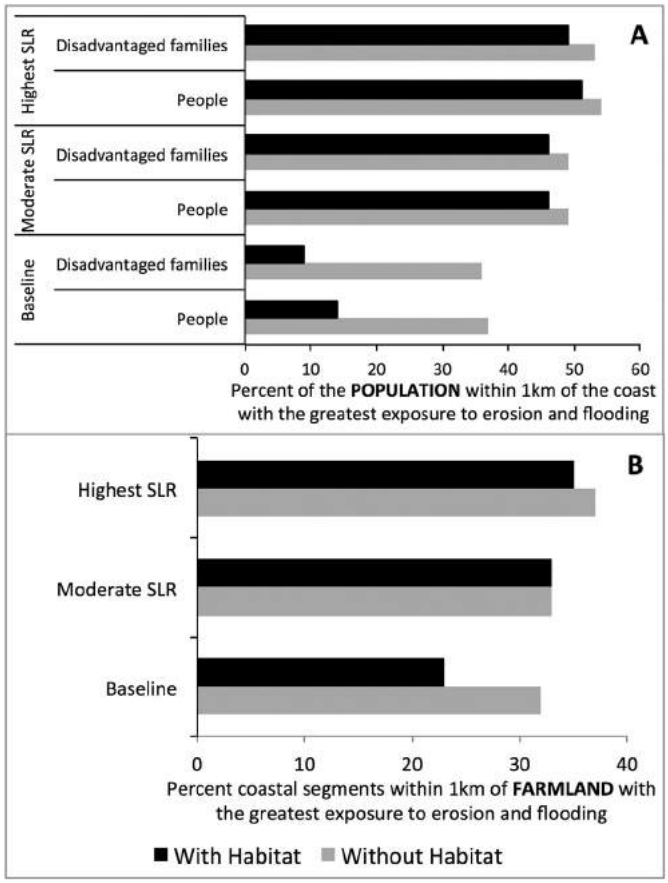

Fig. 5. Greater Monterey County IRWM Region. A) Percent of the population (people) and disadvantaged families (here defined as people below the poverty line from the 2010 U.S. Census data) within 1 km of the highest vulnerability coastal segments; and B) Percent highest vulnerability coastal segments within 1 km of farmland with habitats present (black bars) and habitats removed (gray bars) at baseline, moderate and highest sea-level rise.

5.2. Coastal vulnerability results for the Santa Cruz IRWM region

With the highest rise in sea level almost half of the Santa Cruz coastline is highly exposed (top quartile of the vulnerability index values) to coastal hazards, increasing the vulnerability of people and disadvantaged families most exposed to coastal flooding and erosion by approximately one-third (Fig. 6). This rise in sea level will also increase vulnerability of water-resource related structures and farmland (Fig. 6).

Coastal dunes and wetlands protect over 60% of the Santa Cruz IRWM region coastline (Fig. 2). Loss of these natural habitats increases the water-resource related structures most exposed to erosion and flooding by as much as 10% (Fig. 6). At the highest sea level and with loss of existing habitats there is a 50% increase in farmland most vulnerable to flooding and erosion and an increase in vulnerability of water-resource related structures by approximately 75% (Fig. 6).

6. Using vulnerability analysis results in climate change adaptation planning

Planners used results from our vulnerability analysis to inform the climate adaptation planning process for integrated regional water management in Monterey and Santa Cruz IRWM regions. In Monterey, the vulnerability analysis was included as part of the climate guidance in the final IRWM plan. The information in these plans helps guide prioritization of water-resources related funding in the regions.

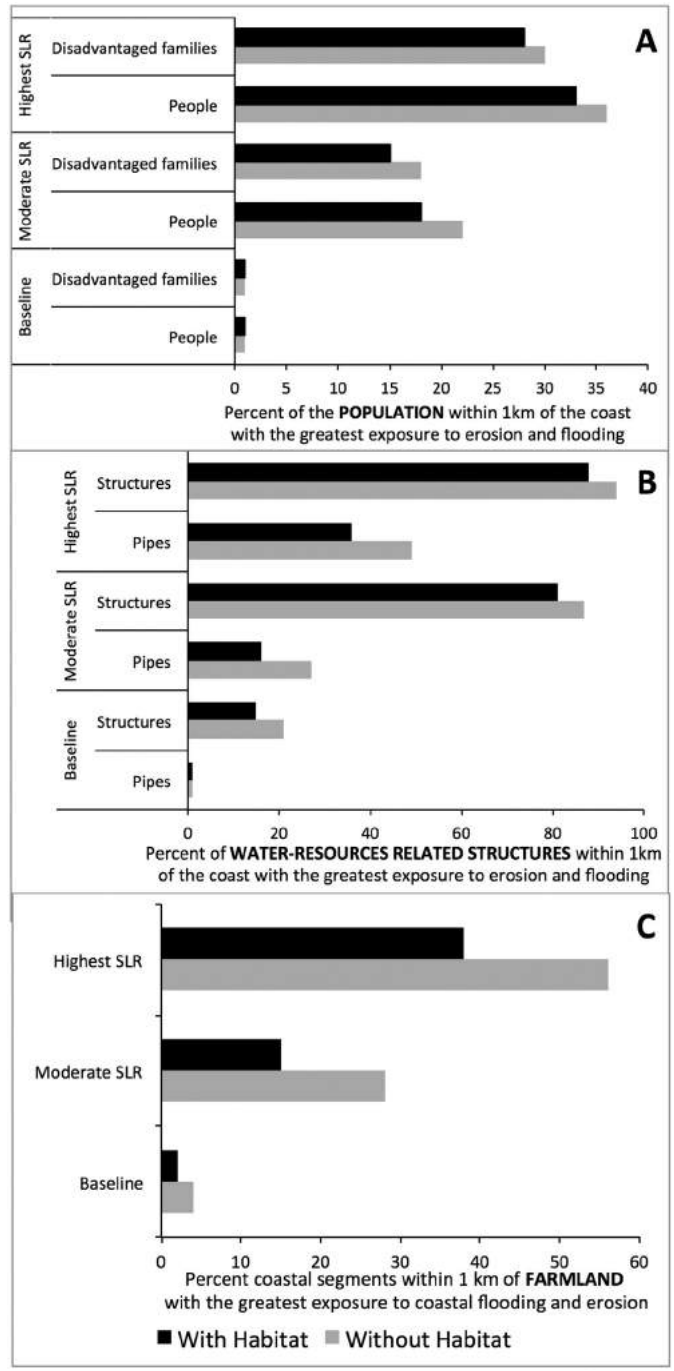

Fig. 6. Santa Cruz County IRWM Region. A) percent of the population (people) and disadvantaged families (here defined as people below the poverty line from the 2010 U.S. Census data) within 1 km of the highest vulnerability coastal segments, B) percent highest vulnerability coastal segments within 1 km of pipe water-resource related infrastructure (pipes) and percent of pump, well, and treatment plant infrastructure (structures) within 1 km of the highest vulnerability coastal segments, and C) percent highest vulnerability coastal segments within 1 km of farmland with habitats present (black bars) and habitats removed (gray bars) at baseline, moderate and highest sea-level rise.

In addition, information about coastal vulnerability and the role of habitats in providing protection to people and infrastructure prompted Monterey planners to submit funding requests to the Regional Water Management Group to: 1) implement coastal dune

habitat restoration and protection within the highest vulnerability sections of the coast and 2) conduct a cost-benefit analysis of climate change adaptation strategies, including restoring and protecting natural infrastructure. The climate change adaptation proposal was widely supported by the Monterey County planners (RWMG, 2012) and it has since been funded by the California Coastal Conservancy through a grant program that supports long-term planning for sea-level rise under the Coastal Act.

In Santa Cruz, the IRWM plan is not yet finalized, but information from the analysis is included in the draft plan. In addition, our engagement led to conceptual use of the natural infrastructure information in the planning process (McKenzie et al., in press). Our results highlighted the extent of the Santa Cruz IRWM coastal region that is vulnerable to flooding and erosion under the highest sea-level scenario. Insights from these results informed modifications to the conceptual framework developed by the Santa Cruz IRWM region planners to include strategies that address the multiple benefits associated with natural infrastructure approaches to flood control and sea-level rise (2nd Nature, 2013). The review of these results and maps also led to discussions and preliminary analyses of natural infrastructure restoration and/or enhancement opportunities. We used the maps and outputs from the analysis, historical maps (2nd Nature, 2013) and guidance regarding priorities in the region to identify realistic wetland restoration scenarios that are being considered for inclusion in the Santa Cruz IRWM plan to guide restoration efforts in the region and support multiple benefits.

Our results helped planners prioritize and target the protection or restoration of natural infrastructure to reduce coastal hazards for people, water-related infrastructure, and farmland. However, natural infrastructure may not always be an effective or desirable substitute for built infrastructure or may be most effective in conjunction with built infrastructure (Lowe et al., 2013). More specific quantitative studies that model these shoreline and habitat changes (ESA PWA, 2014), and compare the costs and benefits of specific natural and built infrastructure approaches are necessary to advance from strategic to tactical guidance (McKenzie et al., in press). As mentioned above, we are currently collaborating with local experts using the results from this analysis to guide specific quantitative studies comparing these costs and benefits which would take into account shoreline change and effects of sea-level rise on habitats to provide more tactical guidance.

There are inherent uncertainties in any planning process—and climate adaptation planning is no exception. We addressed some uncertainty in the biophysical realm (driven, in part by uncertainties in social and economic realms) by exploring six sea-level rise and habitat scenarios as explicit recognition of uncertain futures. Although beyond the scope of this study, a more thorough examination of the uncertainty of linked social, economic, and natural systems within a planning process would benefit regional adaptation planning.

7. Producing salient information for regional planning

The iterative process of co-producing regional model results with IRWM planners helped the interdisciplinary team provide analysis, information, and guidance that better matched the IRWM planners' information needs. For example, we discussed possible management and sea-level rise futures with the planners and examined guidance documents to build relevant scenarios. Careful review of guidance documents (CDWR, 2012; CDWR, 2011), consultants' reports (ESA PWA, 2012, 2nd Nature, 2013), and early presentations of model results to the planners and local technical advisory committees (to set expectations and introduce the modeling methodology) led to the collaborative selection of spatial scales and metrics meaningful to the regional and state goals of the plan.

Planners and stakeholders responded to the iterative presentation of interim visual results by volunteering additional local knowledge (including better local data). Interdisciplinary experts and planners also used the interim presentations of results and related discussions with planners and local technical advisory committees to find common language for the scientific outputs, determine the best terminology to present to stakeholders, and increase the usability of the information for practical planning purposes. This process ultimately increased the technical and knowledge capacity of planners while increasing the saliency of the information provided by scientists.

8. Conclusions

Vulnerability assessments that take into account the ways in which natural infrastructure protects communities from sea-level rise and storms are an important step to help communities determine resilient, multi-benefit climate adaptation strategies. However, to produce useful science on where and when natural habitats provide protection and to guide active planning decisions, interdisciplinary experts and planners must co-produce information that is relevant at the regional scale, credible to decision-makers, and sufficiently salient (Cash et al., 2003; Moser and Ekstrom, 2010; Moss and Scarlett, submitted for publication). Our iterative approach to communication using an interdisciplinary team and "boundary object" to facilitate translation of scientific information to the specific decision context led to our work generating products that helped shape the decision space.

Our collaborative work is one of the first regional vulnerability assessments to analyze where natural habitats reduce the vulnerability of water infrastructure and coastal populations to erosion and flooding in coastal California and to use that information to inform public decision-making on climate change adaptation in coastal communities. We find that vulnerability of water-resource related structures and coastal populations increases with sea-level rise, and that the presence of natural habitats reduces vulnerability. However, the protective value of natural habitats is variable along the coast, depending on forcing conditions, habitat type, and distribution of the communities, farmland, and water resources-related infrastructure. Providing maps and data of where natural infrastructure is protecting people and property is an important step in informing the smart use of natural habitats for climate adaptation planning.

California has over 3 400 miles of tidal shoreline that will be impacted by sea-level rise and storms in the future. Protection, restoration, and enhancement of natural habitat to protect coastal regions from these impacts are practical and cost-effective approaches in many regions of California. However, decision-makers and planners need transparent and collaborative tools and approaches at the regional level to support these efforts, particularly in areas of the coast where political limitations or familiarity with built infrastructure approaches may lead to skepticism about the role of natural infrastructure. Our regional approach could be transferred to other coastal decision contexts in California and beyond as these regions decide how to adapt their communities and infrastructure to future sea-level rise.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ocecoaman.2014.03.019.

References

2nd Nature, 2013. Santa Cruz IRWM Conceptual Framework Update. Santa Cruz, CA.

Abeles, A., Grimmer, K., Papendick, H., 2011. Preparing for the Future: Climate Change and the Monterey Bay Shoreline Summary Report. Center for Ocean Solutions, California.

Adger, W.N., Brown, K., Nelson, D.R., Berkes, F., Eakin, H., Folke, C., Galvin, K., Gunderson, L., Goulden, M., O'Brien, K., Ruitenbeek, J., Tompkins, E.L., 2011. Resilience implications of policy responses to climate change. Wiley Interdiscip. Rev. Clim. Change 2, 757–766.

Arkema, K.K., Guannel, G., Verutes, G., Wood, S. a., Guerry, A., Ruckelshaus, M., Kareiva, P., Lacayo, M., Silver, J.M., 2013. Coastal habitats shield people and property from sea-level rise and storms. Nat. Clim. Change 3, 1–6.

Atchison, C., 2011. Santa Cruz Climate Adaptation Plan. City of Santa Cruz, Santa Cruz, CA.

Barbier, E.B., Koch, E.W., Silliman, B.R., Hacker, S.D., Wolanski, E., Primavera, J., Granek, E.F., Polasky, S., Aswani, S., Cramer, L.A., Stoms, D.M., Kennedy, C.J., Bael, D., Kappel, C.V., Perillo, G.M.E., Reed, D.J., 2008. Coastal ecosystem-based management with nonlinear ecological functions and values. Sci. (New York, N.Y.) 319, 321–323.

Berry, A., Fahey, S., Meyers, N., 2013. Changing of the guard: adaptation options that maintain ecologically resilient Sandy Beach ecosystems. J. Coast. Res. 289, 899–908.

Caldwell, M., Segall, C.H., 2007. No day at the Beach: sea level rise, ecosystem loss, and public access along the California coast. Ecol. Law Q. 34, 533–578.

Caldwell, M.R., Hartge, E., Ewing, L., Griggs, G., Kelly, R., Moser, S., Newkirk, S., Smyth, R., Woodson, B., 2013. Coastal issues coordinating lead authors. In: Garfin, G., Jardine, A., Merideth, M., LeRoy, S. (Eds.), Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment. Southwest Climate Alliance. Island Press, Washington, DC, pp. 168–196.

California Coastal Act, 1976.

California Employment Development Department, 2010. Employment by Industry Data. http://www.labormarketinfo.edd.ca.gov/.

California Endangered Species Act, 1984.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jäger, J., Mitchell, R.B., 2003. Knowledge systems for sustainable development. Proc. Natl. Acad. Sci. U S A 100, 8086–8091.

CDNR, 2009. California Climate Adaptation Strategy. Sacramento, California.

CDWR, 2011. Climate Change Handbook for Regional Water Planning. Sacramento, California.

CDWR, 2012. Integrated Regional Water Management Guidelines. Sacramento, CA.

Clark, W., Tomich, T.P., Van Noordwijk, M., Dickson, N.M., Catacutan, D., Guston, D., McNie, E., 2010. Toward a General Theory of Boundary Work: Insights from the CGIAR's Natural Resource Management Programs. In: HKS Faculty Research Working Paper Series RWP10-035. John F. Kennedy School of Government, Harvard University.

CNRA, 2012. California Adpatation Planning Guide. Sacramento, California.

CO CAT, 2010. State of California Sea-level Rise Interim Guidance Document. Developed by the Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), with Science Support from the Ocean Protection Council Science Advisory Team (D. Cayan, G. Griggs, S. Johnson, and T. Haymet). Sacramento, CA.

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T. a., Dugan, J., Jones, A., Lastra, M., Scapini, F., 2009. Threats to sandy beach ecosystems: a review. Estuar. Coast. Shelf Sci. 81, 1–12.

Economics Climate Group, 2009. Shaping Climate-Resilient Development: a Framework for Decision-making. ClimateWorks Foundation, Global Environmental Facility, European Commission, McKinsey & Co., The Rockefeller Foundation, Standard Chartered Banks and SwissRe, Washington, DC.

Eichenberg, T., Bothwell, S., Vaughn, D., 2010. Climate Change and the public trust doctrine: using an ancient doctrine to adapt to rising sea levels in San Francisco Bay. Golden Gate Univ. Environ. Law J. 3. http://digitalcommons.law.ggu.edu/gguelj/vol3/iss2.

Ekstrom, J.A., Moser, S.C., Torn, M., 2011. Barriers to Climate Change Adaptation: a Diagnostic Framework. Lawrence Berkeley National Laboratory, Berkeley, CA.

ESA PWA, 2014. Monterey Bay Sea Level Rise Vulnerability Assessment – Technical Methods Report. San Francisco, CA.

ESA PWA, Caldwell, M., King, P., Mcgregor, A., 2012. Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay. San Francisco, CA.

Everard, M., Jones, L., Watts, B., 2010. Have we neglected the societal importance of sand dunes? An ecosystem services perspective. Aqua. Conserv. Mar. Freshw. Ecosyst. 20, 476–487.

Executive Order S-13-08, 2008.

Fabry, V.J., Seibel, B.A., Feely, R.A., Orr, J.C., 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. ICES J. Mar. Sci. 65, 414–432.

Farber, D.A., 2008. Owning up to the environment. Environ. Law Rep. 40 (10), 10994.

Gedan, K.B., Kirwan, M.L., Wolanski, E., Barbier, E.B., Silliman, B.R., 2010. The present and future role of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm. Clim. Change 106, 7–29.

Griggs, G., 2005. California's Retreating Coastline: Where Do We Go From Here?. California and the World Ocean Conference.

Griggs, G., Haddad, B., 2011. City of Santa Cruz Climate Change Vulnerability Assessment, pp. 1–74. Santa Cruz, CA.

Guston, D.H., 2001. Boundary organizations in environmental policy and science: an introduction. Sci. Technol. Hum. Values 26, 399–408.

Hapke, C., Reid, D., Richmond, B., 2006. National Assessment o f Shoreline Change Part 3: Historical Shoreline Change and Associated Coastal Land Loss Along Sandy Shorelines of the California Coast. US Geological Survey Open-file Report 2006–1219.

Hart, J.A., Grifman, P.M., Moser, S.C., Abeles, A., Myers, M.R., Schlosser, S.C., Ekstrom, J.A., 2012. Rising the Challenge: Results of the 2011 California Coastal Adaptation Needs Assessment. USCSG-TR-01-2012.

Heberger, M., Cooley, H., Herrera, P., Gleick, P., Moore, E., 2009. The Impacts of Sea-level Rise on the California Coast. California Energy Commission, Sacramento, CA.

Jones, H., Hole, D., Zavaleta, E., 2012. Harnessing nature to help people adapt to climate change. Nat. Clim. Change 2, 504–509.

Kareiva, P., Tallis, H., Ricketts, T.H., Daily, G.C., Polasky, S. (Eds.), 2011. Natural Capital: Theory and Practice of Mapping Ecosystem Services. Oxford University Press, Oxford.

King, P., Mcgregor, A.R., Whittet, J.D., 2010. The Economic Costs of Sea-level Rise to California Beach Communities. California Department of Boating and Waterways, Sacramento, CA.

Kirwan, M., Temmerman, S., 2009. Coastal marsh response to historical and future sea-level acceleration. Quat. Sci. Rev. 28, 1801–1808.

Koch, M., Bowes, G., Ross, C., Zhang, X.-H., 2013. Climate change and ocean acidification effects on seagrasses and marine macroalgae. Glob. Change Biol. 19, 103–132.

Kraus, N.C., Mcdougal, W.G., 2013. The effects of seawalls on the beach: part i, an updated literature review C. J. Coast. Res. 12, 691–701.

Lemos, M.C., Kirchhoff, C.J., Ramprasad, V., 2012. Narrowing the climate information usability gap. Nat. Clim. Change 2, 789–794.

Lowe, J., Battalio, B., Brennan, M., Crooks, S., Holmes, M., Niemi, E., Toms, C., 2013. Analysis of the Costs and Benefits of Using Tidal Marsh Restoration as a Sea Level Rise Adaptation Strategy in San Francisco Bay. ESA PWA, San Francisco, CA.

Lubell, M., Lippert, L., 2011. Integrated regional water management: a study of collaboration or water politics-as-usual in California, USA. Int. Rev. Adm. Sci. 77, 76–100.

McKee, K.L., Cahoon, D.R., Feller, I.C., 2007. Caribbean mangroves adjust to rising sea level through biotic controls on change in soil elevation. Global Ecol. Biogeogr. 16, 545–556.

McKenzie, E., Posner, S., Tillmann, P., Bernhardt, J.R., Howard, K., Rosenthal, A., 2014. How is ecosystem service knowledge used in decision-making? An exploratory analysis of international case studies. Environ. Plan. C (in press).

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being. Island Press, Washington, DC.

Moser, S., Ekstrom, J., 2010. A framework to diagnose barriers to climate change adaptation. Proc. Natl. Acad. Sci. 107, 22026–22031.

Moss, R., Scarlett, L., 2014. Decision Support Supporting Policy, Planning, and Resource Management Decisions in a Climate Change Context. National Climate Assessment, Washington, DC, p. 925 (submitted for publication).

National Research Council, 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. The National Academies Press, Washington, D.C.

Peloso, M.E., Caldwell, M.R., 2011. Dynamic property rights: the public trust doctrine and takings in a changing climate. Stanf. Environ. Law J. 30, 51–120.

Pinsky, M., Guannel, G., Arkema, K., 2013. Quantifying wave attenuation to inform coastal habitat conservation. Ecosphere 4, 1–16.

Rayner, S., 2005. Weather forecasts are for wimps: why water resource managers do not use climate forecasts. Clim. Change 69, 197–227.

Reed, D.J., 1995. The response of coastal marshes to sea-level rise: survival or submergence? Earth Surf. Process. Landf. 20, 39–48.

Regional Water Management Group, 2012. Greater Monterey County Integrated Regional Water Management Regional Water Management Group Meeting Minutes. October 17, 2012. Moss Landing, CA.

Shepard, C.C., Crain, C.M., Beck, M.W., 2011. The protective role of coastal marshes: a systematic review and meta-analysis. PloS One 6, e27374.

Tallis, E.H., Ricketts, T., Guerry, A., Wood, S., Sharp, R., Authors, C., Nelson, E., Ennaanay, D., Wolny, S., Olwero, N., Vigerstol, K., Penning-, D., Mendoza, G., Aukema, J., Foster, J., Forrest, J., Cameron, D., Arkema, K., Lonsdorf, E., Kennedy, C., Verutes, G., Kim, C., Guannel, G., Papenfus, M., Toft, J., Mar-, M., Bernhardt, J., Griffin, R., Glowinski, K., Chaumont, N., Perelman, A., Lacayo, M., Tallis, C., 2013. InVEST 2.5.6 User's Guide. The Natural Capital Project, Stanford.

Thieler, E.R., Hammar-Klose, E.S., 2000. Assessment of Coastal Vulnerability to Future Sea-Level Rise: Preliminary Results for the U.S. Pacific Coast. U.S. Geological Survey, Open-File Report 00-178.

Thornton, E.B., Sallenger, A.H., Conforto Sesto, J., Egley, L.A., McGee, T., Parsons, A.R., 2006. Sand mining impacts on long-term dune erosion in southern Monterey Bay. Mar. Geol. 229, 45–58.
Turner, W.R., Bradley, B. a., Estes, L.D., Hole, D.G., Oppenheimer, M., Wilcove, D.S., 2010. Climate change: helping nature survive the human response. Conserv. Lett. 3, 304–312.
White, D.D., Wutich, A., Larson, K.L., Gober, P., Lant, T., Senneville, C., 2010. Credibility, salience, and legitimacy of boundary objects: water managers' assessment of a simulation model in an immersive decision theater. Sci. Public Policy 37, 219–232.
Zedler, J.B., Kercher, S., 2005. Wetland resources: status, trends, ecosystem services, and restorability. Annu. Rev. Environ. Resour. 30, 39–74.