

Can We Keep Up with Changing Estuaries?

Moving from science to action in San Francisco Bay



Letitia Grenier

Association of State Wetlands Managers
May 29, 2019

What We Do



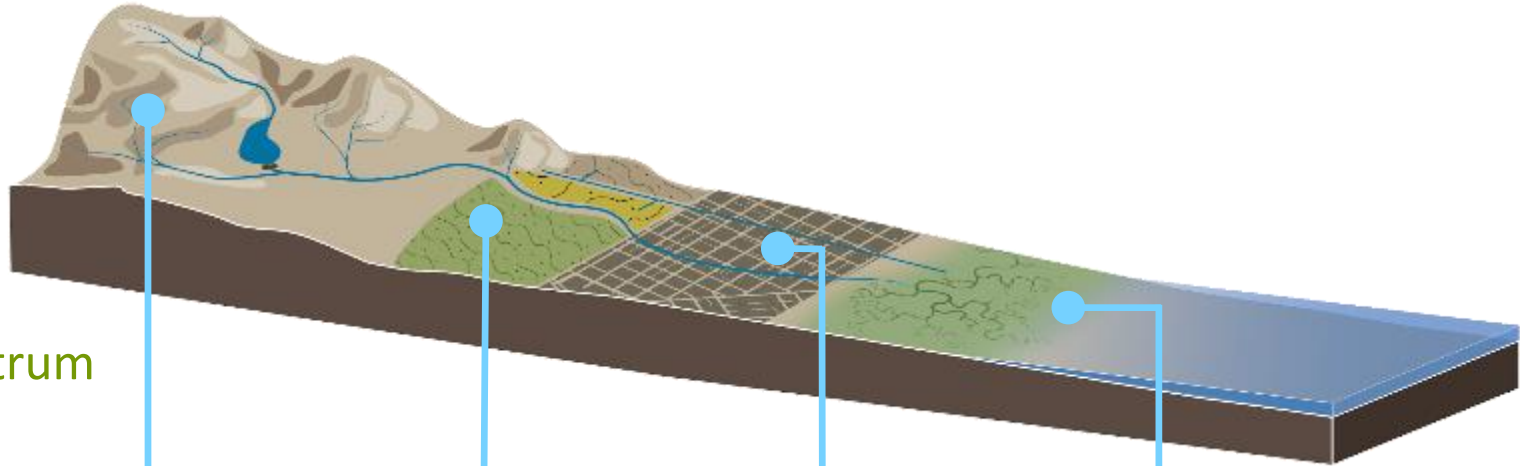
Science: Draw on cutting-edge science from across disciplines

Translation: Turn science into usable local guidance, visions, tools

Implementation: Facilitate integrated actions via partnerships and planning

WORKING WITH NATURE

across the land-use spectrum



WILDLANDS

AGRICULTURE

URBAN

SHORE

Nature-Based Solutions

- Habitat conservation and restoration
- Prevent development
- Emulate fire disturbance

- Wildlife-friendly agriculture
- Creek corridor restoration
- Prevent development

- Native plant urban forest
- Mitigate barriers to wildlife movement
- Creek realignment

- Marshes
- Beaches
- Hybrid shorelines

Resulting Ecosystem Services

- Water capture
- Carbon sequestration
- Manage wildfire risk
- Biodiversity

- Water infiltration
- Habitat connectivity
- Pollination
- Biodiversity

- Flood peak reduction
- Water quality benefits
- Sediment transport
- Biodiversity

- Shoreline protection
- Carbon sequestration
- Water quality benefits
- Biodiversity

Goals Projects

1800

Tidal Marsh



1998

Tidal Marsh 

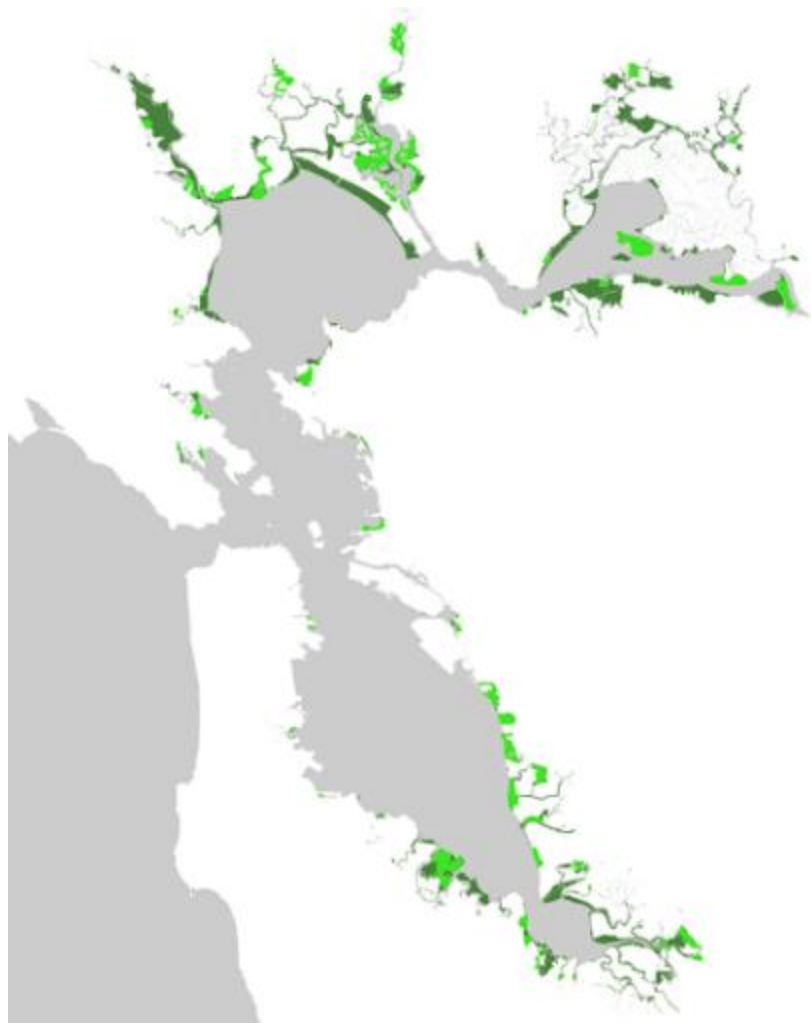
Restored Tidal Marsh 



2009

Tidal Marsh 

Restored Tidal Marsh 

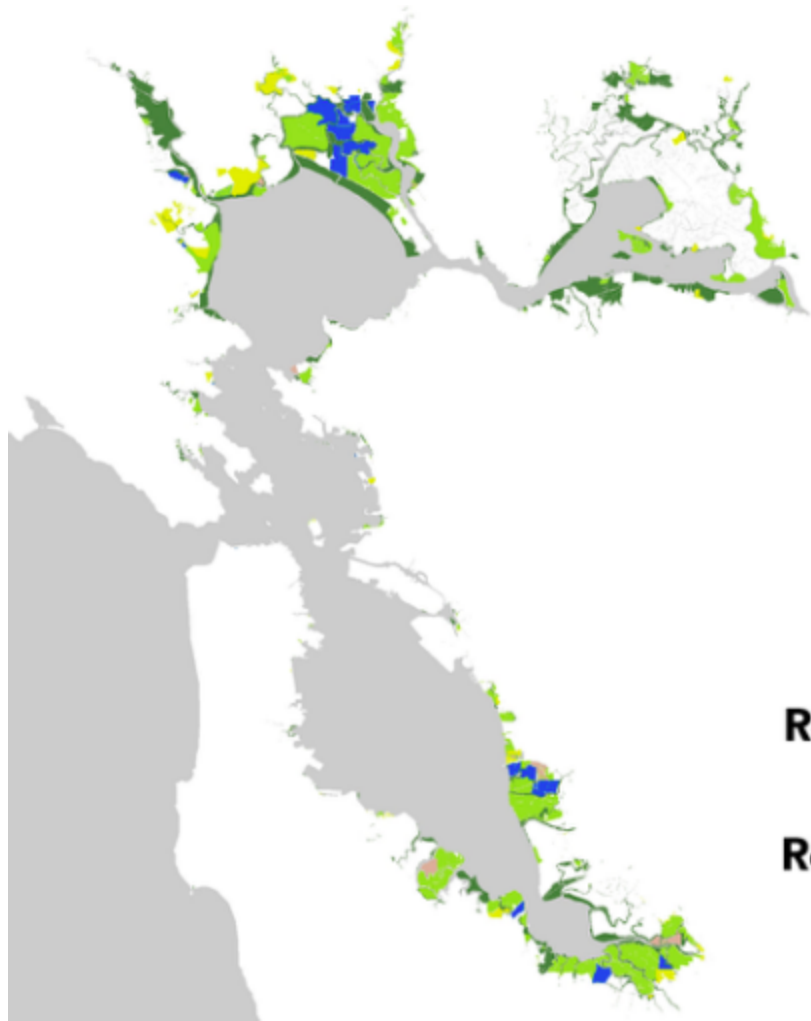




FUTURE

Tidal Marsh 

Restored Tidal Marsh 



FUTURE

Existing Tidal Marsh 

Restored Tidal Marsh 

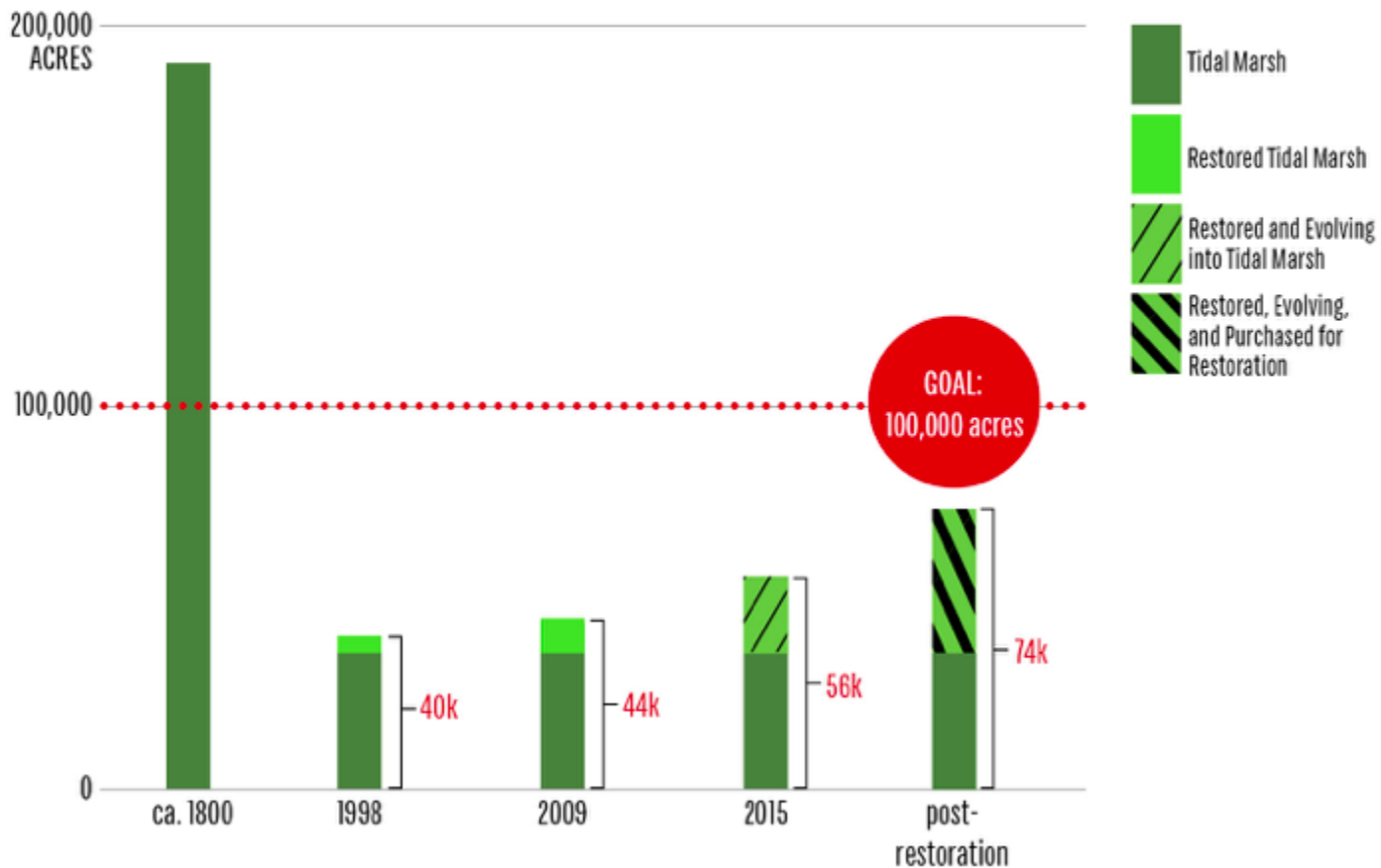
Restored Tidal Flat 

Restored Diked Wetland 

Restored Managed Pond 

TIDAL MARSH

restoration





MEASURING THE IMPACT of the Baylands Goals

LARGEST RESTORATION PROJECT

grew from 350 acres to 15,000 acres

WRITTEN INTO POLICY

Water Board, BCDC, SCC, SFBJV, etc.

DRAMATIC INCREASE IN FUNDING

SBSP, Prop 50, Restoration Authority

INSPIRED OTHER GOALS PROJECTS

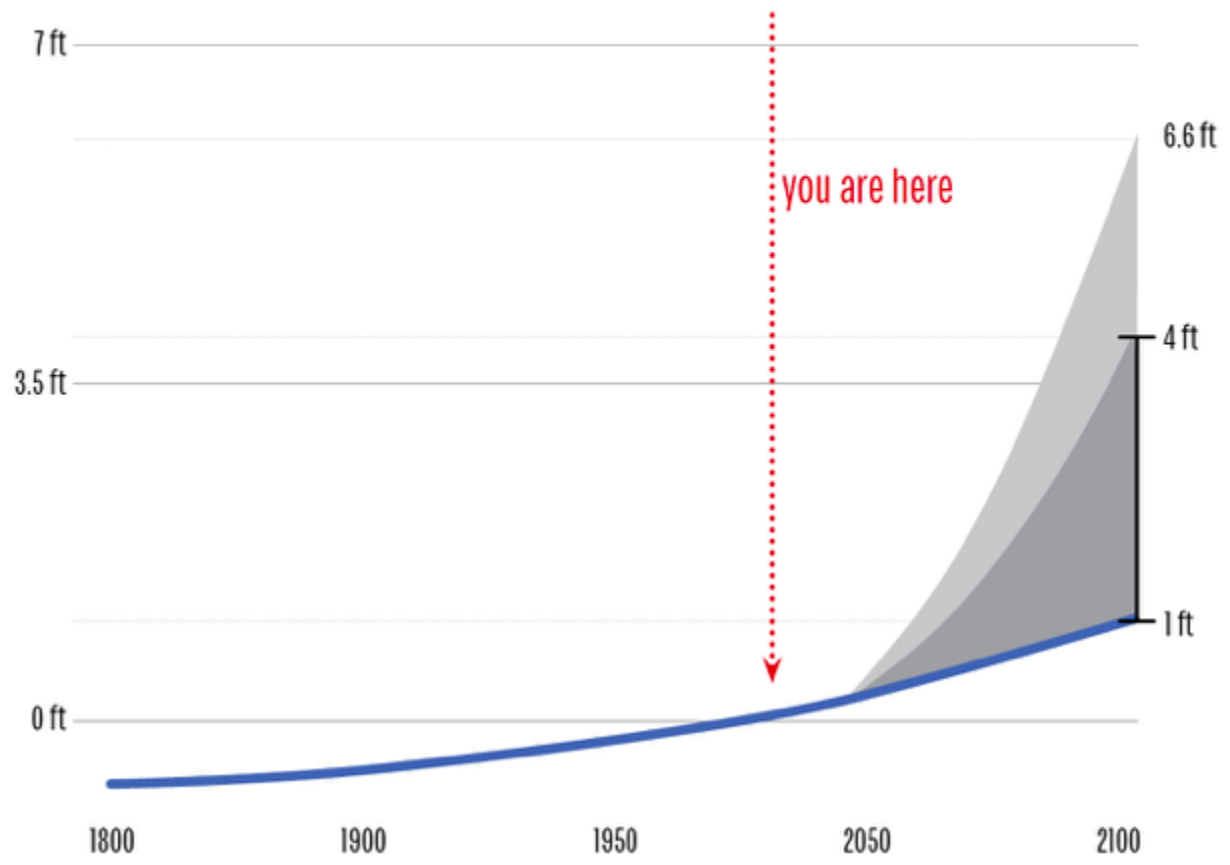
Uplands, Subtidal

GLOBAL SEA LEVEL

change

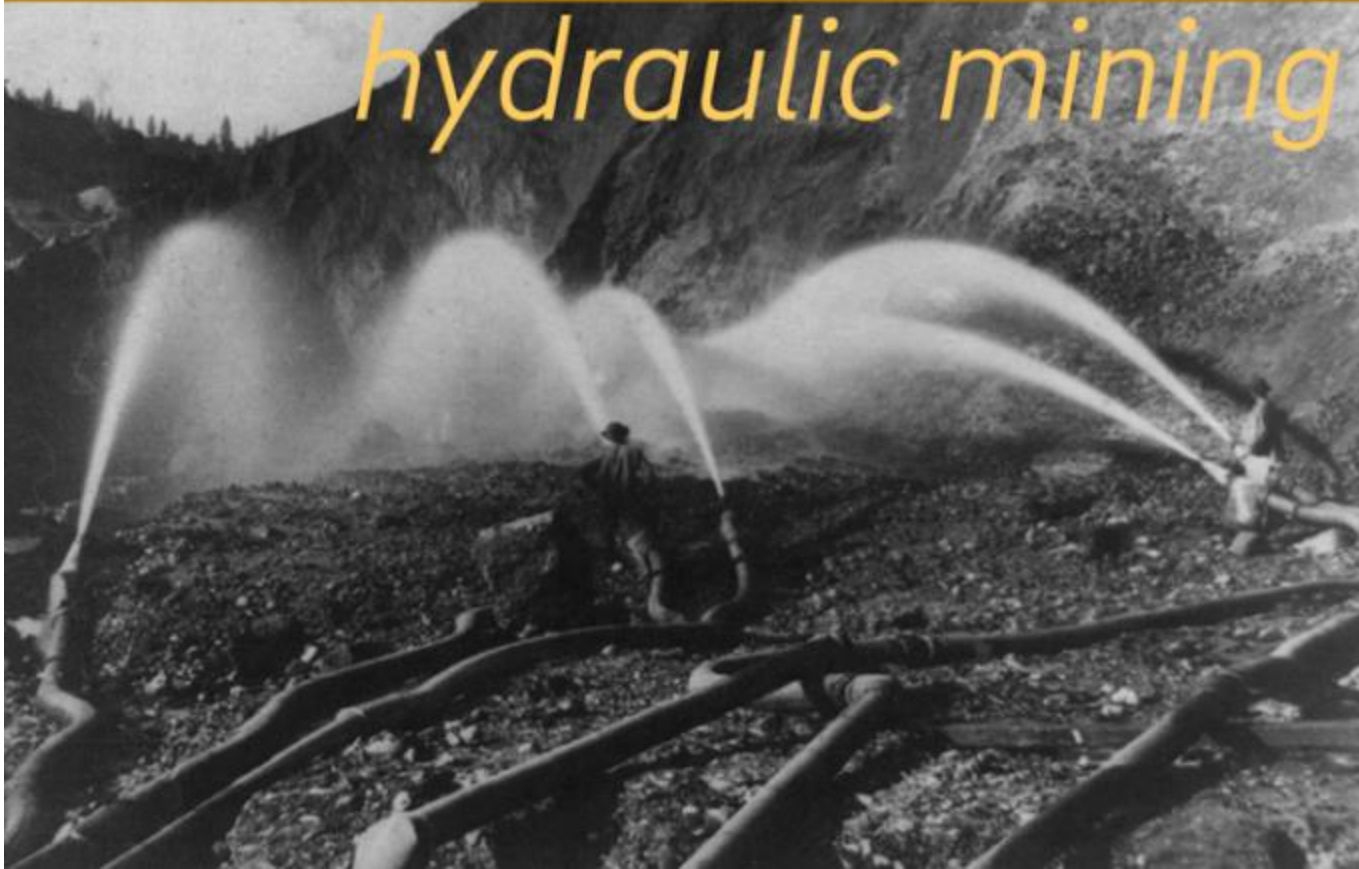
SINCE 1800

Courtesy 3rd National
Climate Assessment,
2014



SEDIMENT SUPPLY

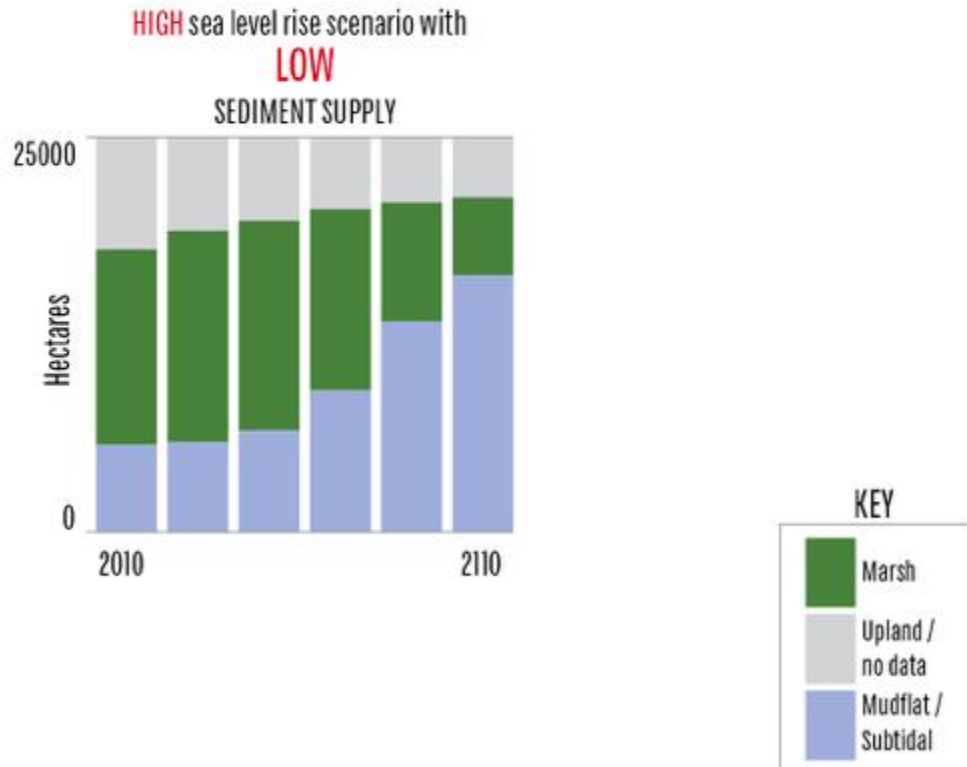
hydraulic mining



THE FUTURE OF MARSHES DEPENDS ON

sediment supply

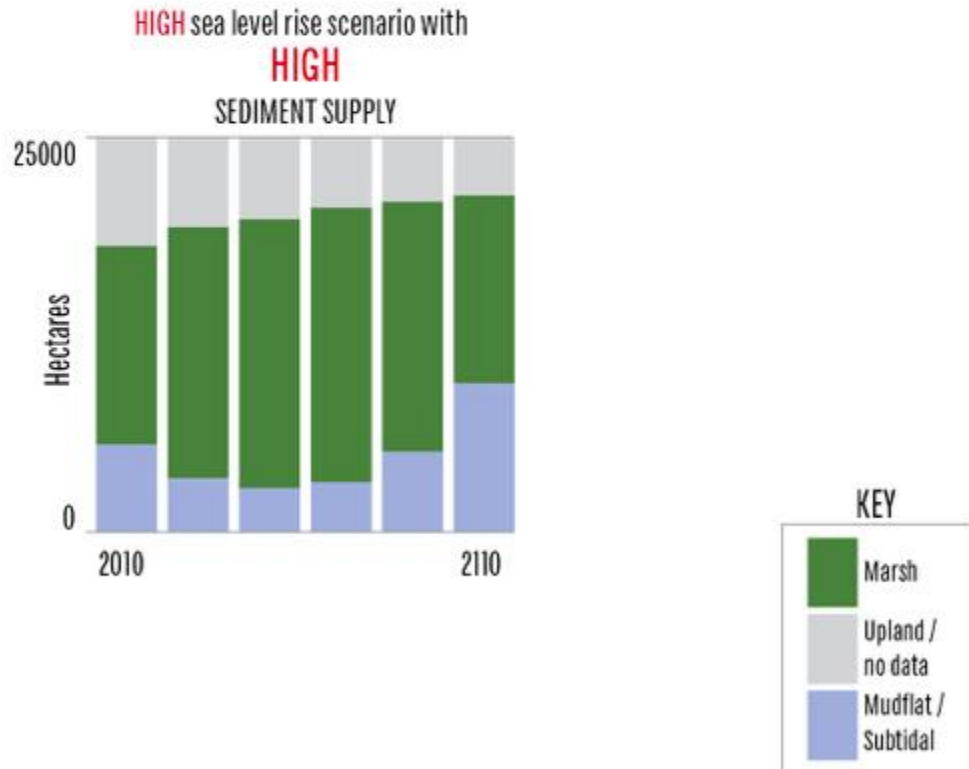
Courtesy Stralberg et al. 2011



THE FUTURE OF MARSHES DEPENDS ON

sediment supply

Courtesy Stralberg et al. 2011



THE
Baylands
AND
Climate Change

WHAT WE CAN DO

BAYLANDS ECOSYSTEM HABITAT GOALS
SCIENCE UPDATE 2015



State of California
Coastal Conservancy

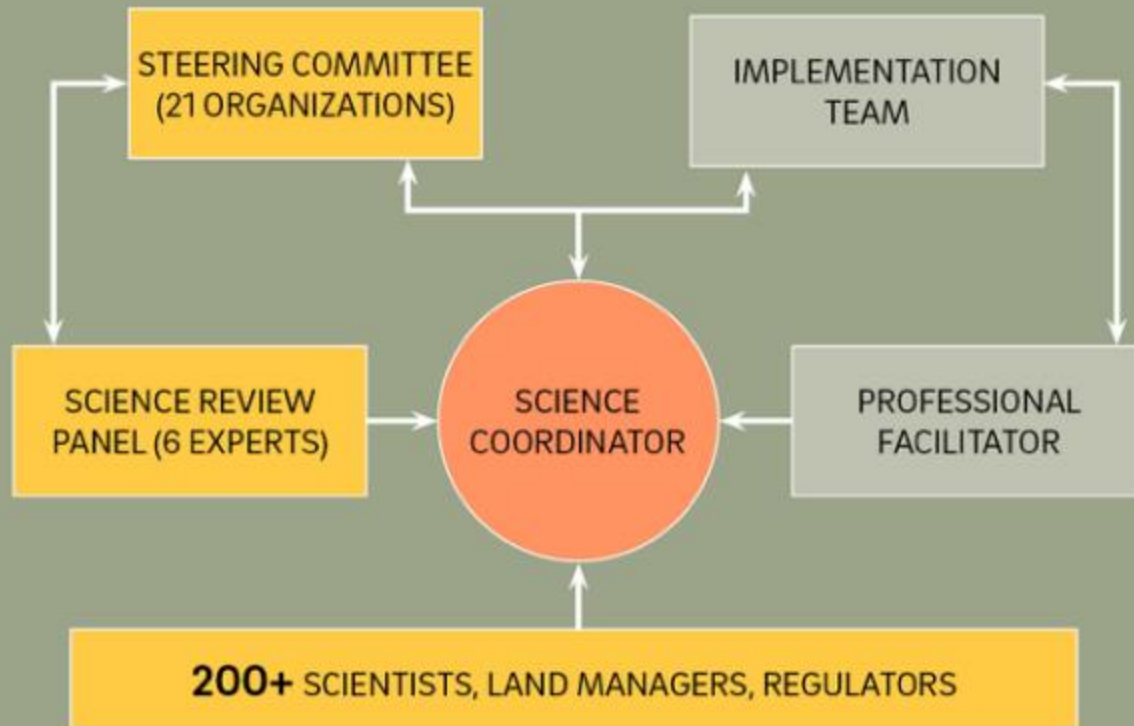


BAYLANDS GOALS 2015

- Science synthesis
- Effect of future change, especially climate and sediment supply, on the Baylands
- Goal is healthy ecosystem, providing a resilient shore for people and wildlife
- Recommendations and landscape visions for the next century



ROBUST COLLABORATIVE PROCESS



STEERING COMMITTEE

*Resource management, regulatory,
restoration organizations*

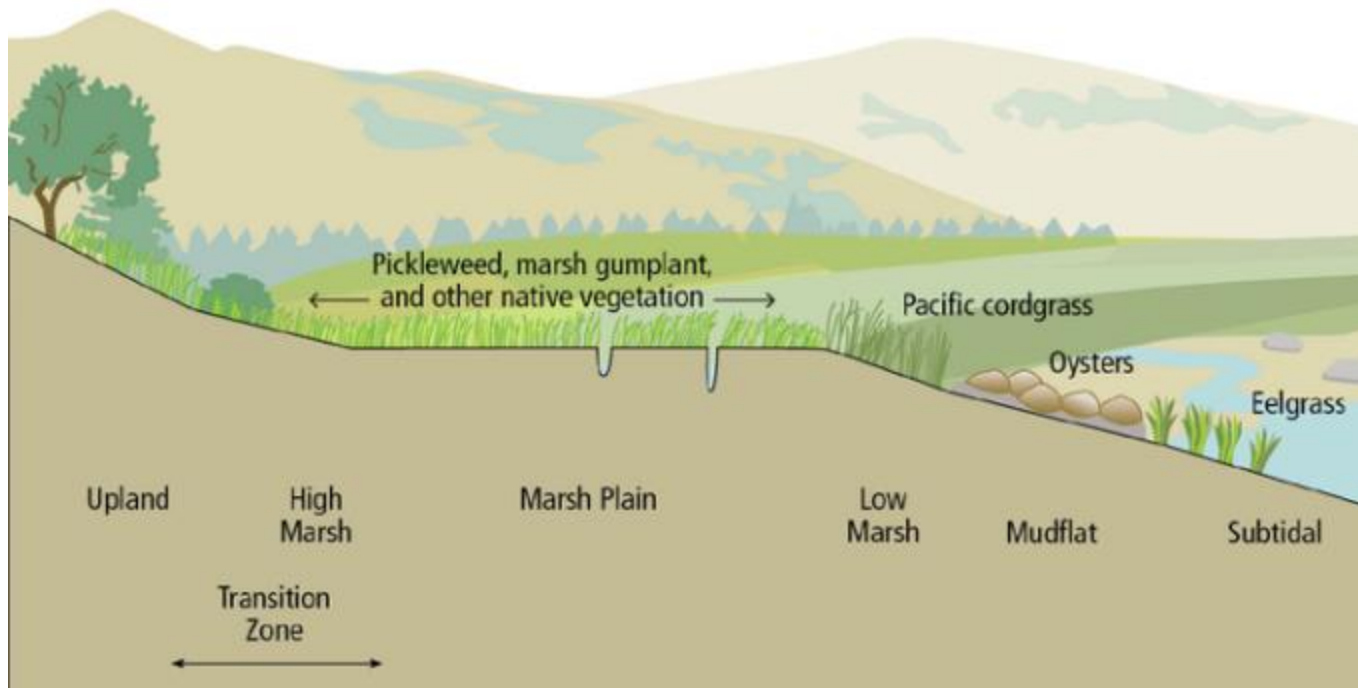
Coastal Conservancy

Delta Conservancy
Delta Stewardship Council
EBRPD
NOAA
Point Blue
SFEI
USACE
USEPA
BAFPAA
Water Board
USFWS
BCDC
DFW
DWR
EBDA
NPS
SFBJV
SFEP
Suisun RCD
URS

Sam Schuchat, Chair (Nadine Peterson)

*Kristal Davis-Fadtke
Marina Brand
Brad Olson (Chris Barton)
Becky Smyth (Korie Schaeffer)
Grant Ballard (Julian Wood)
Robin Grossinger (Lester McKee)
Tom Kendall (Fari Tabatabai)
Sam Ziegler (Luisa Valiela)
Carol Mahoney (C Morrison)
Andree Greenberg (N Feger)
Anne Morkill
Joe LaClair
Carl Wilcox
Erin Chappell
Michael Connor
Kristen Ward
Beth Huning
Judy Kelly
Steve Chappell
Mike Monroe*

Restore COMPLETE SYSTEMS



MEANS
RESTORING

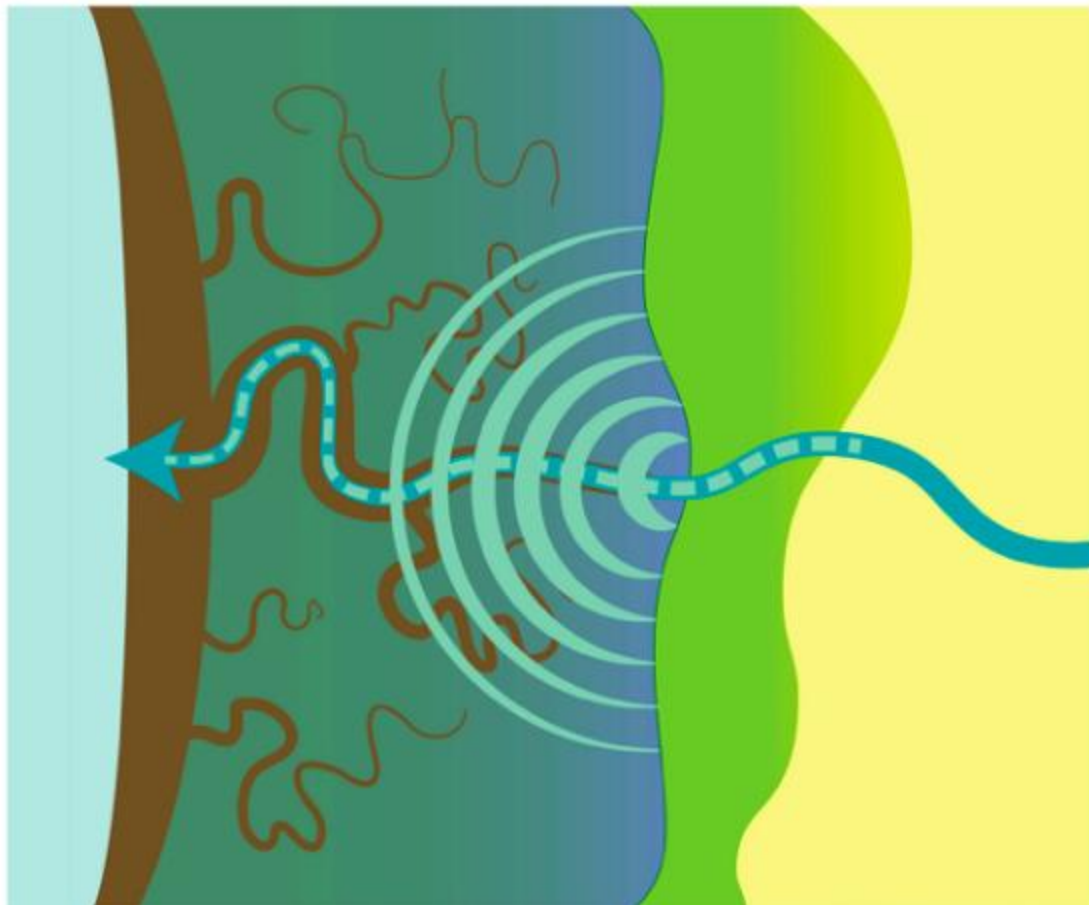
PROCESSES

NOT JUST
PLACES

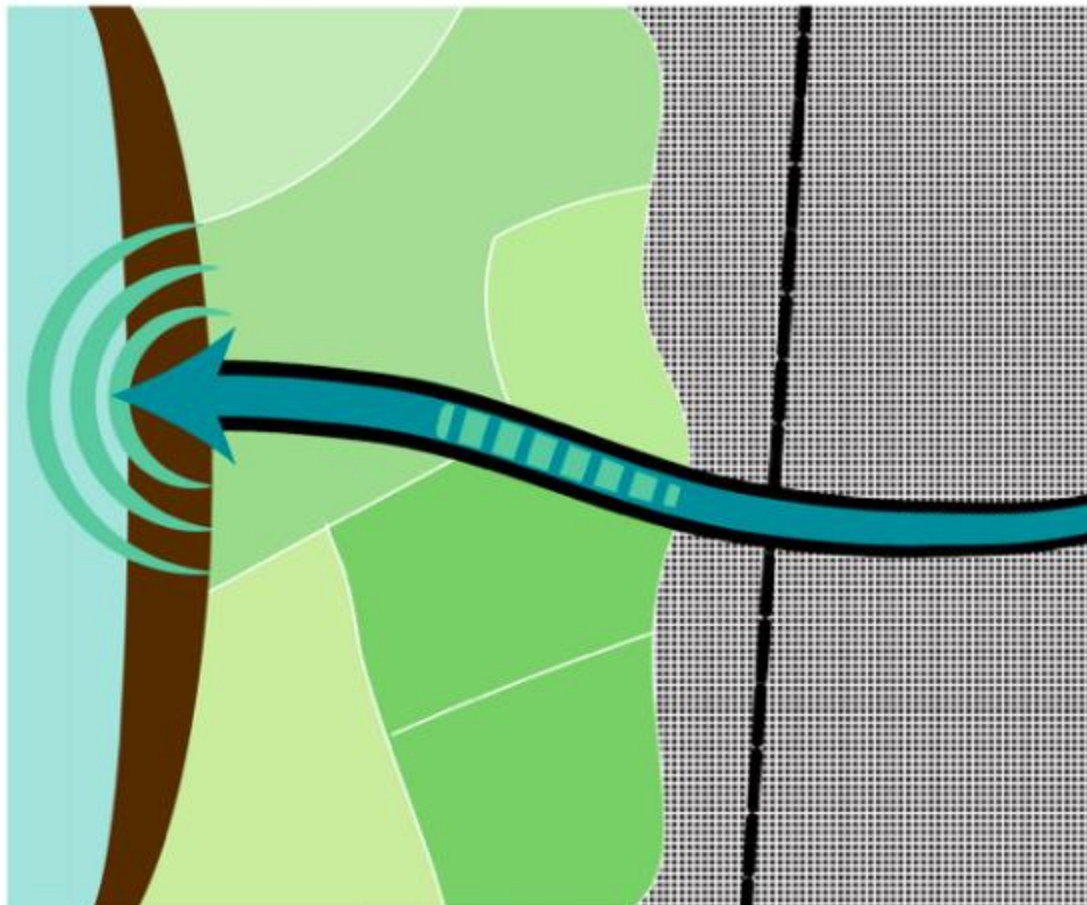
COURTESY PETER BAYE



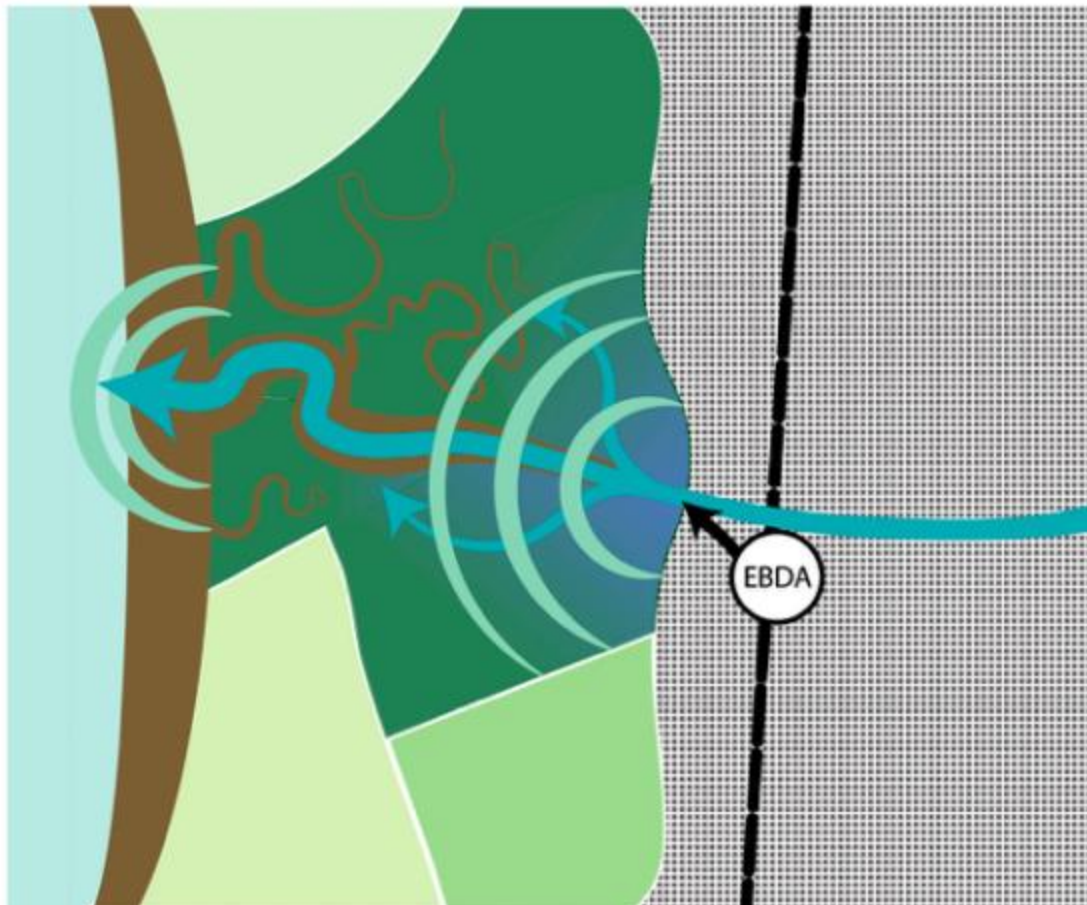
HISTORICAL



MODERN



FUTURE







San Francisco Bay Restoration Authority



Shoreline Adaptation Atlas

capture
Carbon sequestration
Manage wildfire risk
Biodive



ADAPTATION PLANNING USING NATURE'S BOUNDARIES

SAN FRANCISCO BAY SHORELINE ADAPTATION ATLAS

Julie Beagle, SFEI and Laura Tam, SPUR

Jeremy Lowe, Katie McKnight, Sam Safran, Letitia Grenier, SFEI



Photo by Shira Bezael,
SFEI

SFEI | AQUATIC
SCIENCE
CENTER

 **SPUR**

Funding: S.F. Bay Regional Water Quality Control Board

With additional funding from the Bernard and Anne Spitzer Charitable Trust, the Marin Community Foundation, the Seed Fund, the Gordon and Betty Moore Foundation, and Google

Sea level rise is happening



Photo by Shira Bezalel,
SFEI

Adapting to sea level rise will require big changes

Photo by Shira Bezalel,
SFEI



How these changes collectively adapt the shoreline will determine the fate and health of the Bay

Photo by Craig Howell, CC BY 2.0



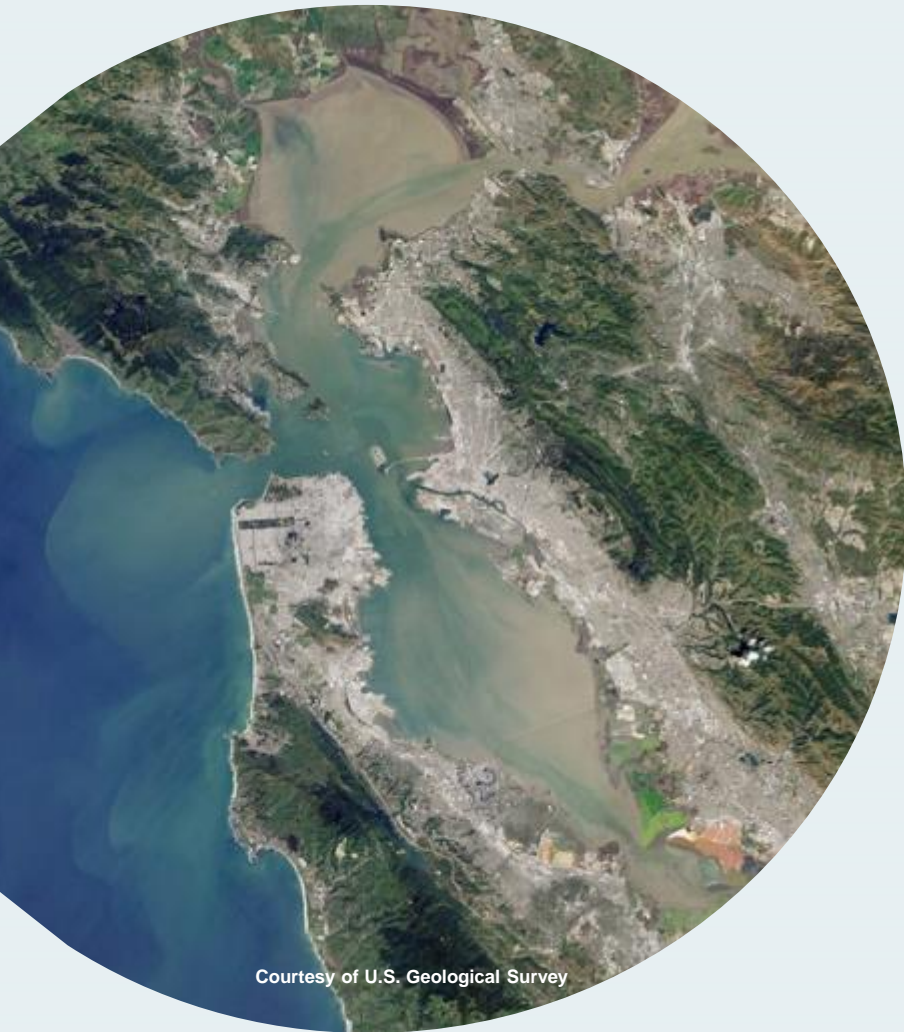
A science-based framework is essential to identify effective adaptation strategies....

CC BY 2.0



...that are appropriate for their particular settings and that take advantage of natural processes.

SFEI



Courtesy of U.S. Geological Survey

In this urbanized estuary...

- The Bay and shoreline are **heterogeneous and dynamic**









Courtesy of Google Earth

SFEI



Courtesy of U.S. Geological Survey

In this urbanized estuary...

- The Bay and shoreline are **heterogeneous and dynamic**
- There is **no one-size-fits-all approach** for SLR adaptation

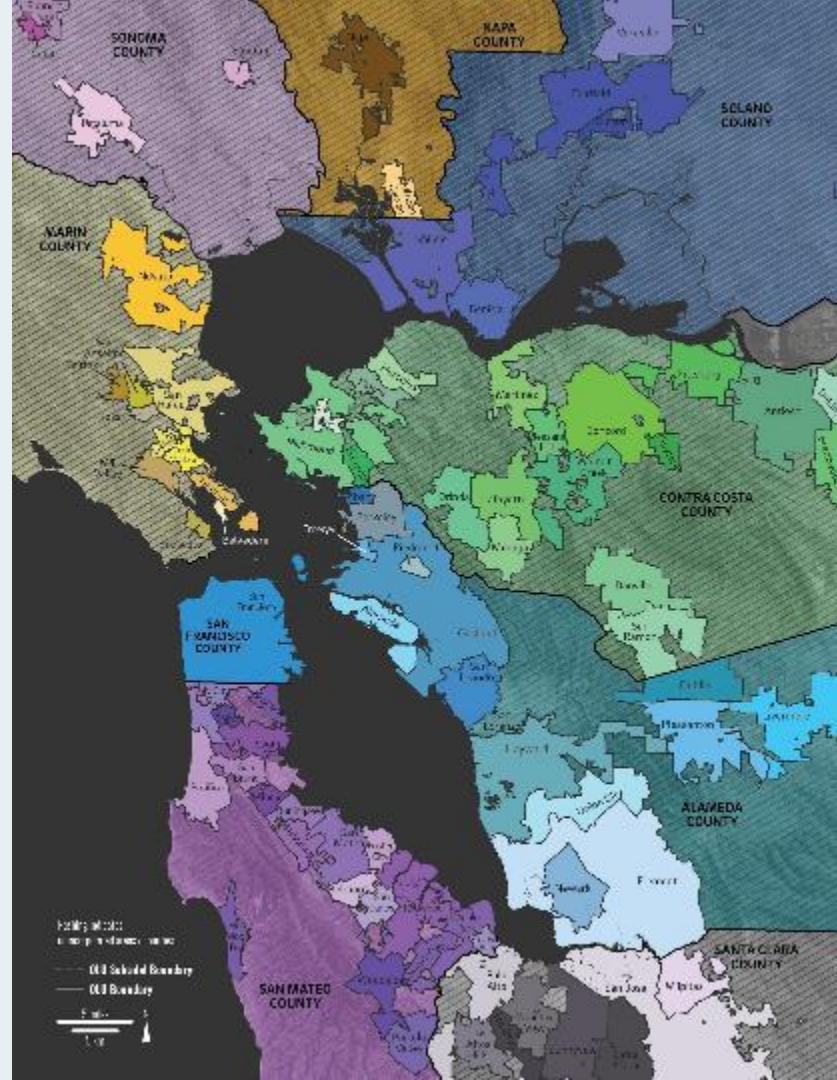


Courtesy of Google Earth

SFEI

Traditional jurisdictions

- 9 counties
- 101 cities
- Multiple special districts
- Regulatory jurisdictions
- Frontline communities in low-lying areas



Sea-level rise
will not stop at
city boundaries.





Photo by: Press Democrat

SFEI



Addressing this challenge by:

- Dividing up the Bay into manageable units that respond to the **physical and ecological processes**
- Mapping **suitability for nature-based adaptation measures**
- **Integrating across the land-water divide**, and connecting bayside measures with landside measures



Courtesy of Google Earth



STEP 1

**Plan using
nature's
boundaries**

*(instead of traditional
boundaries)*

STEP 2

**Identify
adaptation
measures that
could work well
in a given place**

*(and use nature as much
as you can)*

STEP 3

**Use when
bringing
stakeholders
together to
envision a
resilient future**

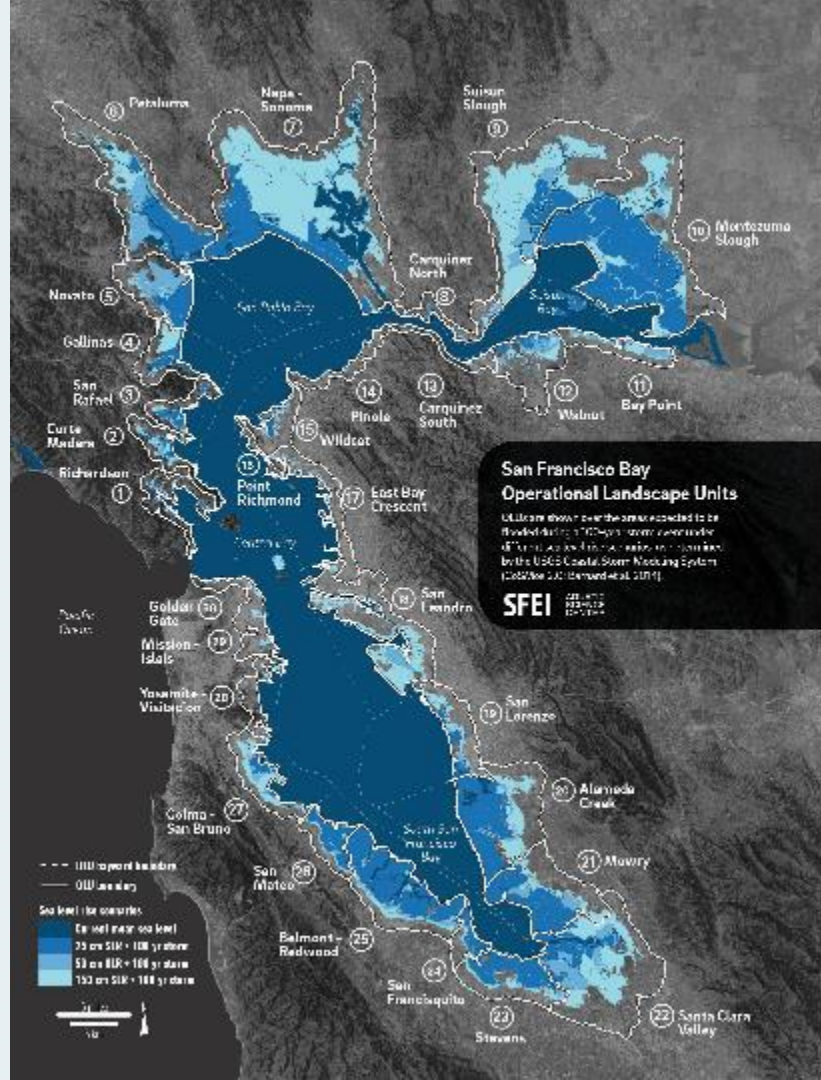
Nature's Boundaries

Operational Landscape Units

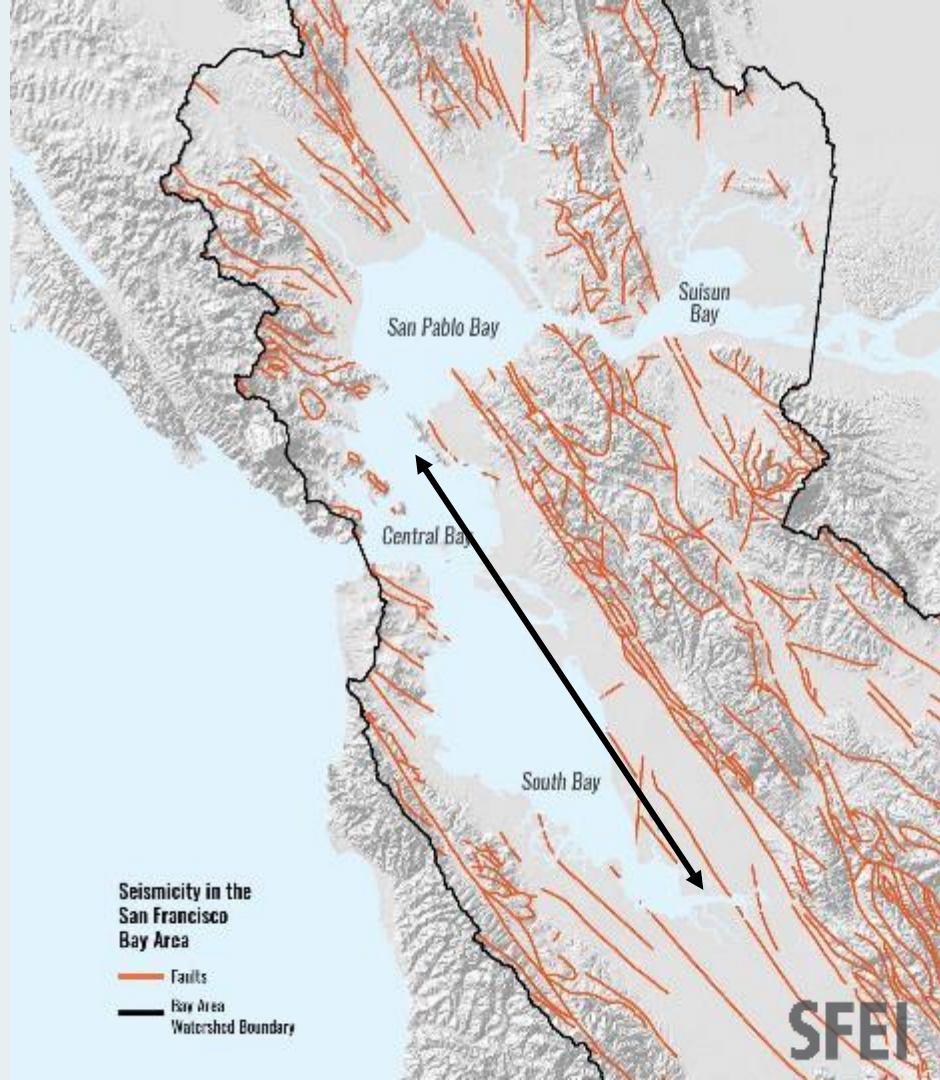
Areas with shared geophysical and land use characteristics *suited for a particular suite of nature-based measures*

- *Bigger than a project*
- *Bigger than a City*
- *Smaller than a County*

SFEI

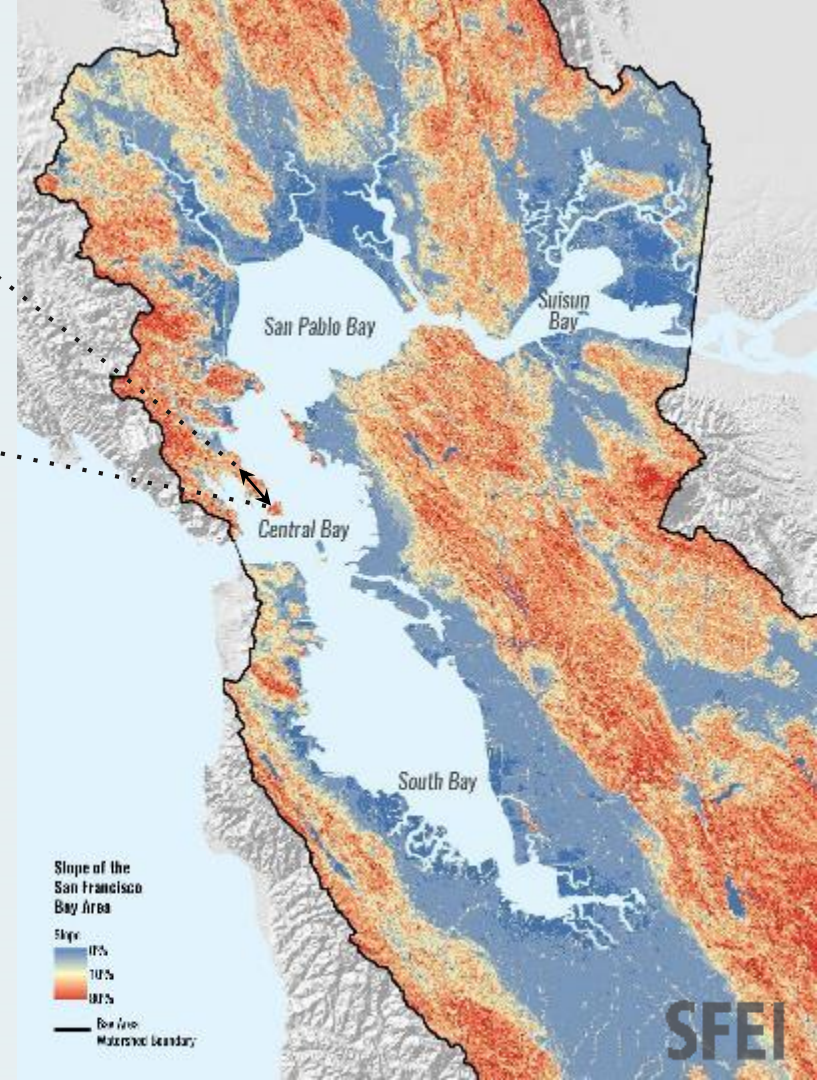
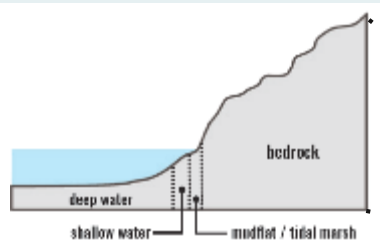


Faults & Topography



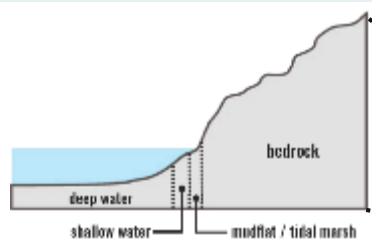
Geomorphic types

1 Headlands & small valleys

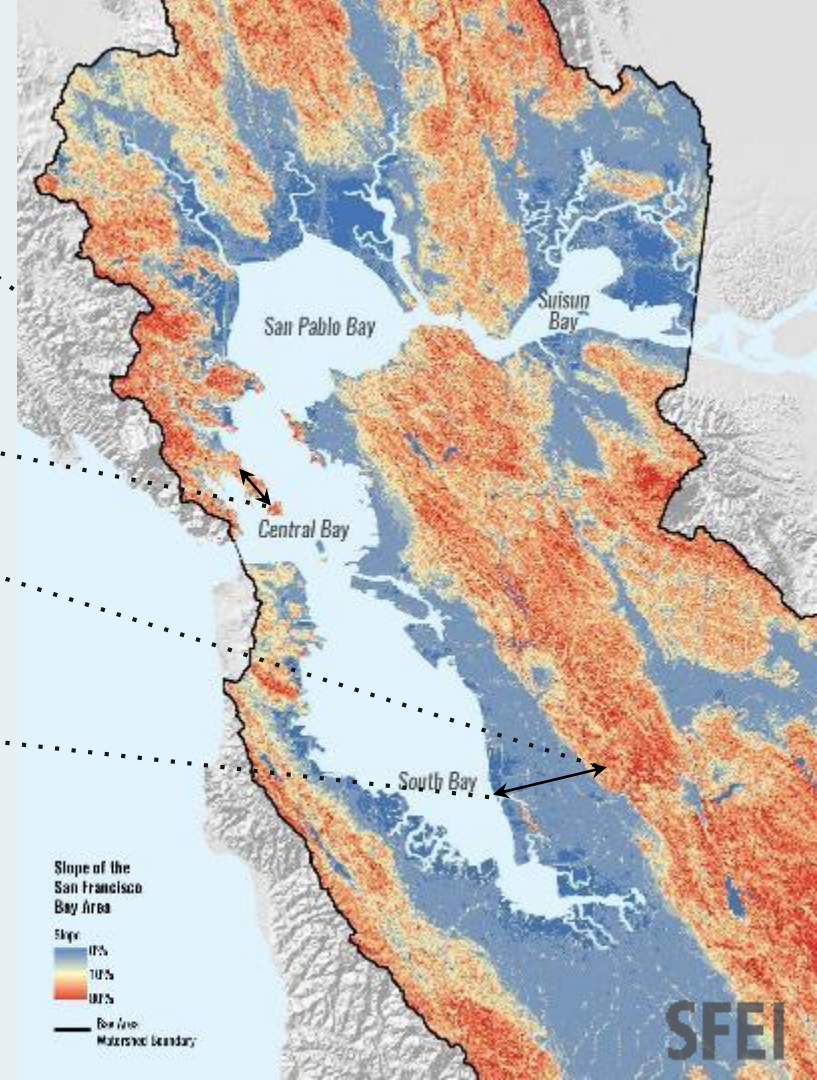
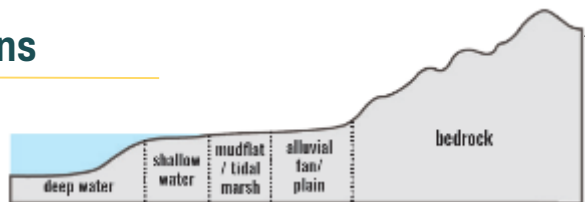


Geomorphic types

1 Headlands & small valleys



2 Alluvial fans & plains



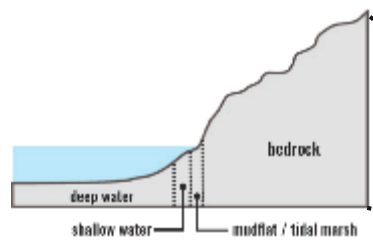
Surficial Geology

USGS

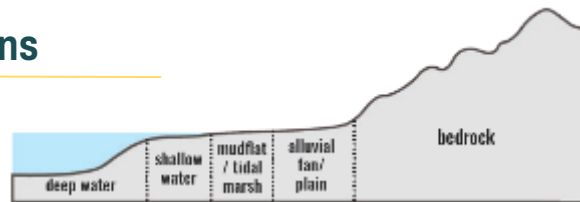
- 
- A detailed surficial geology map of the San Francisco Bay Area, showing various geological units in different colors. The map includes a network of rivers and streams, and a dashed white line indicating a specific geological boundary or feature. The legend on the left identifies the following units:
- Holocene Bay Mud
 - Fine-grained Holocene Alluvium
 - Coarse-grained Holocene Alluvium
 - Late Pleistocene Alluvium
 - Holocene beach and dune sand
 - Franciscan Assemblage
 - Great Valley Sequence
 - Merritt Sands

Geomorphic unit types

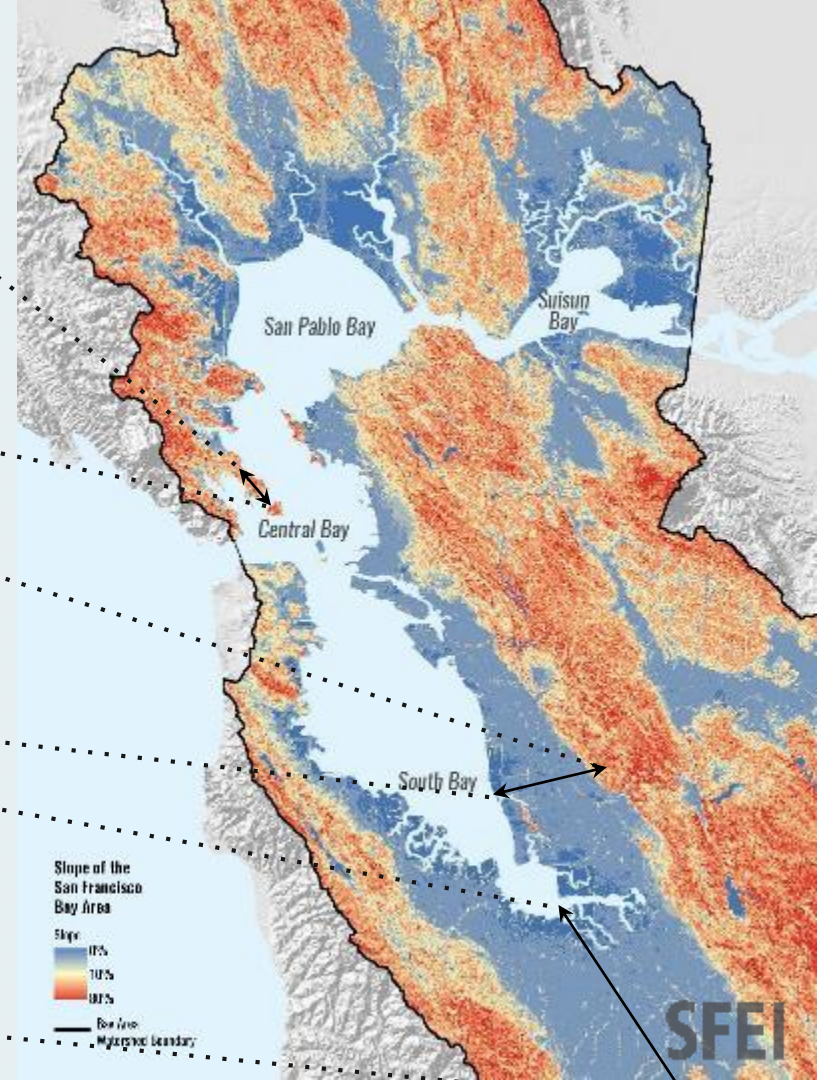
1 Headlands & small valleys



2 Alluvial fans & plains



3 Wide alluvial valleys



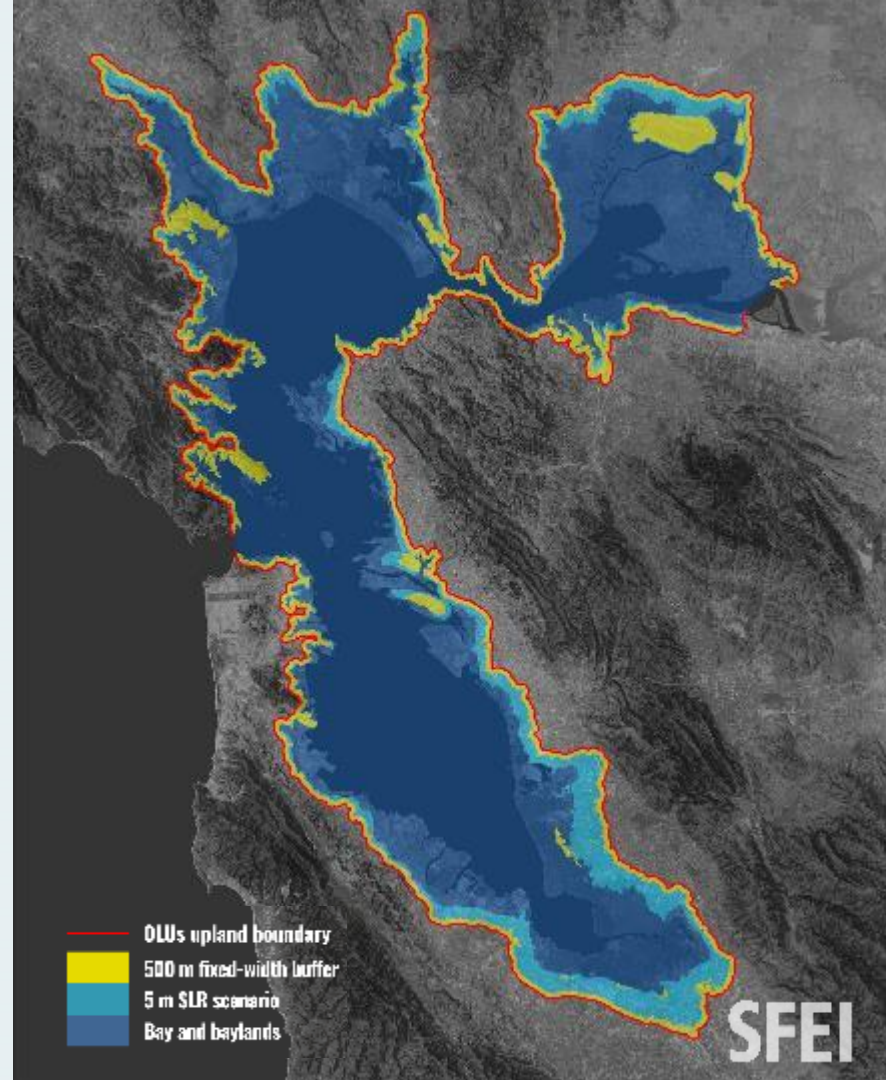


Courtesy of Google Earth

SFEI

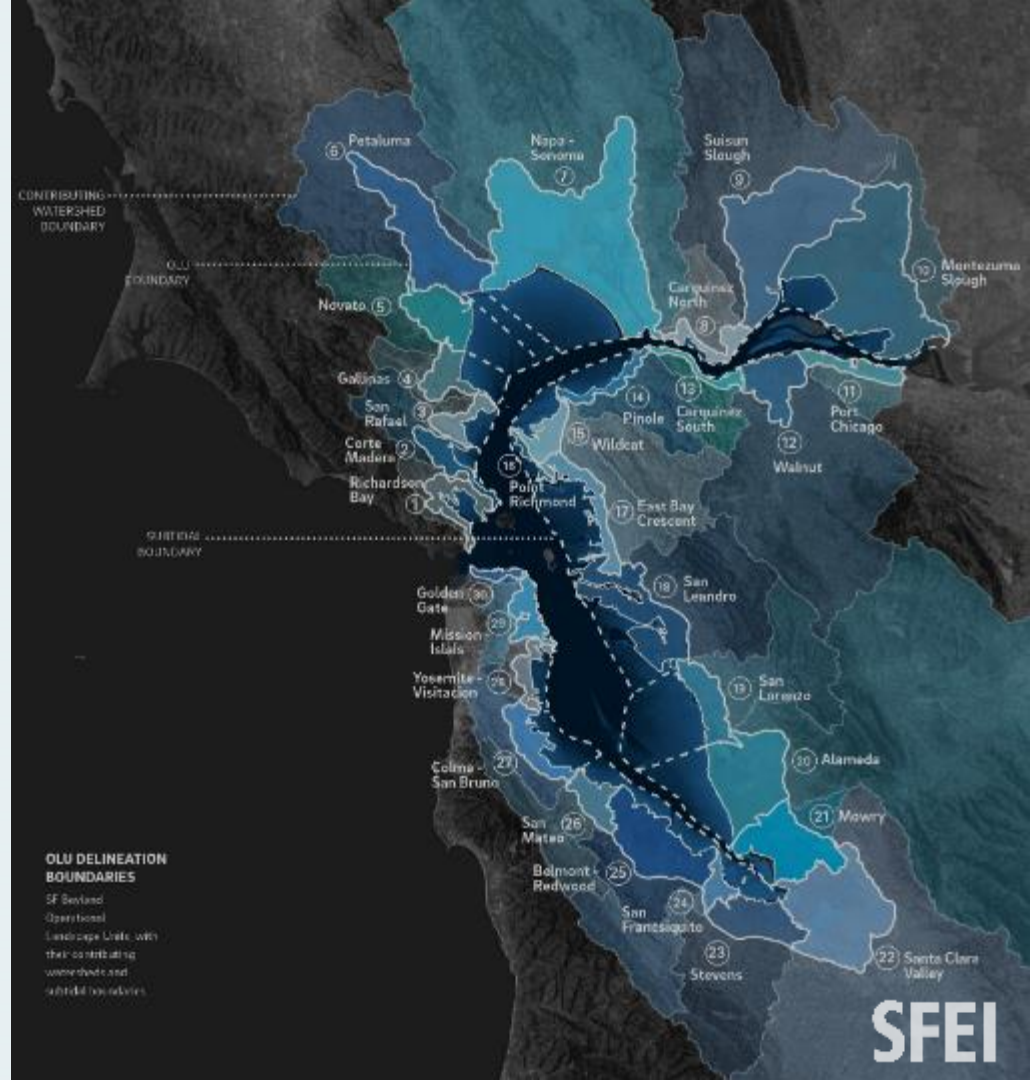
Area of analysis

- **Back boundary**
 - Baylands + 5 m SLR + transition zone with SLR
- **Side boundaries**
 - Drainage divides, tidal sheds, sewer sheds



Data inputs

- Defined by geomorphic units & bathymetry
- Characterized by
 - Physical and ecological factors
 - Built environment patterns
 - Key vulnerabilities

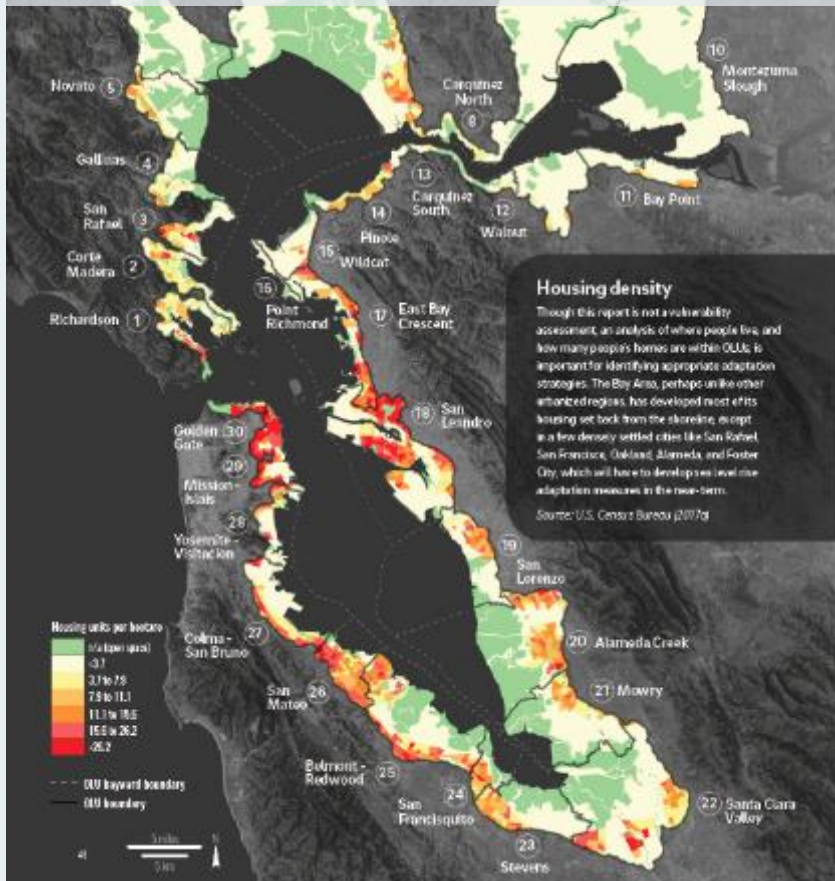


Shoreline characteristics

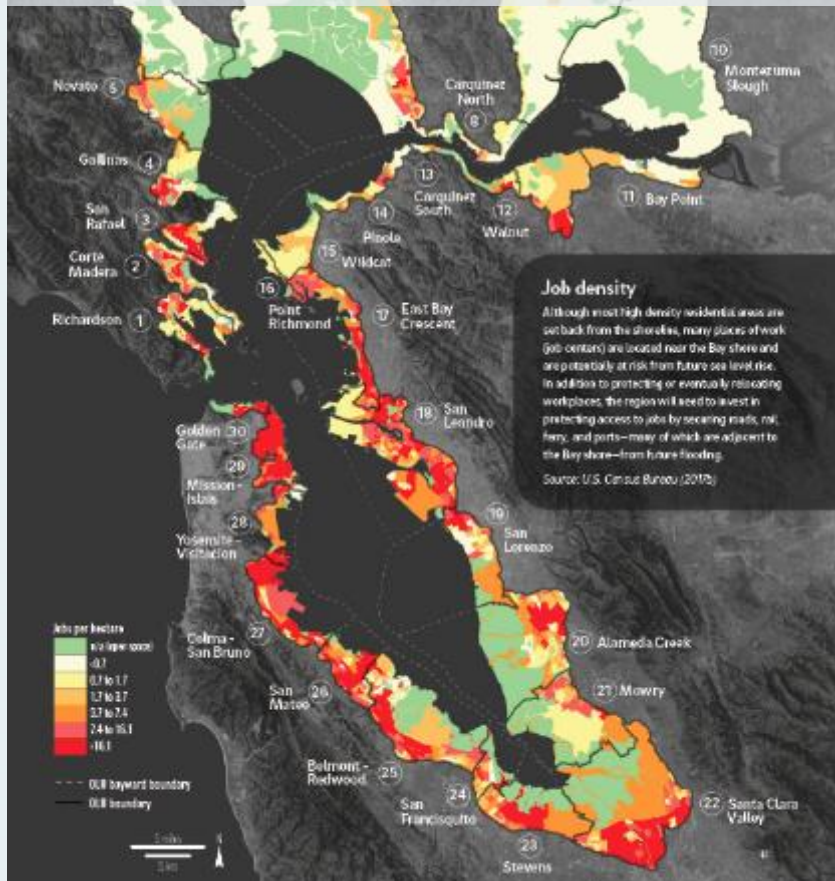
Tidal range



Housing density



Job density





STEP 1

**Plan using
nature's
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*(instead of traditional
boundaries)*

STEP 2

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*(and use nature as much
as you can)*

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**Use when
bringing
stakeholders
together to
envision a
resilient future**

Photo: ESA



SFEI

Photo: Mark Taylor

Wave overtopping



King tides

7.12 ft NAVD - King Tide, 2019
Crab Cove Alameda

Photo: Mike Lowery

**Combined flooding:
creeks, tides,
groundwater**

SFEI

Pairing problems with nature-based measures

PROBLEM (for example)	CAUSE	EXAMPLE MEASURE
Wave overtopping or erosion of levee with wide foreshore	Large waves reach levee	Marsh, fine beach, horizontal levee
Combined flooding	Loss of floodplain	Retention basins, setback levee
Loss of marsh area	Wave erosion of scarp	Coarse beach, oyster reef
Subsided areas behind levee	Diking and draining of marshes	Reconnect to creeks, warping



Photo by Shira Bezalel

What are the benefits of nature-based adaptation?

- Multiple benefits
 - Clean water
 - Flood risk management
 - Food web and wildlife
 - Recreation and scenery
- Costs less
- More adaptable over time

Adaptation measures

Nature-based measures

- Nearshore reefs
- Submerged aquatic vegetation (eelgrass)
- Beaches (sand, cobble, shell)
- Tidal marshes
- Polder management
- Ecotone levees
- Migration space preparation
- Creek-to-bayland reconnections
- Green stormwater infrastructure

Regulatory, financial, policy tools

- Zoning and overlay zones
- Setbacks, buffers, and clustering
- Building codes and building retrofits
- Rebuilding and redevelopment restrictions
- Conservation easements
- Tax incentives and special assessments
- Geologic Hazard Abatement District
- Transfer of Development Rights
- Buyouts

What is in the report

NATURAL AND NATURO-CASCO MEASURES

Submerged aquatic vegetation

COASTAL RISKS MANAGED

OTHER ECOSYSTEM SERVICES

- Ecosystem - Food supply
- Climate regulation
- Water quality improvement
- Recreation
- Other natural services

IMPACT ON SHORELINE

Protect

LOCATION WITHIN THE BAY

Shallow

Medium

Deep

ECOSYSTEM FUNCTIONS

Reduce erosion, trapping and stabilizing the sediments. SAV beds provide structure and habitat for a variety of organisms. Angled posts, girders, and other structures on the vegetated closely, which fish feed on the algae and plants. It is known that the vegetated supports. Some fish use the vegetated as nursery habitat for larvae, such as juvenile bay anchovy that pass through their life cycle.

POLICY CONSIDERATIONS

Developing subtidal for habitat for fish and other organisms may require additional, which requires permits from UMRB, BCC and the Water Board. If fish or other life species may be affected by these structures, consultation with state and federal wildlife agencies, and appropriate management, may be needed.

Areas suitable as suitable for submerged aquatic vegetation (SAV) beds were derived from empirical models developed by the University of California, San Diego (UCSD) and the University of California, Santa Cruz (UCSC). Other species of submerged aquatic vegetation may be present in other areas, but are not included in this analysis. The analysis is based on the Central Bay area with the following characteristics: current velocity, sand transport, and sedimentation (see Table 2) (Subtidal Goals 2010). Other species of submerged aquatic vegetation may be present in other areas, but are not included in this analysis. The analysis is based on the Central Bay area with the following characteristics: current velocity, sand transport, and sedimentation (see Table 2) (Subtidal Goals 2010). Other species of submerged aquatic vegetation may be present in other areas, but are not included in this analysis. The analysis is based on the Central Bay area with the following characteristics: current velocity, sand transport, and sedimentation (see Table 2) (Subtidal Goals 2010).

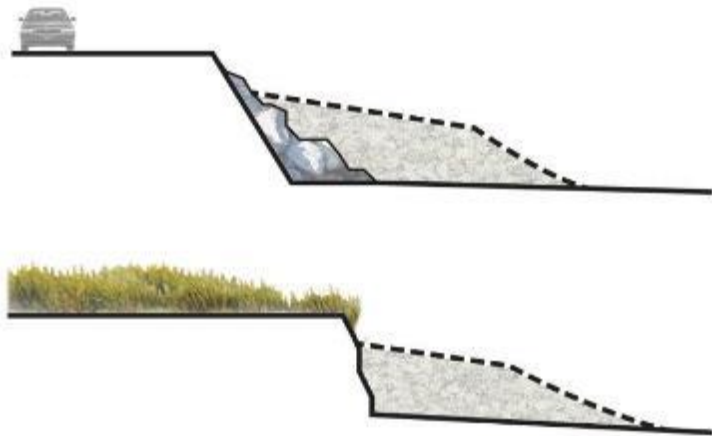
For each measure:

- Landscape configuration and process guidelines
- Ecosystem functions
- Coastal risks managed
- Ecosystem services
- Policy considerations
- Examples

Beaches in S.F. Bay

San Francisco Bay had an estimated **27 miles of beaches** along its shoreline in the 1800s.

Beaches act **as a natural defense against sea level rise** by knocking down waves and protecting infrastructure near the shoreline from erosion.



Substrate Types



Examples of Existing Beaches



Arambaru beach enhancement project

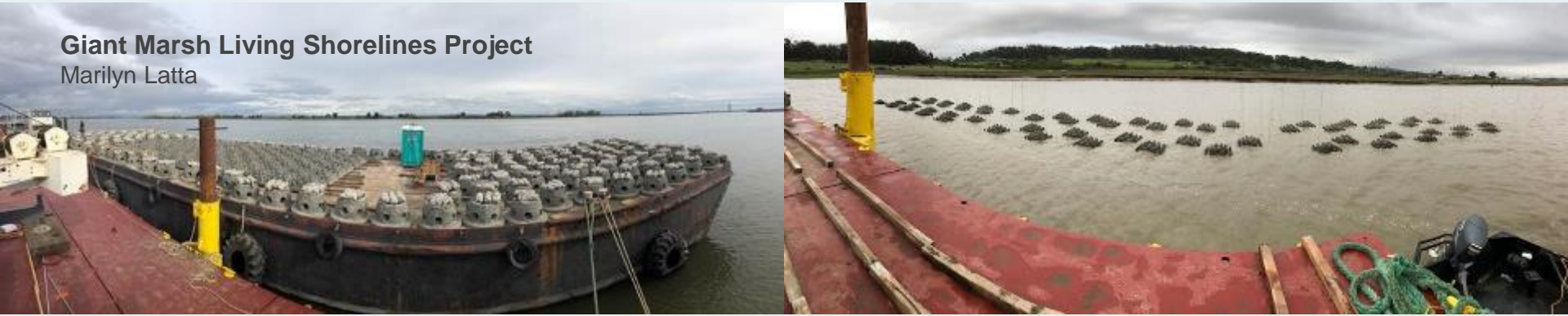
Peter Baye, Roger Leventhal



Living shorelines: oyster reefs

Giant Marsh Living Shorelines Project

Marilyn Latta



Coastal storm-surge barriers: tidal marsh & horizontal levee



The Horizontal Levee

Courtesy of The Bay Institute

Relative elevations

Compares absolute elevation of land with local water levels & tidal range:

$$z^* = \frac{z - MSL}{MHHW - MSL}$$

MHHW = 1
MSL = 0
MLLW = -1

Elevation range (supratidal)

Upland zone



above 200 cm SLR zone

Migration space / Transition zone



within 200 cm SLR zone

Elevation range (tidal, z^*)

Tidal marsh zone



1.02 to 1.38 (-MHHW to -HAT)



0.75 to 1.02 (-MHW to -MHHW)



-0.14 to 0.75 (-MSL to -MHW)

Unvegetated tidal flat zone



-1.00 to -0.14 (MLLW to -MSL)

Subtidal zone



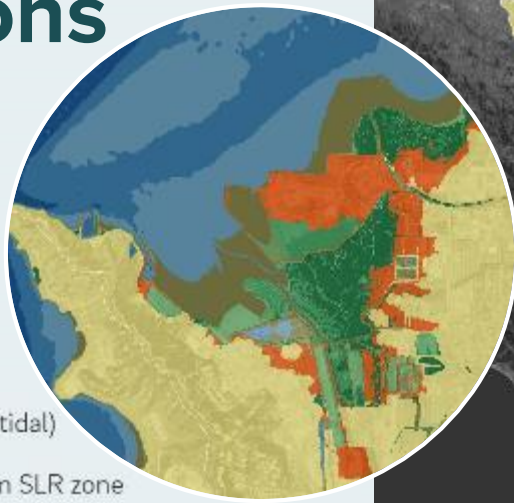
-1.00 to -2.00 (MLLW to 2x MLLW)



-2.00 to -4.00 (2x MLLW to 4x MLLW)



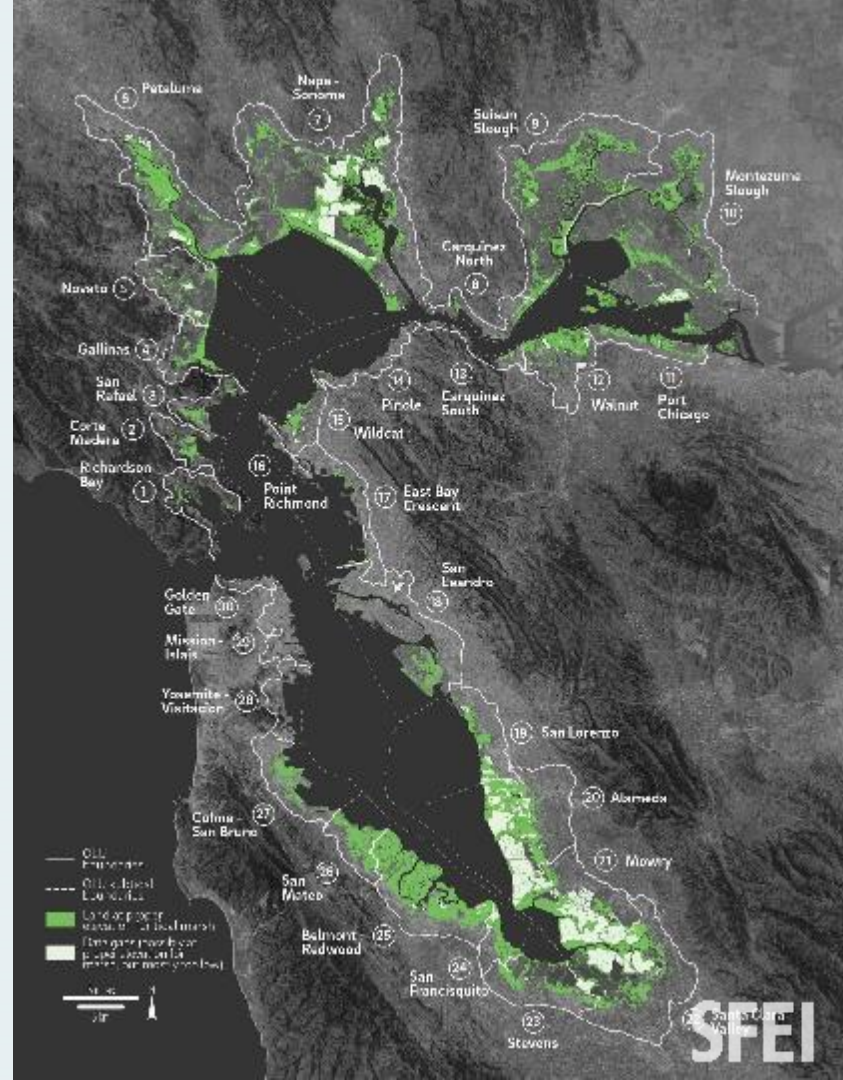
< -4.00 (<4x MLLW)

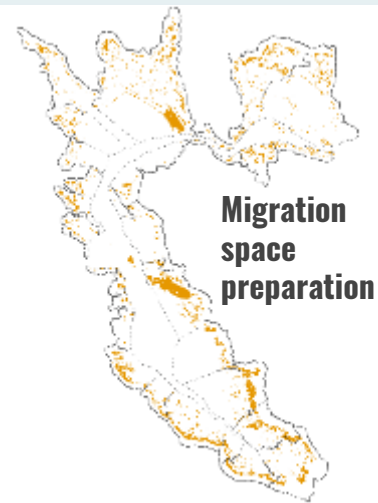
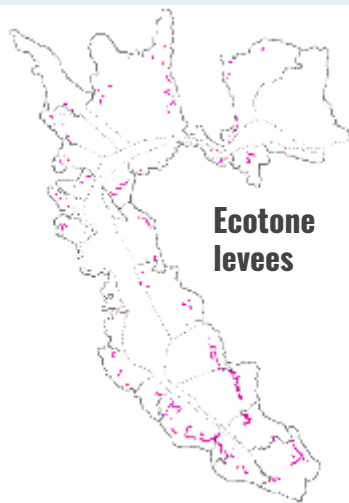
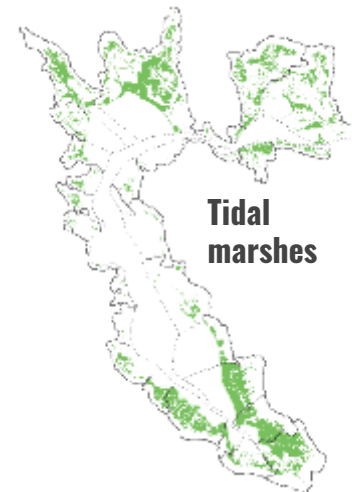
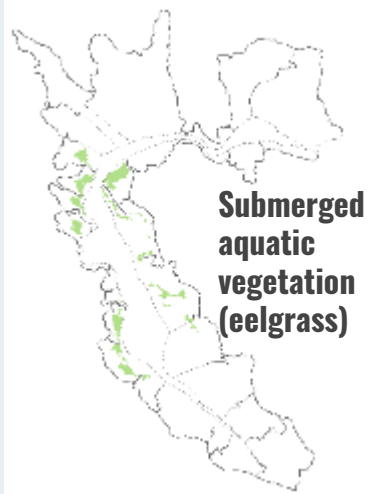
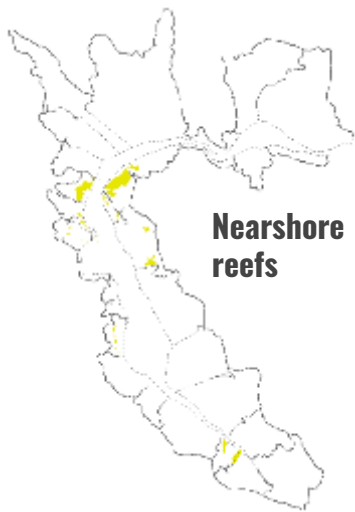


Marsh restoration

Methods:

- Identify areas currently at the right elevation to potentially support tidal marshes using z^* (\sim MSL and \sim HAT)
- Assess width of marsh needed to knock 100-year waves down to \sim 1 ft (0.3 m)





Suitability of nature-based measures

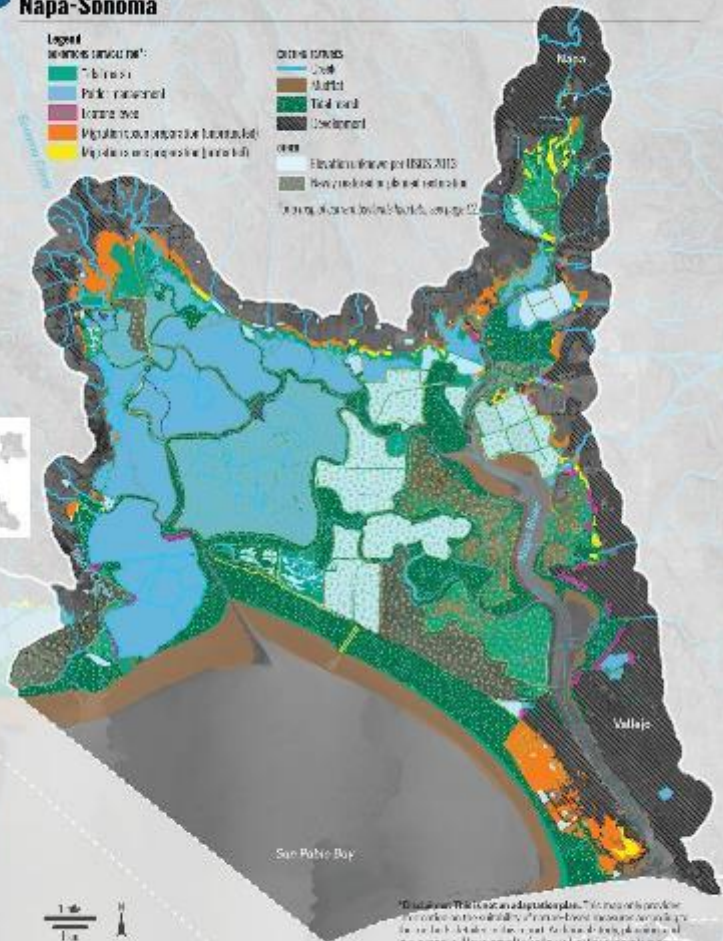
Suitability Rating

-  Limited suitability
-  Some suitability
-  High suitability

	Nearshore reefs (p. 63)	Submerged aquatic vegetation (eelgrass) (p. 68)	Beaches (p. 72)	Tidal marshes (p. 75)	Polder management (p. 50)	Ecotone levees (p. 64)	Migration space preparation (p. 66)
1. Richardson	●	●	●	◐	○	◐	○
2. Corte Madera	●	●	●	◐	◐	◐	◐
3. San Rafael	●	●	●	◐	◐	◐	○
4. Gollins	◐	●	○	●	●	◐	●
5. Novato	○	○	○	●	●	◐	●
6. Petaluma	○	○	○	●	●	○	●
7. Napa - Sonoma	○	○	○	●	●	◐	●
8. Carquinez North	○	○	○	●	○	◐	●
9. Suisun Slough	○	○	○	●	●	◐	●
10. Montezuma Slough	○	○	○	●	●	○	●
11. Bay Point	○	○	○	●	●	◐	●
12. Walnut	○	○	○	●	●	●	●
13. Carquinez South	○	○	○	◐	○	●	●
14. Pinole	●	○	●	◐	○	●	○
15. Wildcat	●	●	●	●	◐	●	●
16. Point Richmond	●	●	●	○	○	○	○
17. East Bay Crescent	●	●	●	◐	○	●	○
18. San Leandro	○	●	●	◐	◐	○	○
19. San Lorenzo	○	●	●	●	◐	●	◐
20. Alameda Creek	○	○	●	●	●	●	●
21. Mowry	○	○	○	●	●	●	●
22. Santa Clara Valley	○	○	○	●	●	●	●
23. Stevens	◐	○	○	●	●	◐	◐
24. San Francisco	●	○	○	●	◐	●	◐
25. Belmont - Redwood	○	○	●	●	●	●	○
26. San Mateo	○	●	●	◐	◐	◐	○
27. Colma - San Bruno	○	●	●	◐	○	◐	○
28. Yosemite - Visitation	●	●	●	○	◐	○	○
29. Mission - Islais	○	●	●	○	○	○	○
30. Golden Gate	○	○	●	○	○	○	○

7 NATURE-BASED ADAPTATION OPPORTUNITIES MAP
Napa-Sonoma

- Legend**
- SONOMA COUNTY OLI:**
- Tribaries
 - Parks (managed)
 - Local levee
 - Migrations/avoidance (unavoidable)
 - Migrations/avoidance (avoidable)
- OTHER:**
- Creek channels
 - Wetland
 - Tidal wetland
 - Development
 - Other
 - Elevation change per USGS 2012
 - Non-vegetated riparian wetlands
 - Topography (contour interval: average 20')



*Disturbance that creates adaptation options. *Some of the products are color-coded with symbols of nature-based measures already in place. *Adaptation is the result of a broad range of activities and may involve different products and/or different opportunities.

7 NAPA / SONOMA

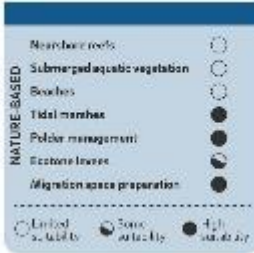
Nature-based Adaptation Measures

In the Napa-Sonoma OLI there has been significant landscape-scale migration and increases such as the Napa-Sonoma Bay Polders and opportunities to restore large connected patches of tidal marsh in the remaining flood by-lands closer to Sonoma Creek. Road and rail corridors that are not suitable for agricultural or other productive uses are candidates for restoration to the wetlands they would be adding levees to protect them from flooding; their creek crossings are narrow, and the original wetland habitat is in the transition zone. All of the original wetland habitat is in the transition zone, and preparing migration space for the marsh to move inland as sea level rises. The majority of the original wetland habitat is in the transition zone, and preparing migration space for the marsh to move inland as sea level rises. The majority of the original wetland habitat is in the transition zone, and preparing migration space for the marsh to move inland as sea level rises. Much of the existing tidal marsh is adjacent to the creeks and is disconnected from undeveloped migration space by large and deep polders such as Sluggs Island. If raised to inter-tidal elevations, these polders could be connected to tidal marsh. However, the amount of sediment needed is considerable and realigning the shoreline may be more feasible. Significant opportunities exist to improve the delivery of freshwater, nutrients, and sediment from Sonoma Creek and the Napa River to build better elevation control closer to upland in these subsided by-lands, and to reduce flooding issues. There are also opportunities for widening the bridge crossings at Sonoma Creek and Tobey Creek if Highway 37 is raised on some combination of embankment and pilings. Levee level creation is less critical in this OLI due to limited presence of development in need of protection, but levee levees could be incorporated into the design of embankments to raise Highway 37 or other roads.

Other Adaptation Opportunities

Like Patukama, the very large Napa-Sonoma OLI - by far the largest in the region - has a wide range of adaptation opportunities. It is a candidate for adaptation measures that allow flooding to occur, and that transition from recreational and agricultural uses to habitat or ecological uses over time, through restoration work, transition from agriculture, and restoring public access. This OLI is a good place for a variety of adaptation measures, including: **Acquiring migration space** from recreational and agricultural uses to habitat or ecological uses over time, through restoration work, transition from agriculture, and restoring public access. This OLI is a good place for a variety of adaptation measures, including: **Easements, buyouts in open/protected areas** for a variety of adaptation measures, including: **Elevating roadways** to allow tidal water to flow toward formerly diked wetlands would significantly support the large scope of restoration possible in this OLI.

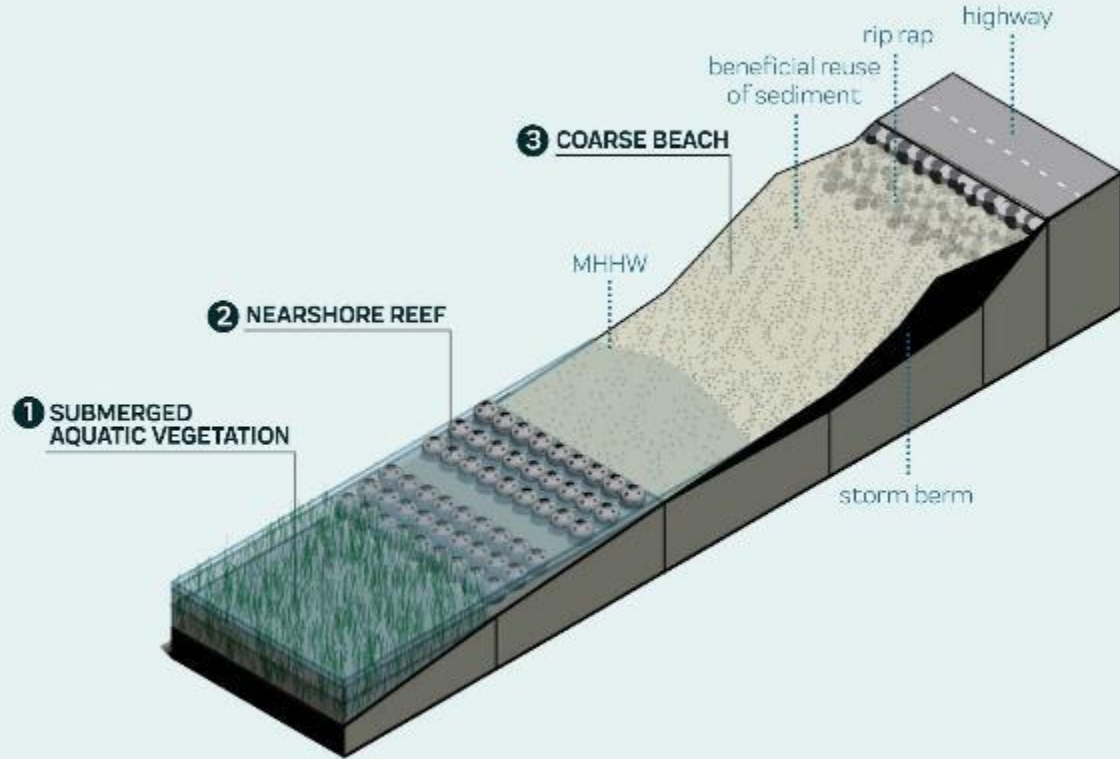
Polder management
Marsh Restoration
Migration Space
Creek connections



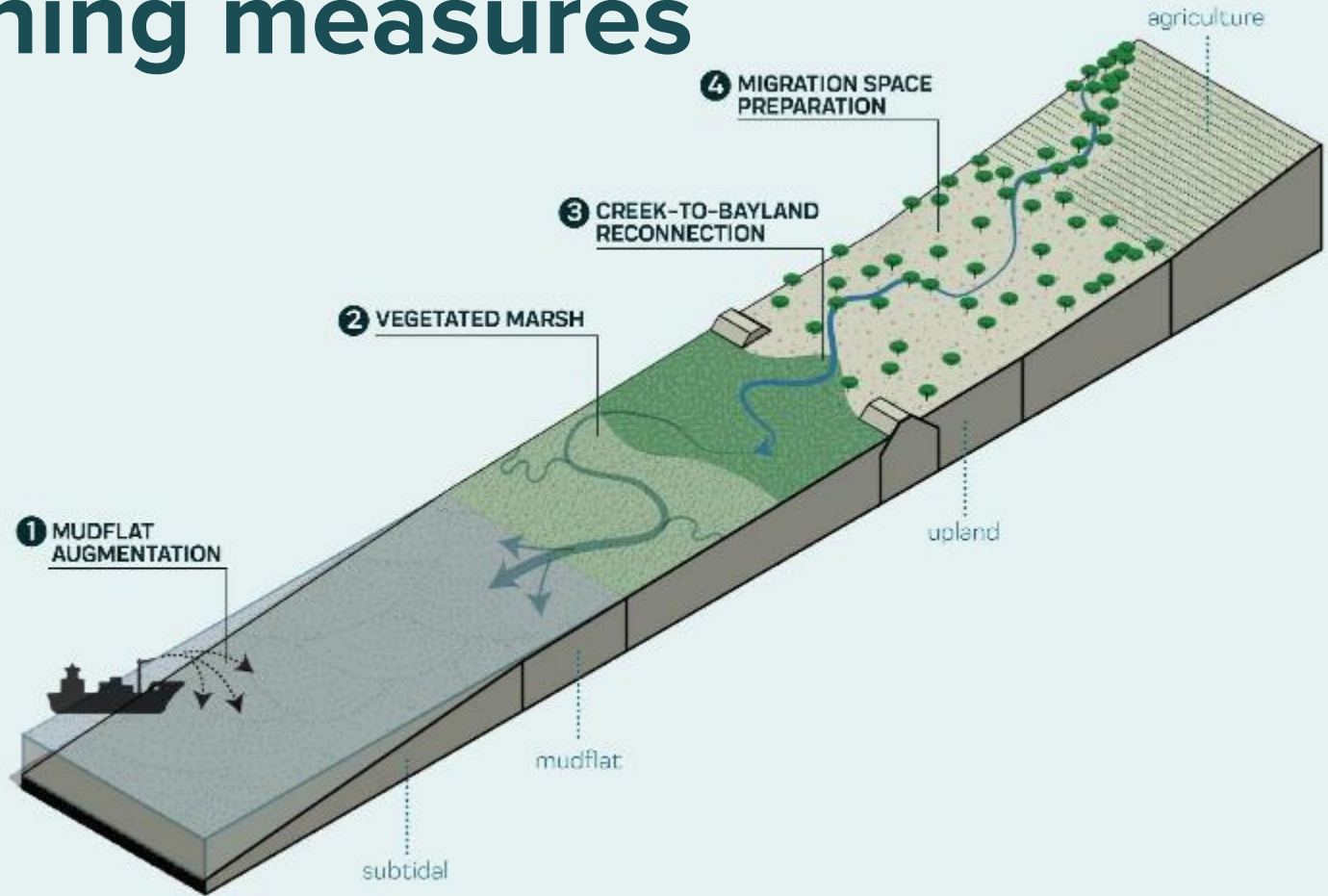
Aerial view looking downstream of the Napa River towards the Napa-Sonoma wetlands through the WestCountry Media LLC (NY OLI)



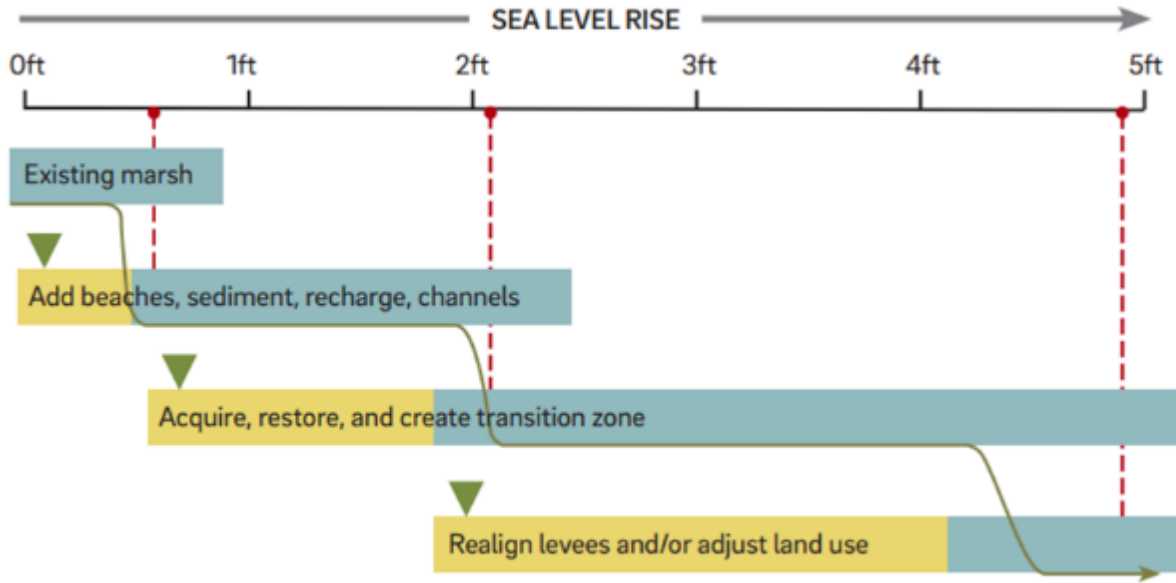
Combining measures



Combining measures



Adaptation pathways



KEY

- Threshold
- Decision point
- Lead time required to implement
- Timing of actions to be effective

Conceptual phasing of measures triggered by sea-level rise, rather than a chronological timeline (adapted from Goals Project 2015).



STEP 1

**Plan using
nature's
boundaries**

*(instead of traditional
boundaries)*

STEP 2

**Identify
adaptation
measures that
could work well
in a given place**

*(and use nature as much
as you can)*

STEP 3

**Use when
bringing
stakeholders
together to
envision a
resilient future**

How can this be used?

- As a toolkit to bring together stakeholders around a given shoreline unit
- A resource to assist environmental review and permitting (Bay Conservation Development Commission, Regional Water Board)
- Guidance for developers and project applicants
- Local, regional planners, and communities creating adaptation plans and policies



Who is using this?

- **Bay Conservation Development Commission** for their vulnerability analysis
- **San Mateo and Marin Counties** to gather stakeholders, begin adaptation planning, create scenarios of future shorelines
- **Local cities** for adaptation planning

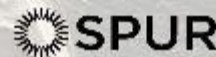


SAN FRANCISCO BAY SHORELINE Adaptation Atlas

Working with Nature to Plan for Sea Level Rise
Using Operational Landscape Units



SFEI San Francisco
Estuary Institute



THANK YOU

Goals Projects

- baylandsgoals.org

Adaptation Atlas

- sfei.org/adaptationatlas

Contact

- letitia@sfei.org



When the water crosses over (the horizontal levee)

- What is the landscape like in the **'dry land'** part of the OLU?
- What are the **land uses** that may be potentially **inundated?**
- What is the **'menu'** of available **structural, policy, financial, and regulatory** measures?









Courtesy of Google Earth

SFEI

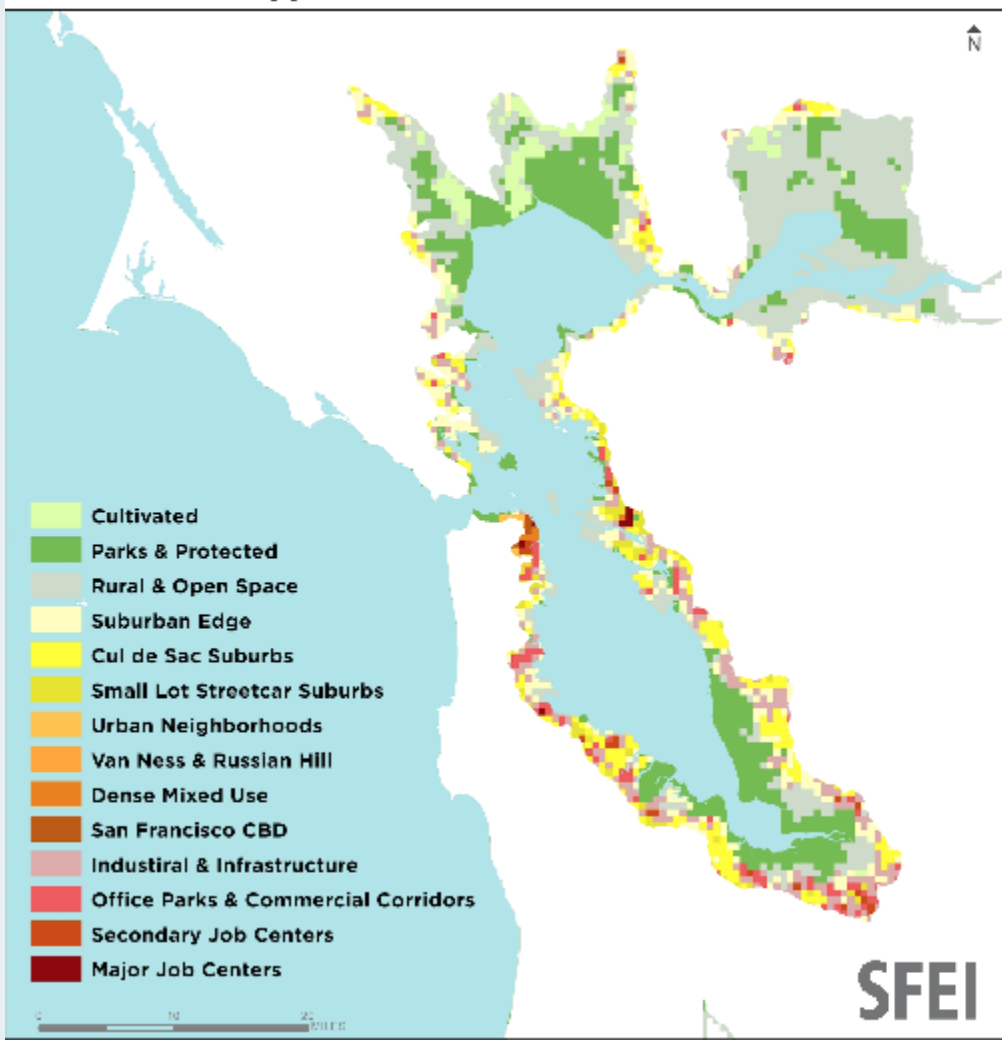
Place-types index

Five factors in characterizing land uses as place-types:

- Intersection density
- Permeability
- Housing unit density
- Job density
- Land use mix

Open space categories additionally classified using CPAD, NLCD

SPUR Place Types in OLU





Open space

Suburban edge



Urban neighborhoods

Office parks and commercial



Secondary job centers

Dense mixed use



Adaptation measures

Nature-based measures

- Nearshore reefs
- Submerged aquatic vegetation (eelgrass)
- Beaches (sand, cobble, shell)
- Tidal marshes
- Polder management
- Ecotone levees
- Migration space preparation
- Creek-to-bayland reconnections
- Green stormwater infrastructure

Regulatory, financial, policy tools

- Zoning and overlay zones
- Setbacks, buffers, and clustering
- Building codes and building retrofits
- Rebuilding and development restrictions
- Conservation easements
- Tax incentives and special assessments
- Geologic Hazard Abatement District
- Transfer of Development Rights
- Buyouts

Regulatory, financial, & policy tools

- We convened landscape architects, building engineers, and urban designers to vet suitable flood control strategies by place-type
- We used this information to suggest planning and policy measures for specific OLU's based on their land use mix, and the sequence of place-types in a transect from the shoreline landwards

POLICY AND REGULATORY MEASURES
Building codes and building retrofits

CONSTAL RISKS MANAGED

DEFINITION
 Building codes regulate construction to help developers withstand flooding. For the existing built environment, building retrofits may be imposed by ordinance. Though an orderly zone, they may be implemented by incentives instead of regulation.

LANDSCAPE CONFIGURATION, DESIGN, & PROCESS GUIDELINES
 Building codes and permit conditions can require new development to incorporate flood-resistant features, such as impact flooding. Builders can be required to elevate mechanical equipment, flood-proof ground floors, or other features to raise above the base flood elevation. New building codes may reduce the cost of future floods for building sectors or individual structures. They do not address neighborhood connectivity, ensure public safety during flooding, or help existing buildings nearby.

CO-BENEFITS
 For existing buildings, some building types—generally smaller, shorter types—can be raised up, or glass or steel, typically about a meter or more above a design flood elevation to prevent structural damage. Others can be flood-proofed with water-resistant materials. Flood vents, and for water-tight garages, can help to prevent water infiltration. Raising buildings individually does not address transportation, accessibility, or public realm flooding problems. And flood-proofing systems will eventually leak, especially if subject to frequent exposure. Benefits of this measure include aesthetic reduction in cost of future adaptation or flood response, protection of greenery values, and improved safety.

IMPACT ON SHORELINE
 Positive / Neutral / Negative

LOCATION
 Coastal / Inland

POLICY CONSIDERATIONS
 The National Flood Insurance Program requires new construction, depending on the risk level of the location, to either meet above-the-base flood elevation (BFE), flood-proofed (for nonresidential) or elevated building equipment or elevated on piles. But local governments could assist these requirements in currently unregulated areas, or increase threshold requirements so that building elevations considered below the threshold and more eligible for the program. Some Districts and New Jersey have adopted higher base flood elevations for residential and nonresidential buildings. The major concern is that these measures, if imposed on existing structures, may be imposed within congregate spaces to prevent existing buildings from paying flood tax. However, some buildings cannot be retrofitted, and in urban city active areas some buildings cannot be safely raised. Raising buildings to a higher additional nonresidential can be the same as with flood-tolerant. Finally, increasing building elevation to prevent flood-proofing may have other design implications—could affect access, pedestrian circulation, and streetscape appearance.

Retrofits to a very flexible building may only work for the short term, depending on how fast sea levels rise.

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FINANCIAL MEASURES
Transfer of Development Rights (TDR)

DEFINITION
 In a TDR program, local governments support smart growth and inland development away from high-risk areas by designing "sending" areas of "sending" areas. Through existing property owners in "sending" areas can sell development credits in exchange for a conservation easement on their property and forgoing additional development. Property owners and developers in "receiving" areas can buy credits to receive additional stories, height, or floor area. These programs create market incentives to shift development to preferred areas without "take away".

LANDSCAPE CONFIGURATION, DESIGN, & PROCESS GUIDELINES
 As one measure to address sea level rise and flooding, local governments could designate sending areas in vulnerable locations, designate receiving areas on higher ground whose development should occur, and then establish a credit market. For example, Montgomery County, Maryland, established sending areas to preserve agricultural lands and receiving areas to shift development to transportation corridors. A regional program could include one or more jurisdictions, and participating could be connected to conservation easements or development in the future once development right is sold over time. For example, a small town may sell TDRs to a city like New Jersey (inland), where a TDR program administered by a state agency could coordinate and assist a developer credit bank to transfer credits. It has previously transferred over 1,000 credits to private and public development.

POLICY CONSIDERATIONS
 TDRs may be complicated to set up and to administer, especially in an environment where "receiving" areas may be hard to find or designate. Because they are voluntary, they might not work as designed if sellers are unwilling to participate.

CONSTAL RISKS MANAGED

CO-BENEFITS
 • Reduces flood damage
 • Improves quality of life
 • Preserves scenic resources
 • Reduces risk of loss of life

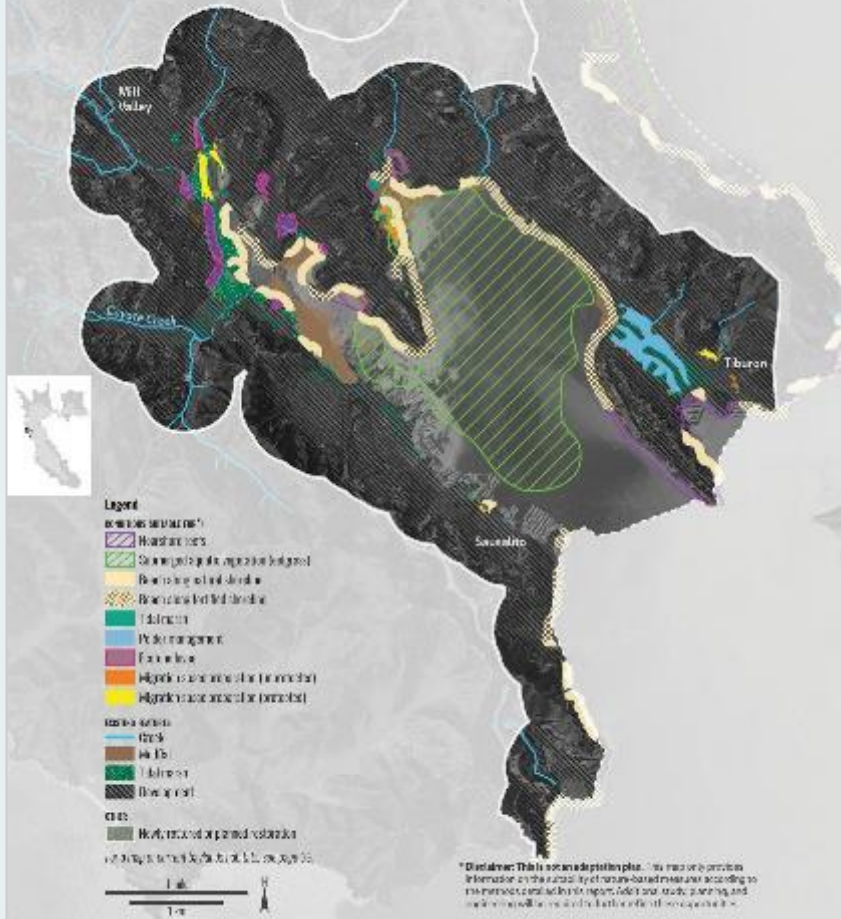
IMPACT ON SHORELINE
 Positive / Neutral / Negative

LOCATION
 Coastal / Inland

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1 NATURE-BASED ADAPTATION OPPORTUNITIES MAP
Richardson



1 RICHARDSON

Nature-based Adaptation Measures

The Richardson ODU has limited space near the Bay with steep slopes, so confining a valley that root-ties below sea level was also opportunities for nature and nature-based adaptation such as marshes. The mouth of Coyote Creek is an area prone to flooding and creating an estuary levee, sediment supply to the marsh has been impeded by the presence of levees as well as increased sediment concentrations in the Bay. The removal and placement of sediment should be considered. Setting back the levee near the mouth of Coyote Creek to reduce backwater effects along the floodplain. Nearshore reefs and submerged aquatic vegetation would provide habitat for marine life. Beaches could be restored or along eroding shorelines such as has been altered at Anemba Island. Green stormwater infrastructure could be implemented in the upper watershed to slow down runoff, reduce fluvial loading in the developed valleys, and slow the conveyance of floodwater to the Bay.

Oyster reefs
Horizontal Levees
Beaches
Eelgrass
Creek connections

Selected Measures	Suitability
NATURE-BASED	
Nearshore reefs	●
Submerged aquatic vegetation	●
Beaches	●
Tidal marshes	●
Polder management	○
Estuary levees	○
Migration space preparation	○

○ Limited suitability ● Some suitability ● High suitability



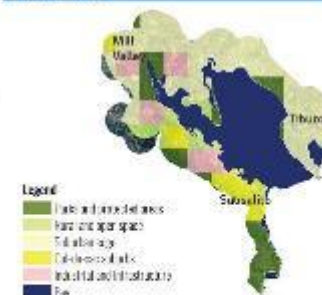
Reefing along Sausalito's shoreline in Richardson ODU (Photo by Shira Black, SFE)

Other Adaptation Opportunities

The predominant place types in Richardson are suburban residential, commercial, and industrial. Other place types include open/protected areas, parks, and creek connections. For parks and protected areas, suitable adaptation measures include securing wildlife transition zones through easements or buyouts, allowing sea level rise to take its course. For industrial and infrastructure, suitable adaptation measures include elevating roads and infrastructure, and moving infrastructure to higher ground.

Easements, buyouts in open/protected areas
Not intensifying development, elevating roads, buildings, re-zoning

Place Types Map





Courtesy of U.S. Geological Survey

Next Steps

- **Continuing to improve the science and fill data gaps**
- **Get data online in an interactive map**
- **Working with communities across the Bay to help apply and translate this work**