

# SF BAY ADAPTATION ATLAS:

## PLANNING WITH NATURE

### Using Operational Landscape Units

RMP Annual Meeting | October 10, 2019

Julie Beagle, SFEI

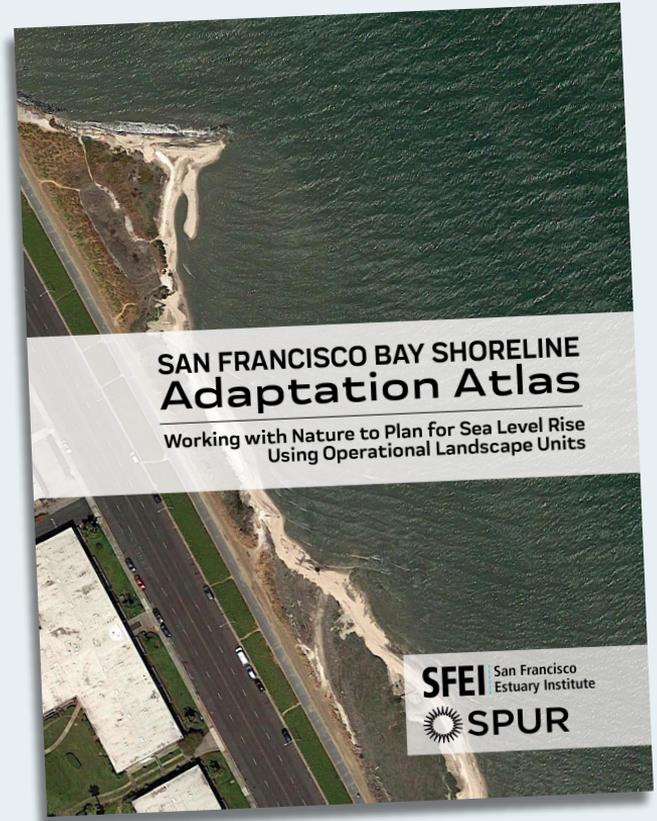


Funding: S.F. Bay Regional Water Quality Control Board

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

# Outline

- **Brief discussion of Adaptation Atlas methods and resulting tool**
- **New directions for supporting science and integration with water quality initiatives**
- **Applications of the Adaptation Atlas**



# The SF Bay Shoreline Adaptation Atlas

- A place-specific framework to work with nature to adapt to sea level rise
- Nature-based and hybrid infrastructure and policy options can be more effective, less expensive, and more beneficial than traditional grey options
- Spans jurisdictions, allowing stakeholders to come together to develop effective adaptation strategies

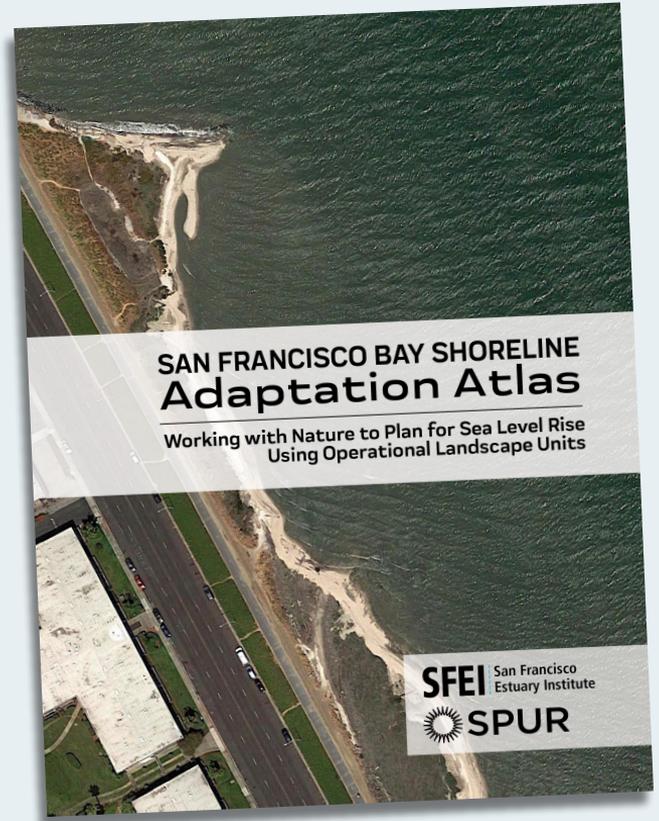




Photo by: Press Democrat

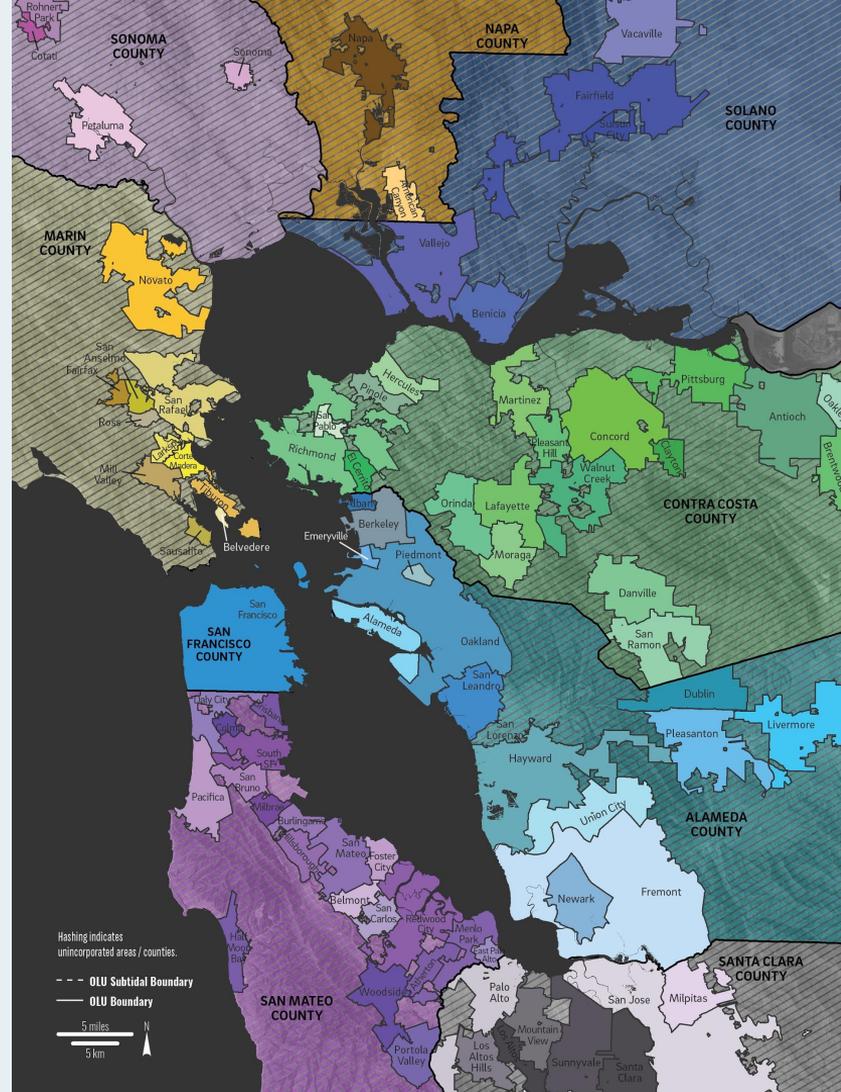


**Sea level rise  
will not stop at  
city boundaries.**



# Traditional jurisdictions

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





**STEP 1**

**Plan using  
nature's  
boundaries**

*(instead of traditional  
boundaries)*

**STEP 2**

**Identify  
adaptation  
measures that  
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in a given place**

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

**STEP 3**

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

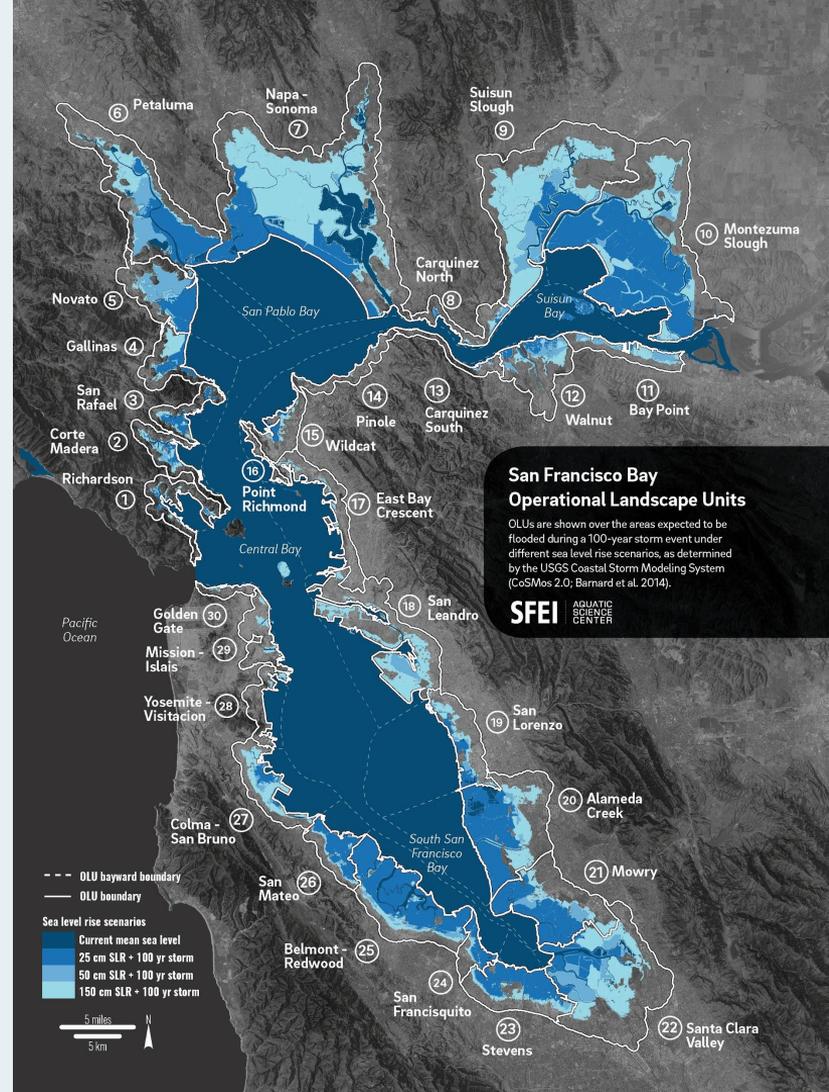
# Nature's Boundaries

## Operational Landscape Units

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

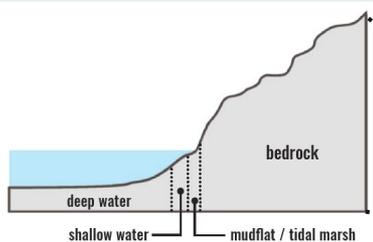
- **Connected hydrologically (tie to watersheds)**
- **Land potentially inundated by SLR under H++ scenario (OPC 2017)**

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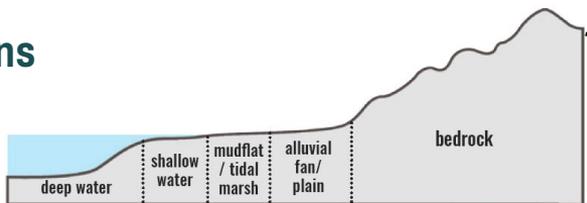


# Geomorphic Unit

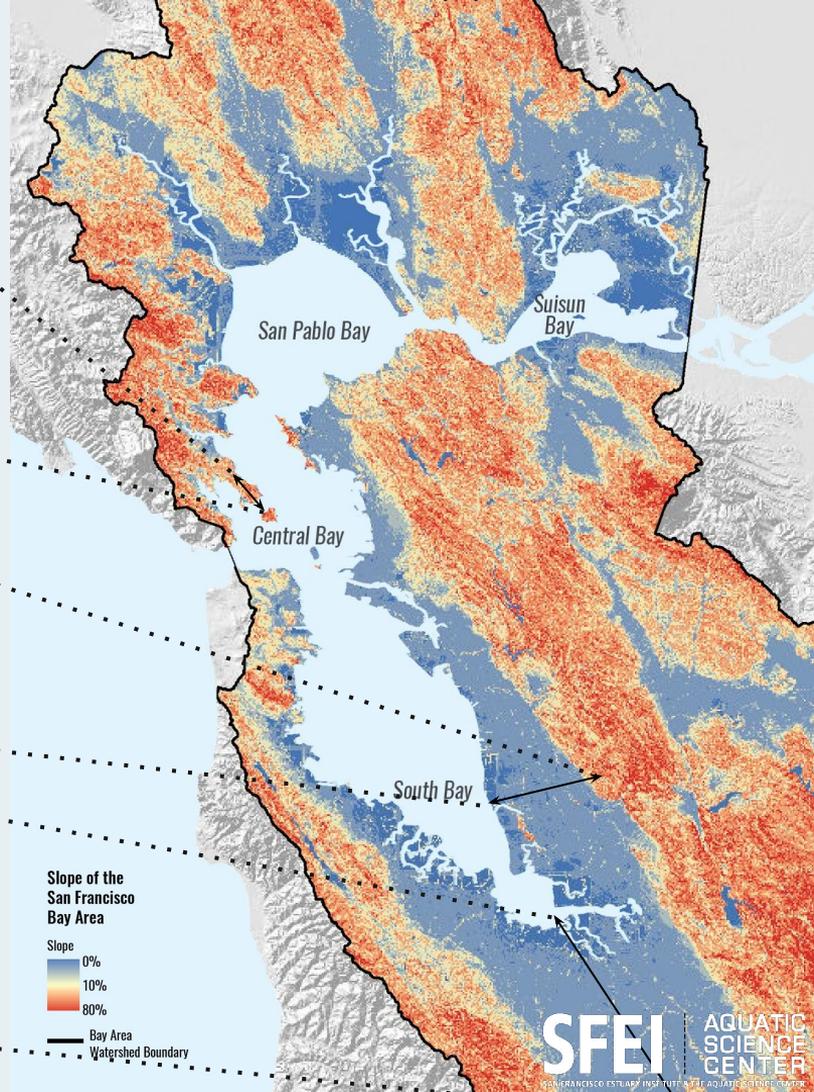
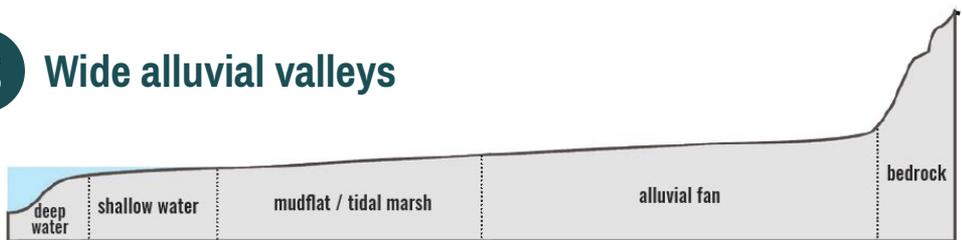
## 1 Headlands & small valleys



## 2 Alluvial fans & plains

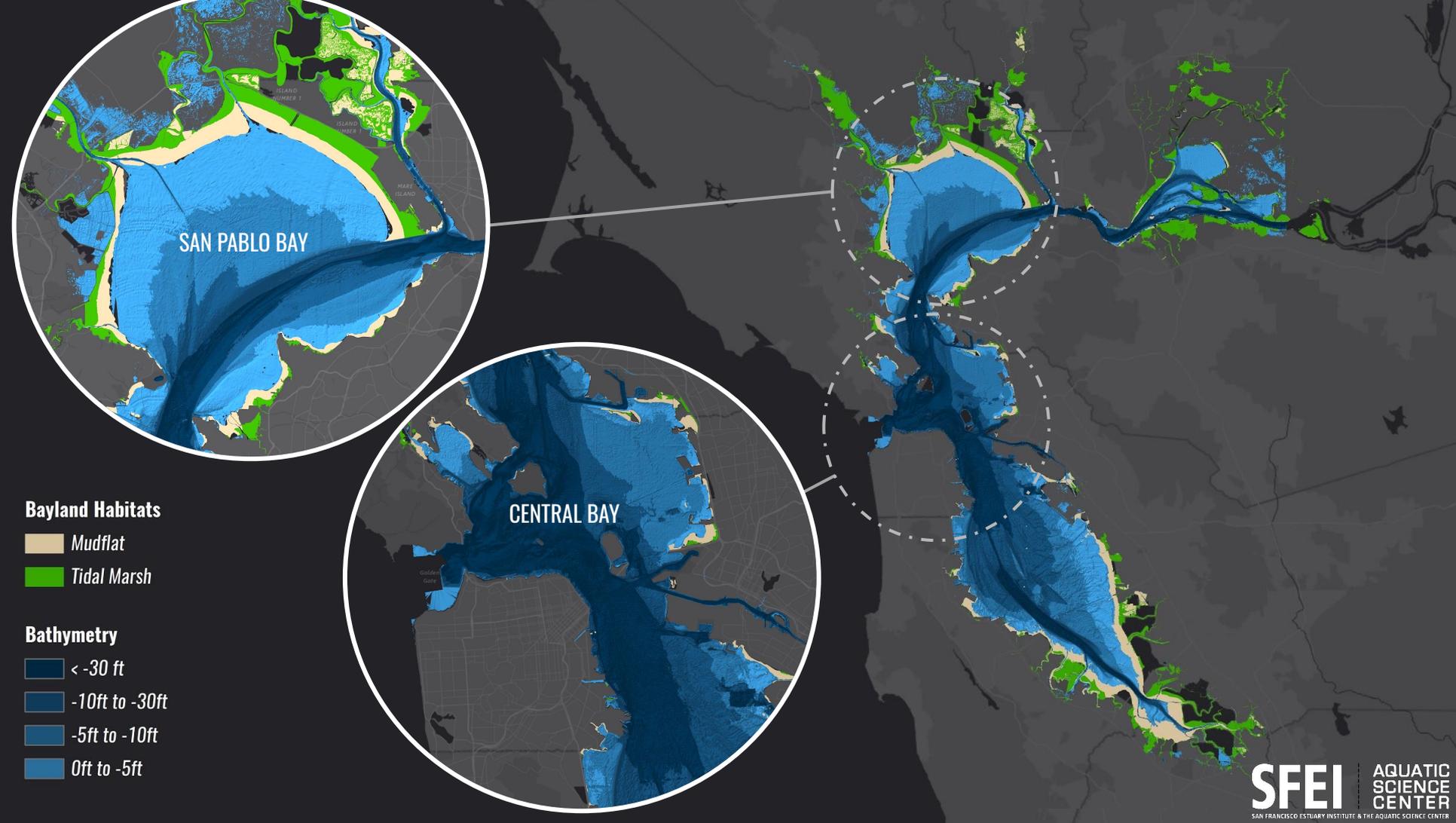


## 3 Wide alluvial valleys









SAN PABLO BAY

CENTRAL BAY

**Bayland Habitats**

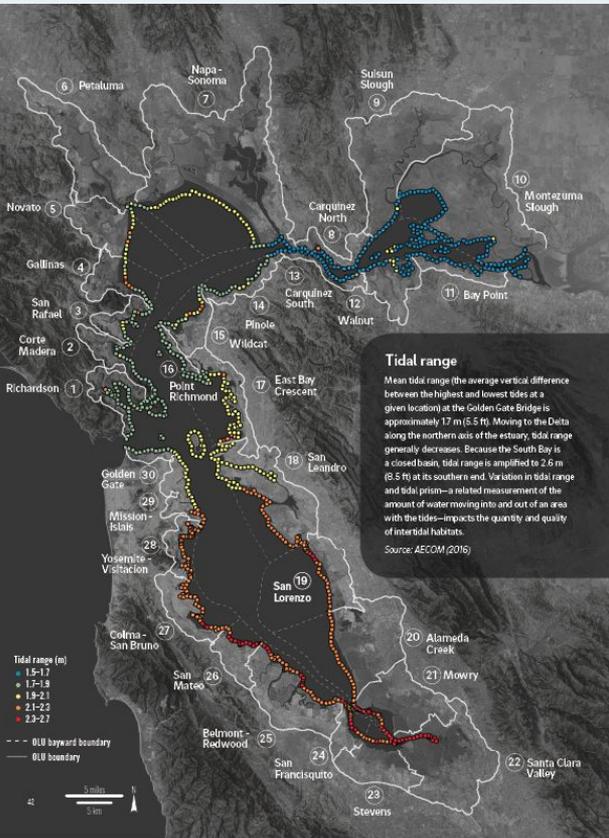
-  Mudflat
-  Tidal Marsh

**Bathymetry**

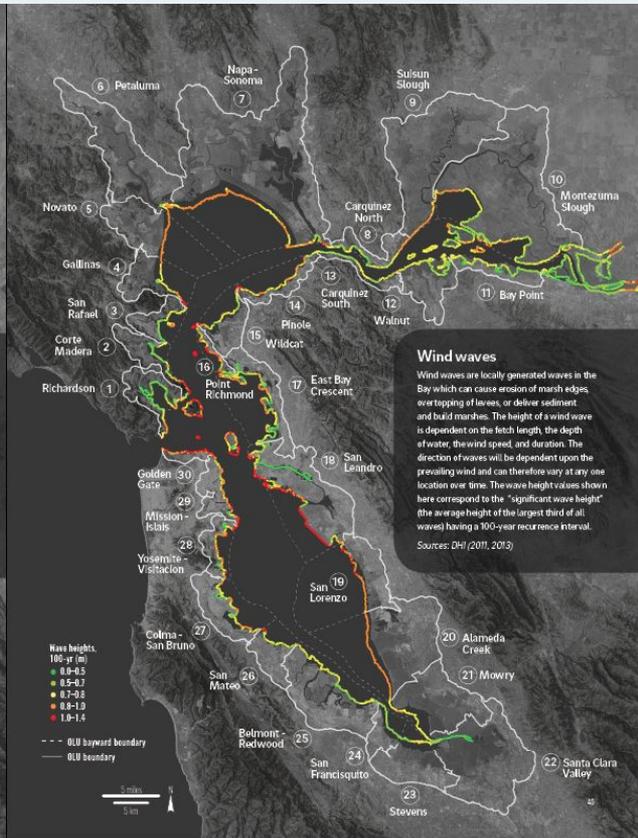
-  < -30 ft
-  -10ft to -30ft
-  -5ft to -10ft
-  0ft to -5ft

# Shoreline characteristics

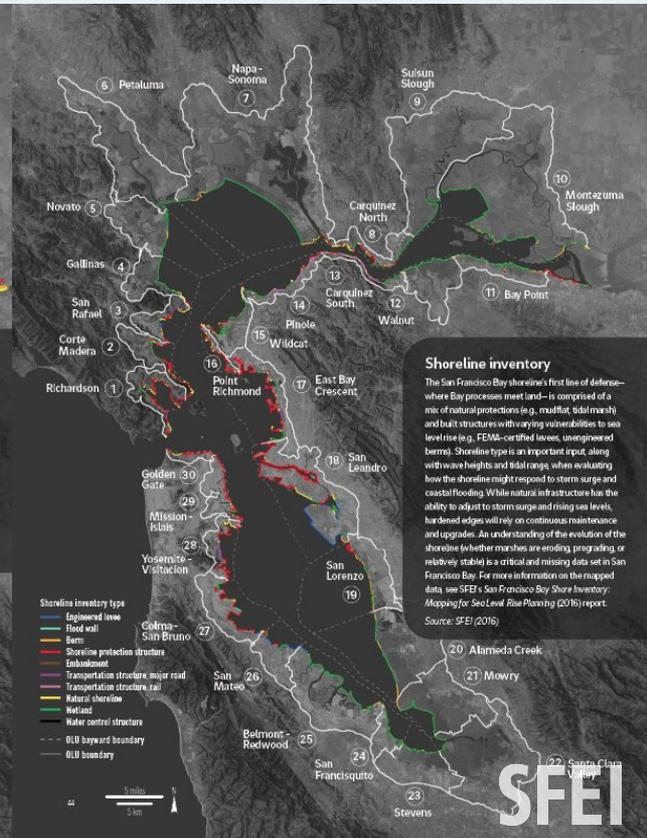
## Tidal range



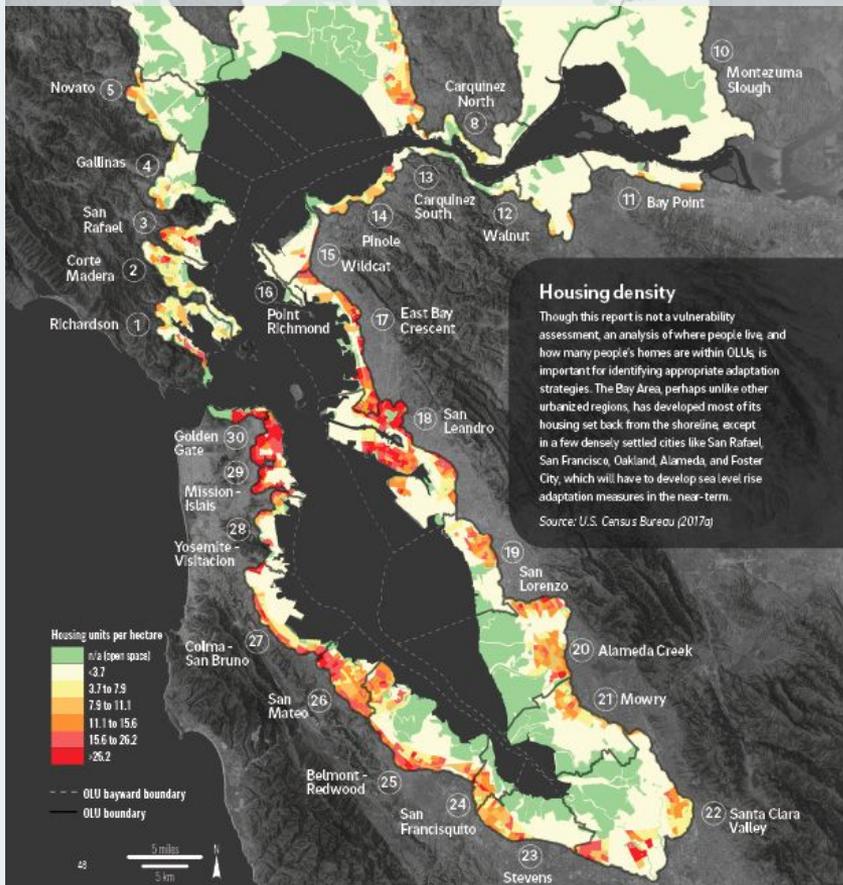
## Wind-wave heights



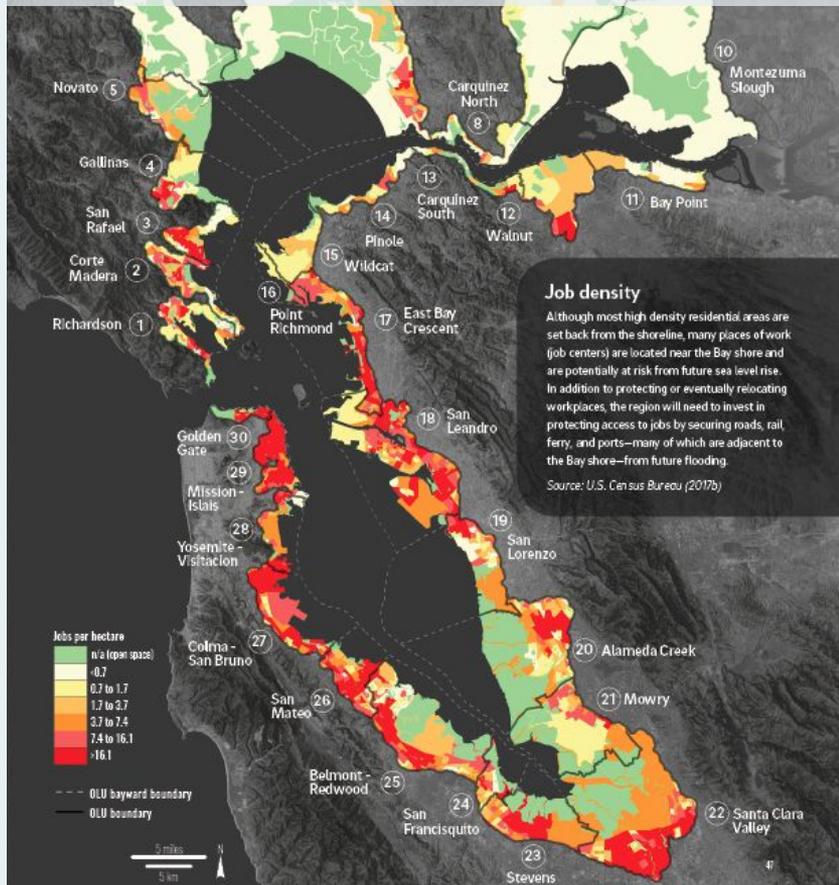
## Shoreline composition



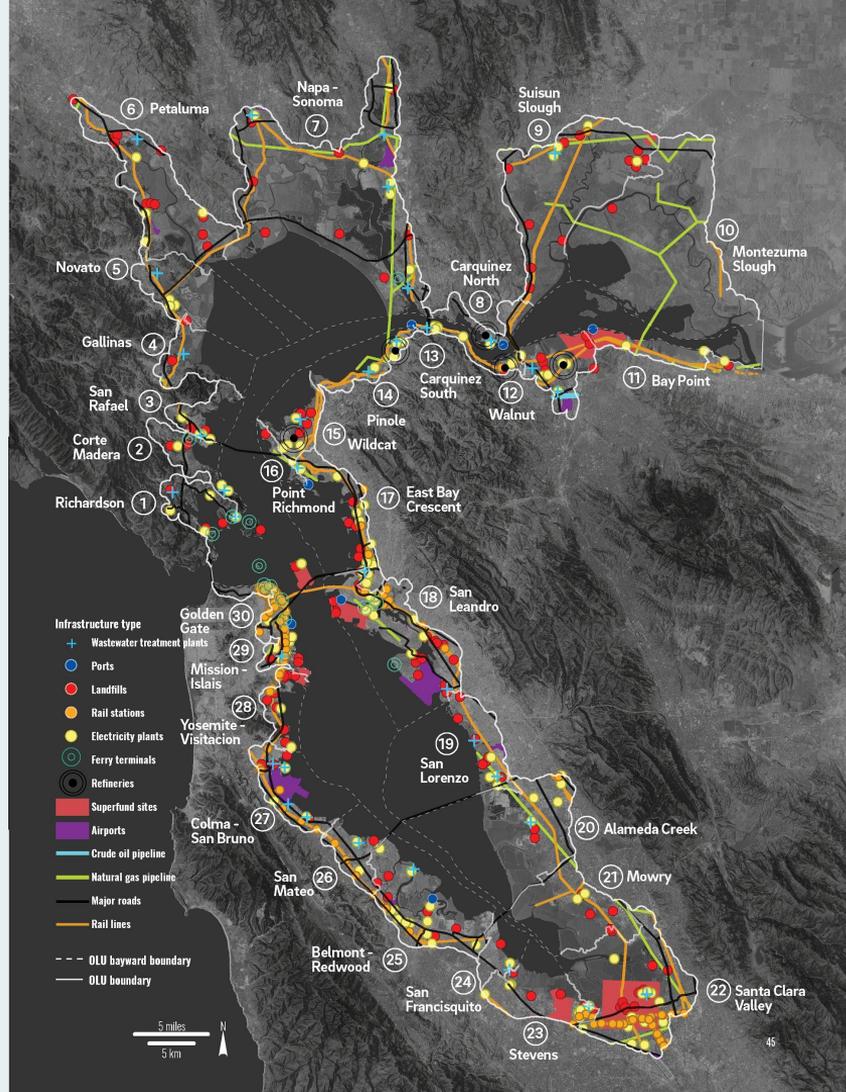
# Housing density



# Job density



# Selected infrastructure





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Photo: Mark Taylor



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Photo: Mike Lowery



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7.12 ft NAVD - King Tide, 2019  
Crab Cove Alameda

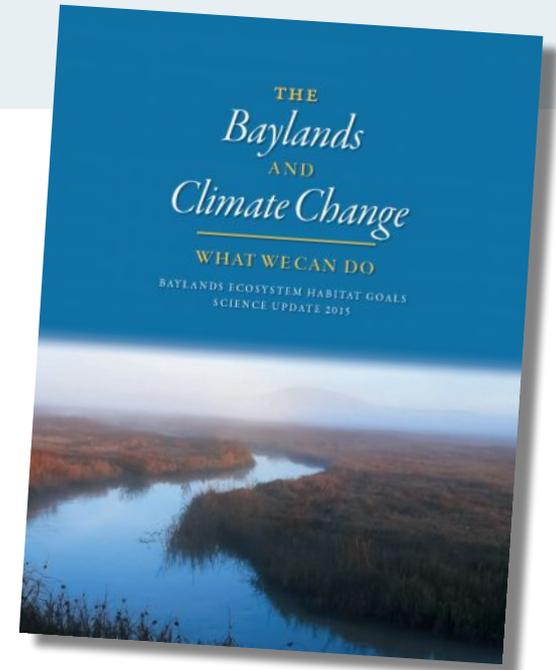
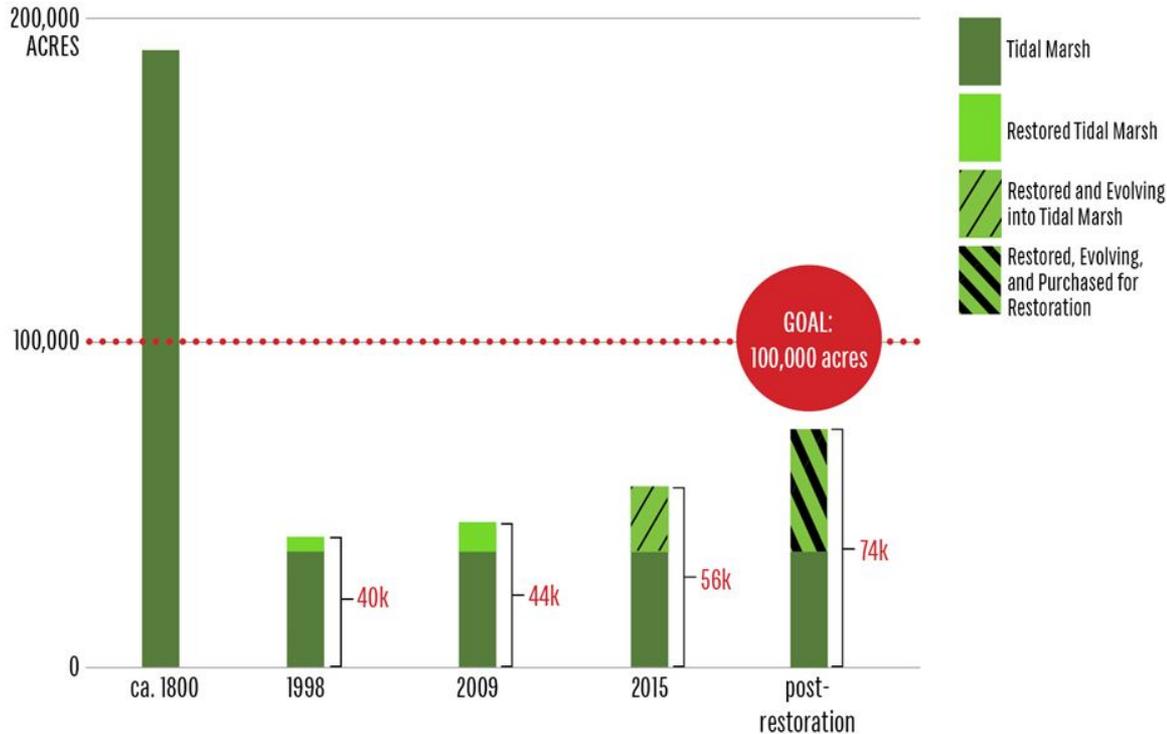


Photo by Shira Bezalel

# 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

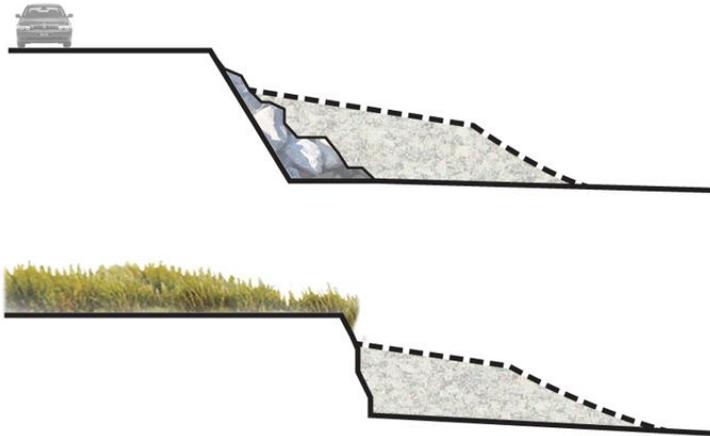
# Bayland Goals Update (2015)



# 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

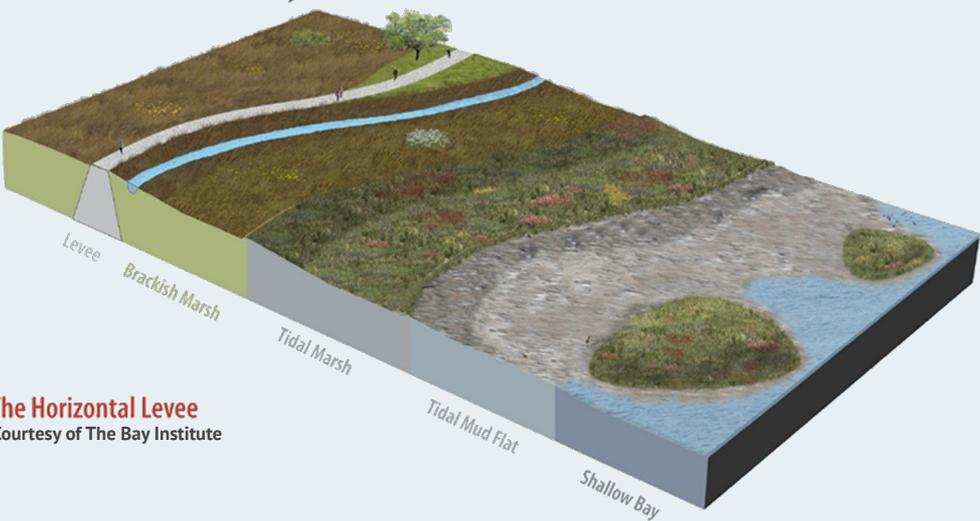


# Living shorelines: oyster reefs

Giant Marsh Living Shorelines Project  
Marilyn Latta



# Horizontal/Ecotone Levees



The Horizontal Levee  
Courtesy of The Bay Institute

# 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

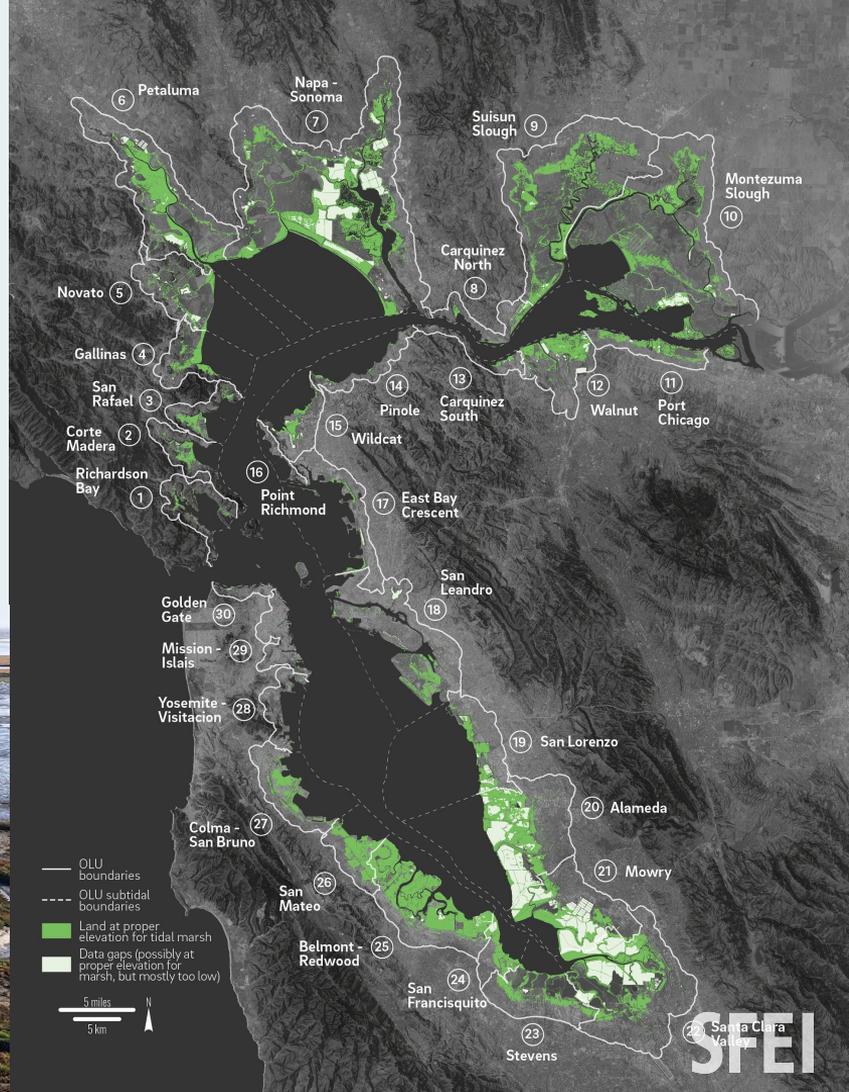
# Marsh restoration

## 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)



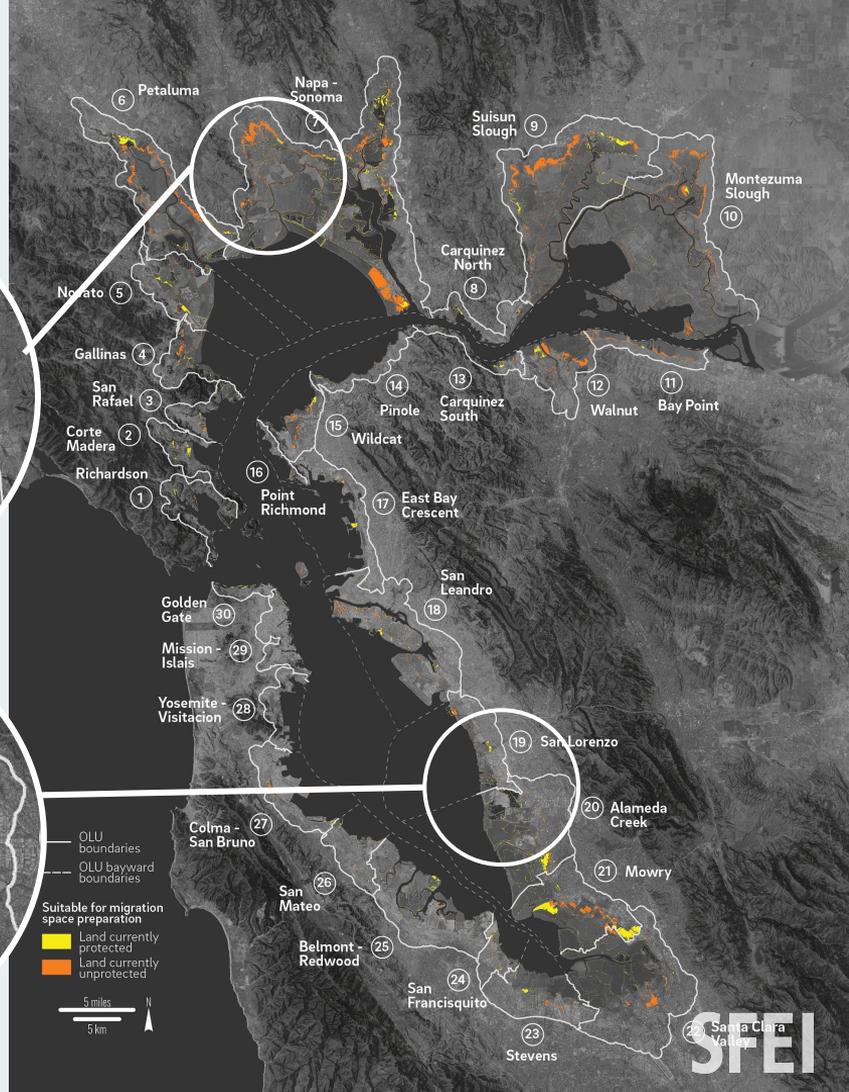
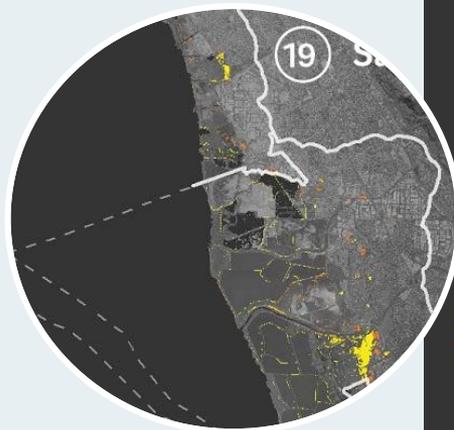
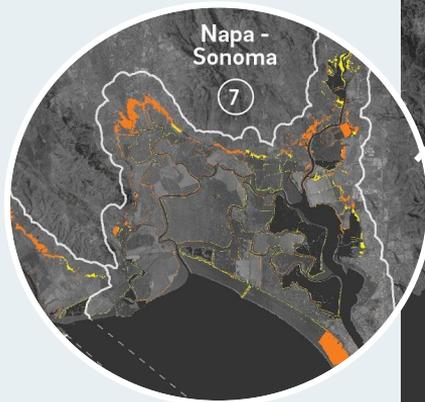
South Bay Salt Pond Restoration Project, 2013

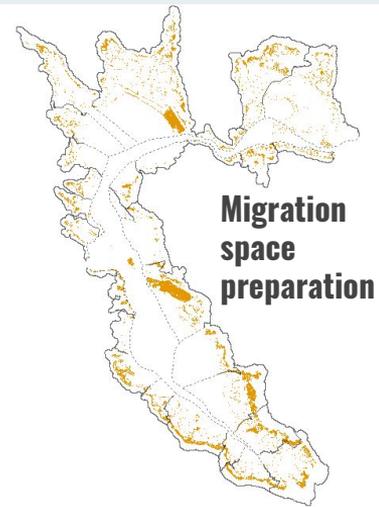
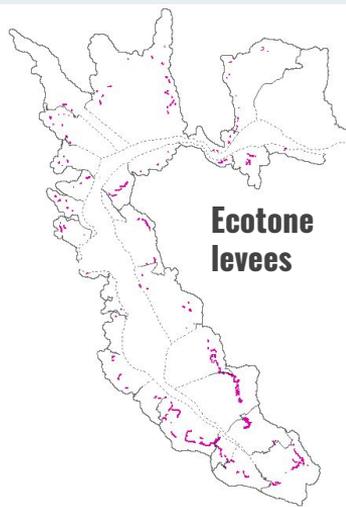
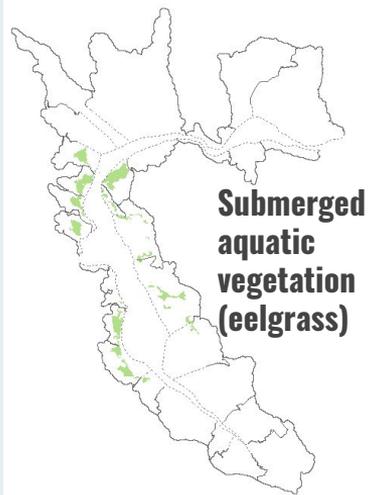
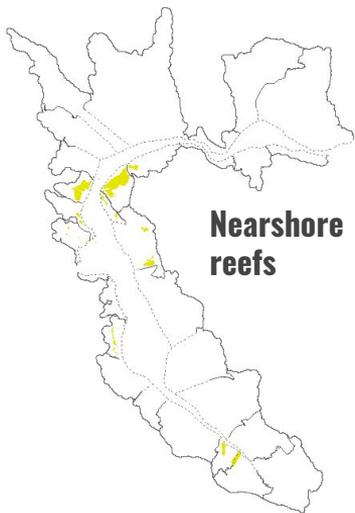


# Migration space

## Methods:

- Identify areas that are above tidal range now, but will be within tidal range in the future (areas where wetlands could migrate)





# Suitability of nature-based measures

## Suitability Rating

 Limited suitability

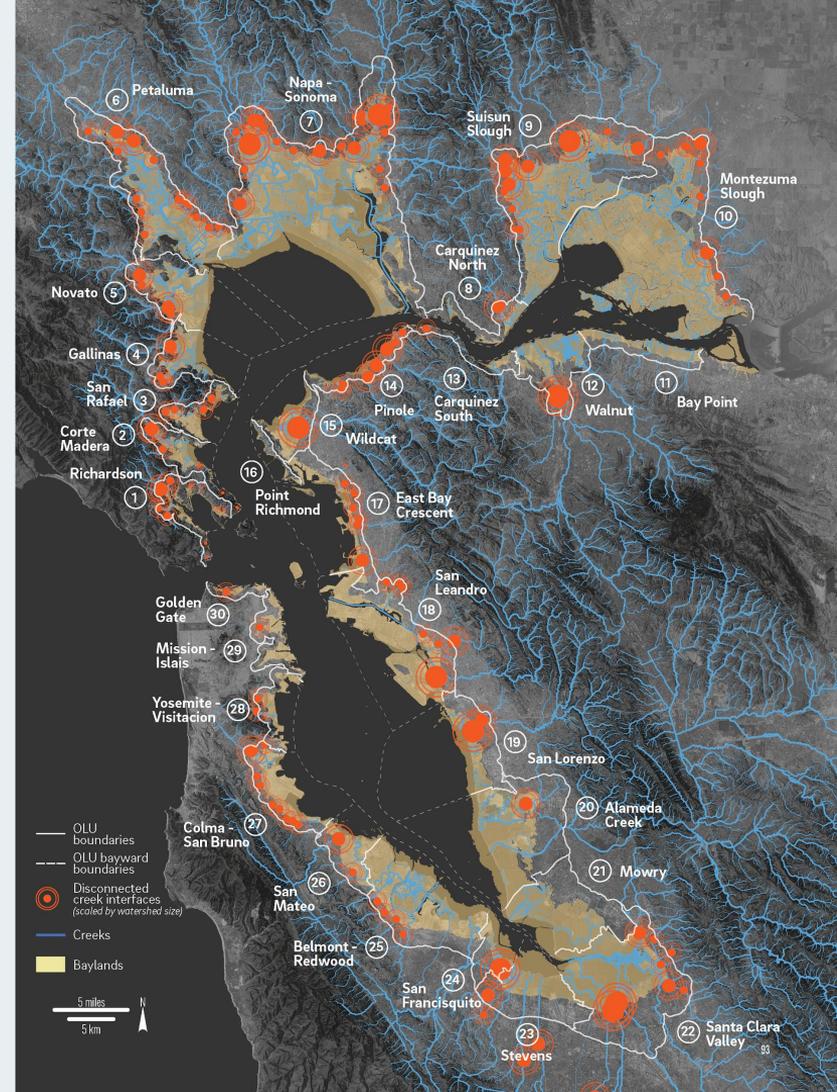
 Some suitability

 High suitability

	Nearshore reefs (p. 66)	Submerged aquatic vegetation (eelgrass) (p. 68)	Beaches (p. 72)	Tidal marshes (p. 76)	Polder management (p. 80)	Ecotone levees (p. 84)	Migration space preparation (p. 88)
1. Richardson	●	●	●	◐	○	◐	○
2. Corte Madera	●	●	●	◐	◐	◐	◐
3. San Rafael	●	●	●	◐	◐	◐	○
4. Gallinas	◐	●	○	●	●	◐	●
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 Francisquito	●	○	○	●	◐	●	◐
25. Belmont - Redwood	○	○	●	●	●	●	○
26. San Mateo	○	●	●	◐	◐	◐	○
27. Colma - San Bruno	○	●	●	◐	○	◐	○
28. Yosemite - Visitacion	●	●	●	○	◐	○	○
29. Mission - Islais	○	●	●	○	○	○	○
30. Golden Gate	○	○	●	○	○	○	○

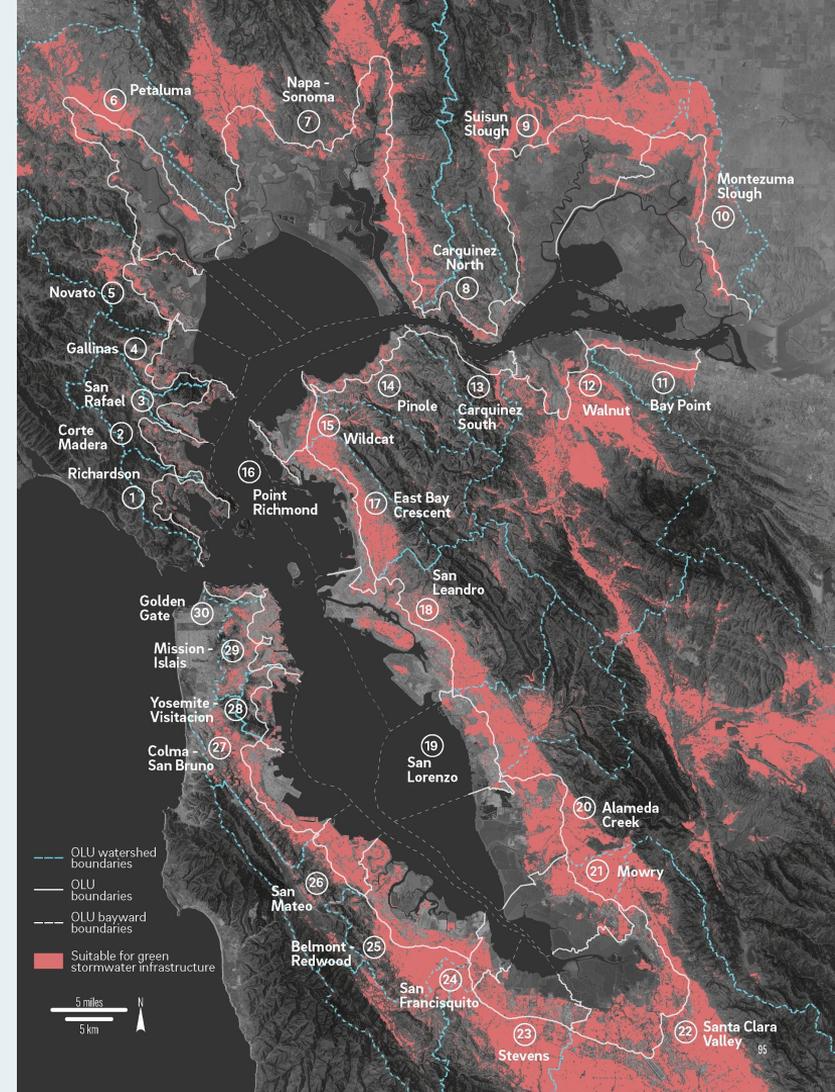
# Potential for creek-to-baylands reconstructions

- Many creeks draining to SF Bay have been hydrologically disconnected to their historical floodplains and baylands
- More research needed to determine most suitable locations for channel reconnection to support bayland habitats and flood risk management based on extent of undeveloped areas and other considerations

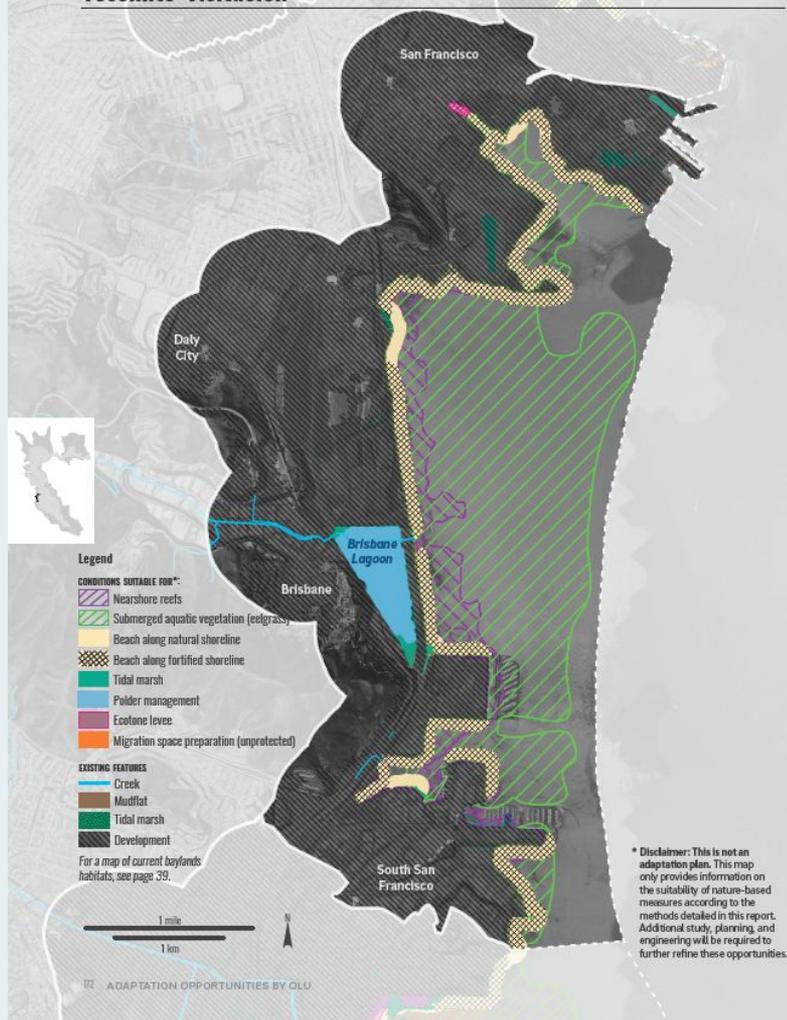


# Potential for green stormwater infrastructure

- Suitable areas based on slope, depth to water table, soil hydrologic type, land use, liquefaction risk, and impervious surface extent
- For green infrastructure to be effective for reducing flood risk, wholesale implementation at scales of whole neighborhoods and cities is needed



## Yosemite-Visitation



## Nature-based Adaptation Measures

The Yosemite-Visitation OLU is characterized by a hardened shoreline extended into the Bay by filling. As such there are few opportunities for nature-based adaptation. Most adaptation opportunities relate to the low-tide terrace (where it exists), and to shallow subtidal areas. Both eelgrass beds and nearshore reefs may be suitable in this OLU. A polder along Highway 101 could be an alternative to riprap to provide a more natural shoreline, and would necessitate hybrid features such as groins or artificial headlands. Brisbane Lagoon is a polder, and tidal action could be restored by improving the culverts under Highway 101, creating opportunities for mudflats, marshes, and ecotone levees within the lagoon. Green stormwater management elements in the upper watershed to reduce fluvial flooding in the developed areas.

**Beaches**  
**Eel grass**  
**Oysters**  
**Polder management**

Selected Measures	Suitability
Nearshore reefs	●
Submerged aquatic vegetation	●
Beaches	●
Tidal marshes	○
Polder management	◐
Ecotone levees	○
Migration space preparation	○
○ Limited suitability    ◐ Some suitability    ● High suitability	



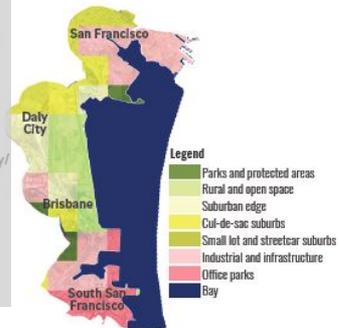
Office parks and industrial buildings located along South San Francisco and Brisbane's shoreline, looking northwest towards Brisbane Lagoon (Photo by Dec Searis, CC BY 2.0)

## Other Adaptation Opportunities

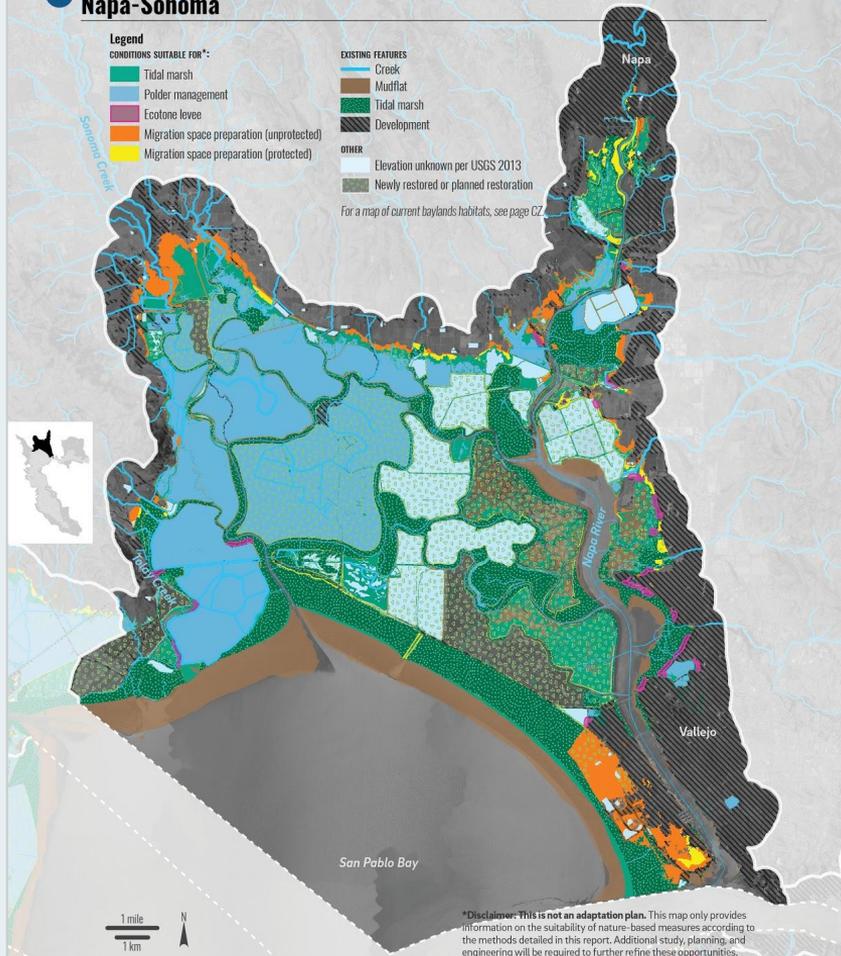
This OLU has a diverse mix of place types including office parks, industrial and infrastructure, developed open space, and low-to-moderate density residential. The highest risk of sea level rise is confined to small areas on the north (Hunters Point) and south (Palo Alto) of the OLU, which are home to office parks and commercial redevelopment areas. Adaptation opportunities for Yosemite-Visitation include densifying and flood-proofing residential areas through building retrofits, perimeter protection with grey infrastructure or hybrid grey/green measures, and land and road elevation.

**Flood-proofing buildings and retrofits**  
**Elevating roadways**  
**Perimeter Protection**

## Place Types Map



# Napa-Sonoma



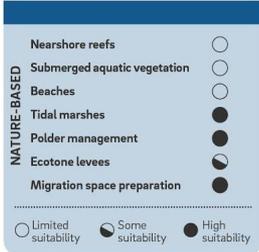
## Nature-based Adaptation Measures

In the Napa-Sonoma OLU there has been significant landscape-scale marsh restoration in areas such as the Napa-Sonoma Salt Ponds and the Napa-Sonoma Baylands. There are also considerable opportunities to restore large connected patches of tidal marsh in the remaining diked baylands closer to Sonoma Creek. Road and rail corridors through the baylands present considerable constraints to the restoration of the marshes; they need existing levees to protect them from flooding, their creek crossings are narrow, and the marshes are in a transition zone. All of the existing and potential tidal marsh will benefit from preparing migration spaces for the marsh to move upland as sea level rises. The majority of migration space preparation is possible in areas where much of it being managed as vineyards, so acquiring and protecting these areas will be key to creating marsh migration pathways. 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 Skaggs Island. If raised to intertidal elevations, these polders could be converted 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 capital closer to upland in these subsidized baylands, and to reduce flooding issues. There are also opportunities for widening the bridge crossings at Sonoma Creek and Tolay Creek if Highway 37 is raised on some combination of embankment and pilings. Ecotone levee creation is less critical in this OLU due to limited presence of development in need of protection, but ecotone levees could be incorporated into the design of embankments to raise Highway 37 or the railroads.

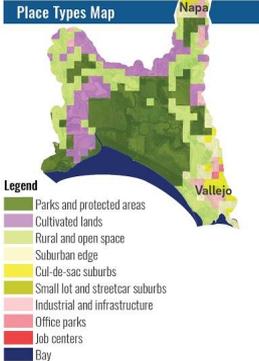
## Other Adaptation Opportunities

Like Petaluma, the very large Napa-Sonoma OLU—by far the largest in the OLU Atlas—has a wide range of potential candidate for adaptation measures that allow flooding to occur and that facilitate transition from recreational and agricultural uses to habitat or ecological uses over time, through restoration work, transition zone acquisition, and realigning public access. This OLU is a good place for shoreline adaptations here can maximize nature-based solutions. A few opportunities for nature-based adaptation measures include conservation easements or voluntary buyouts. For the suburban areas of the OLU that may experience sea level rise further in the future, buyouts might be suitable alternatives to relocation. Voluntary buyouts, depending on what the community prefers to invest in. Elevating Highway 37 to allow tidal action northwards toward formerly diked wetlands would significantly support the large areas of restoration possible in this OLU.

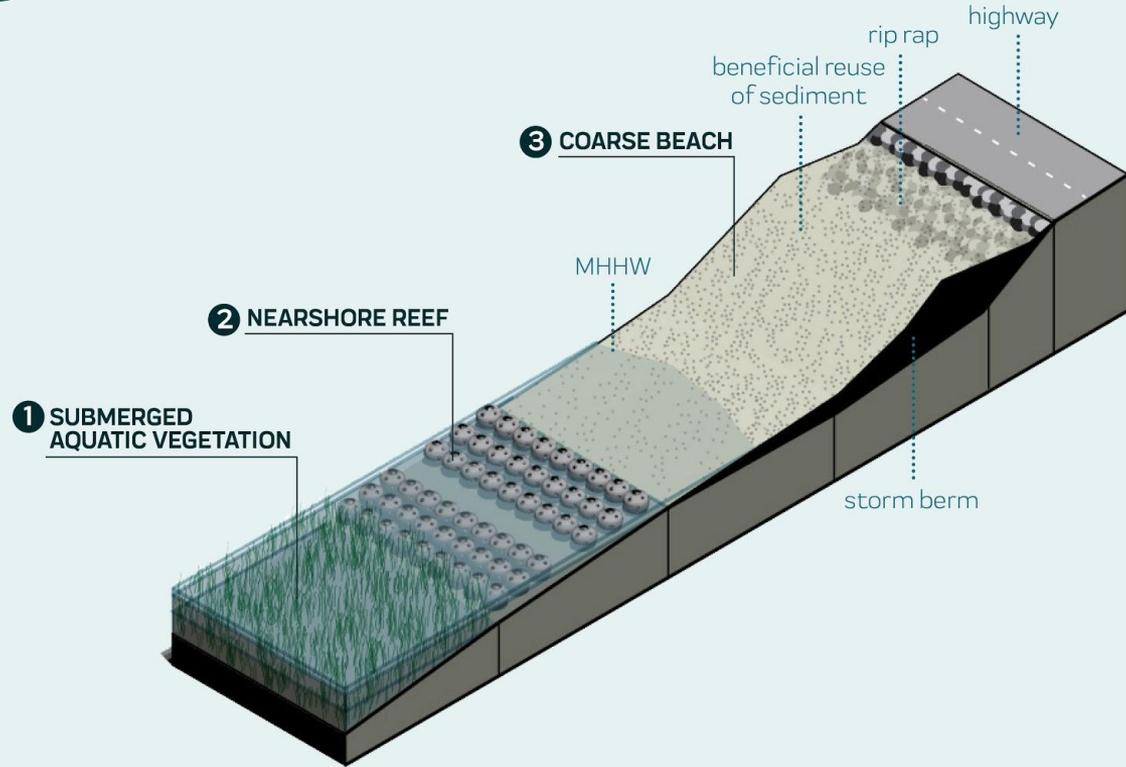
# Polder management Marsh Restoration Migration Space Creek connections



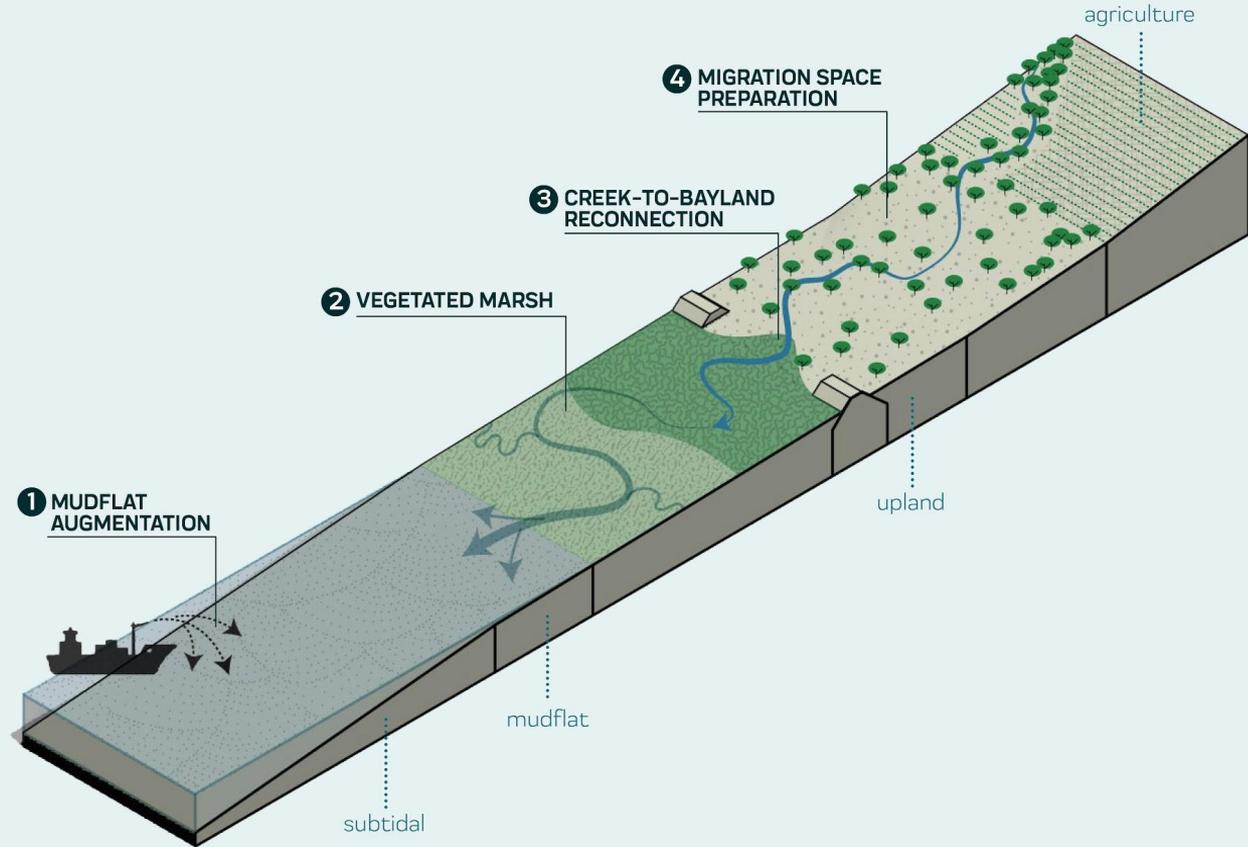
Aerial view looking downstream of the Napa River towards the Napa-Sonoma baylands (Photo by WineCountry Media, CC BY 2.0)



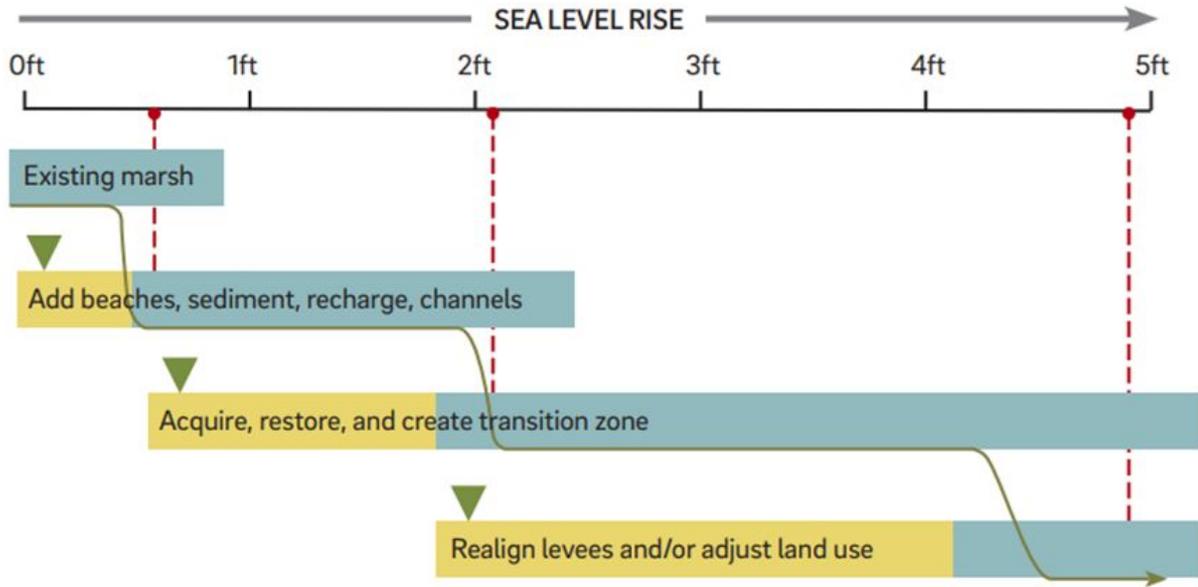
# Combining measures



# Combining measures



# Adaptation pathways



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

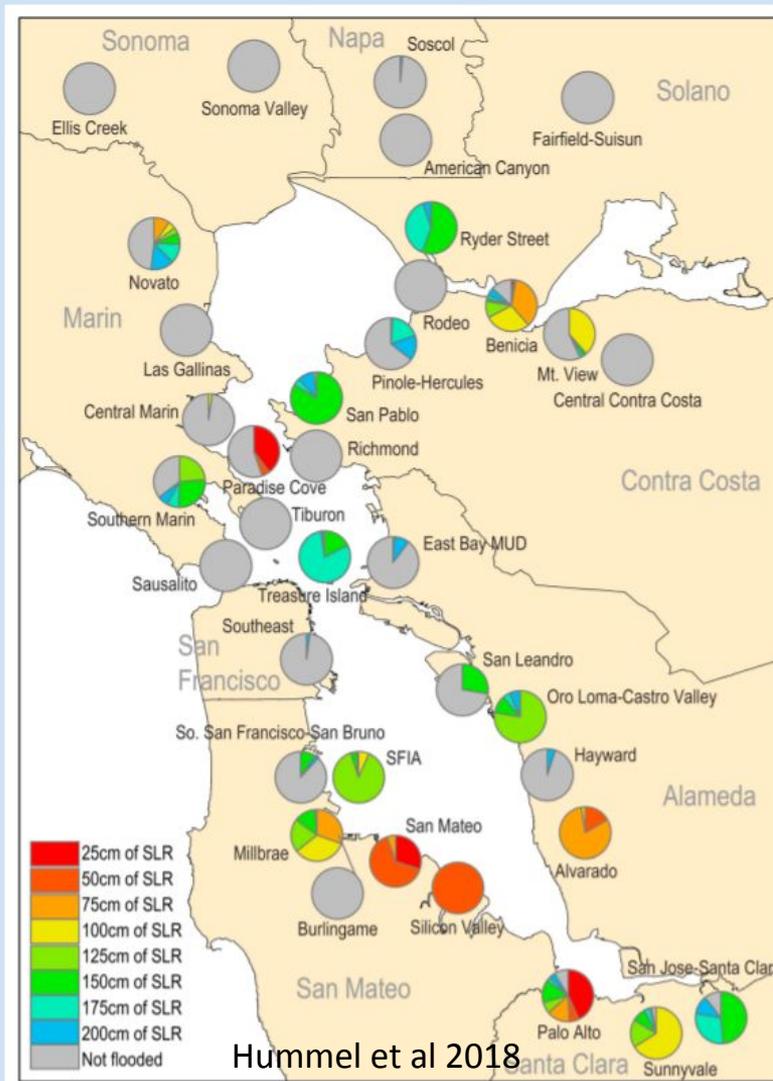
# Funded next steps

- **Understanding tradeoffs in sediment availability**
  - Developing estimates of future bayland sediment demand and Bay sediment supply across a range of climate change scenarios (EPA WQIF)
- **Integrate water quality and infrastructure**
  - Implications between measures and water quality
- **Develop adaptation pathways**



# Funded next steps

- Help inform the best portfolio of water treatment options and beneficial reuse of wastewater (BACWA, SFEI, RB2, SFEP, UCB)
  - Where can green infrastructure reduce nutrient loads while building a more resilient Bay edge?
  - What approaches are most appropriate?
  - How can landscape-scale processes inform planning efforts?



Hummel et al 2018



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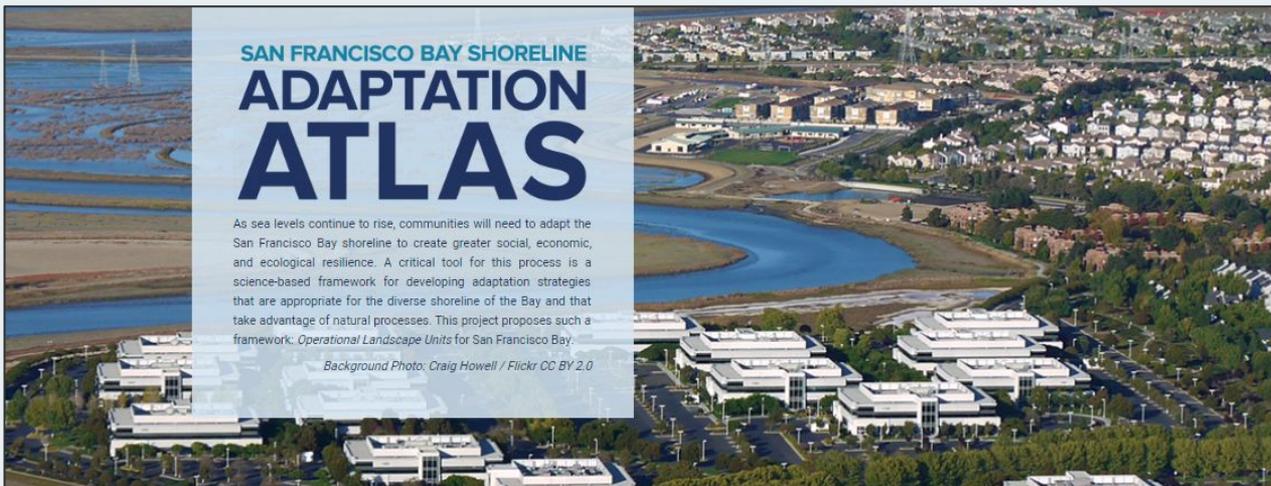
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resilient future**

# 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 (BCDC, RB2)**
- **Guidance for developers and project applicants**
- **Local, regional planners, and communities** creating adaptation plans and policies
- **Guidance for policy changes** within regional agencies



Download the report at [sfei.org/adaptationprojects](https://sfei.org/adaptationprojects)



About

Projects

Outreach

Interactive Map

## Projects that apply the OLU framework

### ▼ San Francisco Bay Shoreline Adaptation Atlas



In the coming decades the San Francisco Bay shoreline will face increasing threats from rising sea levels. A critical but missing tool for this process is a science-based framework for developing climate adaptation strategies that are appropriate to our diverse shoreline settings and that take advantage of natural processes in the Bay. This report proposes such a framework: Operational Landscape Units for San Francisco Bay, or OLU. The primary focus of this framework is to work with nature to identify where natural and nature-based approaches can be used to create a resilient shoreline with multiple benefits.

[High Resolution](#)

[Medium Resolution](#)

[Low Resolution](#)

[Purchase from Amazon](#)

SFEI

# View the interactive map at [resilienceatlas.sfei.org](https://resilienceatlas.sfei.org)



ADAPTATION ATLAS   SHORELINE CHARACTERISTICS   INFRASTRUCTURE   VULNERABILITY   RESTORATION   ALL DATA   ABOUT // DOWNLOADS   RESILIENCE

+ About These Layers

- Legend

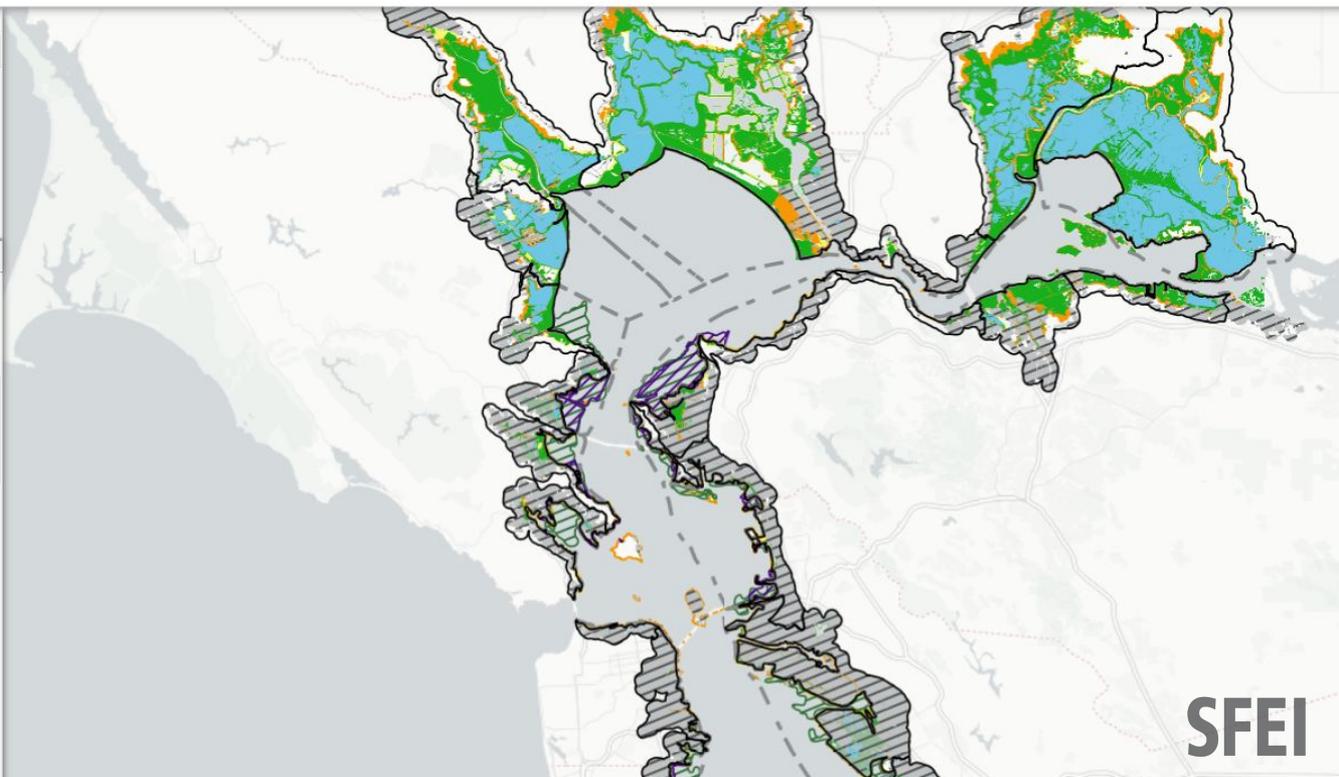
Operational Landscape Units (OLUs)

OLU Watershed Boundary ⓘ

- Nature-based Adaptation Opportunities ⓘ

Nearshore Reefs ⓘ

Submerged Aquatic Vegetation (Eelgrass) ⓘ



SFEI

# THANK YOU

**Contact:** [julieb@sfei.org](mailto:julieb@sfei.org)

**Thanks to our team:** Jeremy Lowe, Sam Safran, Katie McKnight, Letitia Grenier, SFEI  
Laura Tam and Sarah Jo Szambelan, SPUR

**For more info:** [adaptationatlas.sfei.org](http://adaptationatlas.sfei.org)

