Adaptation Planning Using Nature’s Boundaries

Restore America’s Estuaries

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SF Bay Regional Water Quality Control Board
In an urbanized estuary...

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

- There is no one-size-fits-all approach for SLR adaptation

- We can make our shoreline and communities more resilient by working with **people and nature** and at the right scale to implement sea level rise solutions
Traditional jurisdictions

9 counties
Traditional jurisdictions

9 counties
101 cities
Multiple special districts
Regulatory jurisdictions
Frontline communities in low lying areas
Physical processes that govern the shoreline happen at the **Bay scale**.

Too large and complex for individual projects.
Sea-level rise won’t stop at city boundaries.
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.
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
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 (this report lays out the framework)
What is the right scale?

Operational Landscape Units

Areas with shared geophysical and land use characteristics suited for particular suite of nature-based measures
data source: USGS
Hills
Alluvial Plain
Baylands
Shallow Bay
Deep Bay

STEEP HEADLANDS + SMALL VALLEYS
STEEP HEADLANDS + SMALL VALLEYS

ALLUVIAL PLAIN

Percent Slope

0%

80%
Hills
Alluvial Plain
Baylands
Shallow Bay
Deep Bay

STEEP HEADLANDS + SMALL VALLEYS

ALLUVIAL PLAIN

WIDE ALLUVIAL VALLEY

Percent Slope
0%
80%

Baylands
Shallow Bay
Deep Bay
Defining geomorphic units

**HEADLANDS & SMALL VALLEYS**
- Watershed size: small
- Slope: steep
- Bayland width: narrow
- Distance to deep water: small

**ALLUVIAL FANS & ALLUVIAL PLAINS**
- Watershed size: intermediate
- Slope: moderate
- Bayland width: intermediate
- Distance to deep water: intermediate

**WIDE ALLUVIAL VALLEYS**
- Watershed size: large
- Slope: gradual
- Bayland width: wide
- Distance to deep water: large
Subtidal boundary
Approximate depth of closure

Influence of wave height on critical depth of resuspension
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

Wind-wave heights

Shoreline composition

Tidal Range

Wind-Waves

Shoreline Inventory

Tidal Range

Shoreline Composition

Wind-waves are locally generated waves in the Bay region as a result of wind direction and converging of waves. The height of a wind wave is determined by the fetch length, the length of the wind, wind speed, and duration. The fetch length is the distance from the generating wind and can therefore vary at any given location over time.

Data source: FD Governor Nevada, State of Nevada, Field Themes Database, and Extreme Wave Study.
Baylands

Historical baylands

Modern baylands

Elevation capital

Historical Baylands

Approximately 15,000 years ago, before European contact, the Baylands were dominated by low primary habitat types like salt marsh communities, wetlands, and tidal marshes, which covered 20,000 acres. These marshes were home to mudflats, mudflats, and tidal ponds. The Baylands also had many connections to deeper water bodies, which were important for the local ecosystem. This connection to deeper water bodies supported a variety of plant and animal species, including fish, crabs, clams, and other invertebrates.

Modern Baylands

In the 1900s, the draining and diking of tidal marshes allowed for agricultural and wetland production. As a result, most of the marsh was drained and converted into farmland. The Baylands became one of the largest urbanized areas in the United States. By the 1980s, approximately 15,000 acres of marshland had been drained. The remaining tidal marshes were primarily fragmented and isolated, which negatively impacted their ecological function.

Elevation Capital

Elevation capital is determined by comparing the elevation gradient of the local water level and the range of landforms and natural processes. The elevation capital is a measure of the ability of the landscape to support a variety of plant and animal species. The higher the elevation capital, the greater the diversity of habitats and species found in the area.
Housing Density

Where people live, and how many people's homes will be affected by future sea level rise, is important for identifying appropriate adaptation strategies. The San Francisco Bay Area, like other urbanized regions, has developed most of its housing set back from the shoreline, except in a few densely populated cities. San Francisco, Oakland, Alameda, and Foster City, which will have to develop sea level rise adaptation measures in the near term.

Data source: Arcturus Community Survey 2018
Housing Density

Where people live, and how many people's homes will be affected by future sea level rise, is important for identifying appropriate adaptation strategies. The San Leandro, perhaps unlike other urbanized regions, has developed most of its housing set back from the shoreline, except in a few densely settled areas in San Rafael, San Francisco, Oakland, Alameda, and Foster City, which will have to develop new flood adaptation measures in the near term.

Data source: American Community Survey 2018

Job Density

Although most highly-dense residential areas are set back from the shoreline, there are many jobs in the region that close to the Bay and at risk of future sea level rise. In addition to protecting or eventually relocating workplaces, the region will need to invest in protecting access to jobs by conserving roads, rail lines, and ports - most of which are adjacent to the shoreline - from future flooding.

Data source: US Census (2016)
Vulnerability

Depth to groundwater

SLR + Bay shore inventory + FEMA 500-yr flood zone

Infrastructure
**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
(this report lays out the framework)
### Pairing Problems with Nature-based Measures

<table>
<thead>
<tr>
<th>Problem (for example)</th>
<th>Cause</th>
<th>Example measure</th>
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<tbody>
<tr>
<td>Wave overtopping or erosion of levee with wide foreshore</td>
<td>Large waves reach levee</td>
<td>Marsh, fine beach, horizontal levee</td>
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<td>Combined flooding</td>
<td>Loss of floodplain</td>
<td>Retention basins, setback levee</td>
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<td>Loss of marsh area</td>
<td>Wave erosion of scarp</td>
<td>Coarse beach, oyster reef</td>
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<td>Subsided areas behind levee</td>
<td>Diking and draining of marshes</td>
<td>Reconnect to creeks, warping</td>
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# Adaptation measures

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<thead>
<tr>
<th>Nature-based measures</th>
<th>Regulatory, Financial, Policy tools</th>
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<tr>
<td>• Oyster reef creation</td>
<td>• Easements</td>
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<td>• Submerged vegetation restoration</td>
<td>• Land elevation</td>
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<tr>
<td>• Mudflat augmentation</td>
<td>• Policy changes</td>
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<tr>
<td>• Beach creation (sand, cobble, shell)</td>
<td>• Zoning changes or overlays</td>
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<tr>
<td>• Marsh restoration (various)</td>
<td>• Buyouts</td>
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<td>• Polder management</td>
<td>• Transfer of Development Rights</td>
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<tr>
<td>• Horizontal levee creation</td>
<td>• Building retrofits</td>
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<td>• Migration zone preparation</td>
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<td>• Creek to bay connections</td>
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<td>• Green stormwater infrastructure</td>
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</table>
For each measure

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

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 (-MHHW to -MHHW)
- -0.14 to 0.75 (-MSL to -MHHW)
- -1.00 to -0.14 (MLLW to -MSL)
- -1.00 to -2.00 (MLLW to 2x MLLW)
- -2.00 to -4.00 (2x MLLW to 4x MLLW)
- < -4.00 (<4x MLLW)

(Cahoon and Guntenspergen 2010; Swanson et al.)
Marsh restoration

Methods:

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

Concept:

- Subsided areas will need careful management and should be identified
- Actual adaptation approach (e.g., fill placement, warping, or intentional flooding) will vary based on local conditions

Methods:

- Selected any contiguous areas (> 0.3 ha) with elevations below MSL (Z* < 0) and disconnected from tidal inundation by dikes
Migration space preparation

**Methods:**

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

[Image of protected and unprotected areas]
Submerged vegetation restoration
Oyster reef creation
Eelgrass restoration
Mudflat augmentation
Composite beach creation

Polder management
Marsh restoration
Horizontal levee creation
Migration space preparation
Suitability across OLUs

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<tr>
<th></th>
<th>Nearshore reefs</th>
<th>Submerged aquatic vegetation</th>
<th>Mudflats</th>
<th>Beaches</th>
<th>Vegetated marsh</th>
<th>Polders</th>
<th>Horizontal leves</th>
<th>Undeveloped migration space</th>
<th>Creek-to-bayland reconnections</th>
<th>Green stormwater infrastructure</th>
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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
Open space
Suburban edge
Urban neighborhoods
Office parks and commercial
Secondary job centers
Dense mixed use
1. Richardson

Nature-based Adaptation Measures

The Richardson Bay OLU has limited space near the Bay with steep headlands confining a small valley which restricts both where flooding can occur and also opportunities for nature-based adaptation such as marshes. The mouth of Coyote Creek is an area prone to flooding and has space for enhancing the Bushy Marsh vegetated marsh and creating a horizontal levee would be applicable. Opening up the mouth of Coyote Creek by setting back the levee could reduce backwater effects along the creek. Nearshore reef creation and submerged vegetation restoration would provide habitat while attenuating wave energy. Coarse beaches could replace rip rap along the narrower, steeper shoreline. Coarse berms could be used to protect existing marsh scarps from wave erosion. Green stormwater infrastructure could be implemented in the upper watershed to reduce fluvial flooding in the developed valleys and slow the conveyance of floodwater to the Bay. These measures should be considered for projects occurring in this OLU.

Other Adaptation Opportunities

The predominant place-types in Richardson are suburban edge (52%), open space and protected areas (27%), cul de sac suburbs (12%), and industrial and infrastructure (10%). Over time, the types most vulnerable to sea level rise are industrial/infrastructure, parks and protected areas, and cul de sac suburbs. For parks and protected areas, suitable adaptation strategies include securing wetlands transition zones through easements or buyouts - allowing sea level rise to take its course. For industrial and infrastructure, and cul de sac suburbs - which are low-density single-family residential areas - suitable strategies include not intensifying land development, possibly elevating roads and buildings, and within repeat-flood areas moving infrastructure or commercial activities to higher ground through buyouts, relocation incentives, or rezoning.
**Land use types**
- suburban edge
- open space
- industrial

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

**Nature-based Adaptation Measures**

- **Oyster reefs**
- **Horizontal Levees**
- **Beaches**
- **Eel Grass**
- **Creek connections**

**Other Adaptation Opportunities**

- The predominant place types in Richardson are suburban edge, dwellings, and open space (71%). Over time, the types most vulnerable to sea-level rise, industrial infrastructure, and protected areas, suitable adaptation measures include securing property or buyouts - allocating resources to infrastructure, and curbing suburban - which are low-density single-family developments. Richardson is also a commercial hub, which poses new opportunities for infrastructure and commercial developments, such as transitioning to mixed-use development.
Acquiring migration space
Easements, buyouts in open/protected areas
Elevating roadways

Polder management
Marsh Restoration
Migration Space
Creek connections

Nature-based Adaptation Measures
In the Napa-Sonoma OLU there has been significant landscape change that has affected the natural systems and habitat conditions.

Polder management
Marsh Restoration
Migration Space
Creek connections
East Bay Crescent

Nature-based Adaptation Measures

The East Bay Crescent is characterized by the artificial headlands that are currently being maintained by the Army Corps of Engineers. These headlands are composed of a mix of sand, silt, and clay, and they provide a habitat for a variety of coastal species. To enhance these natural features, the East Bay Crescent area has been identified as a potential site for the construction of horizontal levees, beaches, and eel grass beds.

Horizontal Levees
- These levees would be constructed parallel to the shoreline and would help to protect the area from storm surges and erosion.
- They would also create new wetland habitats that could provide additional benefits to the environment.

Beaches
- beaches would be created to provide additional habitat for coastal species and to enhance the recreational opportunities in the area.

Eel Grass
- Eel grass beds would be restored to provide additional habitat for fish and other marine life.

Other Adaptation Opportunities

This OLU has a mixed-use of land, including a significant amount of residential and commercial development. The OLU has a large portion of its land use dedicated to public and private open space. In addition, the majority of the OLU is zoned for single-family residential development, with some areas designated for multi-family residential development. The OLU also has a significant amount of commercial and industrial land use.

Transfer of Development Rights

Elevating roadways

through the use of the horizontal levees, beaches, and eel grass beds.
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 (this report lays out the framework)
How can this be used?

- A resource to assist environmental review and permitting
- Guidance for project applicants
- Local and regional planners creating adaptation plans and policies
- Community-driven resilience plans
Challenges and Limitations

- Based on today’s elevations, tides, waves
- First cut a metrics for suitability (engineering can change) Needs integration with infrastructure. Importance of hybrid solutions
- Political reception, permitting challenges, community engagement
- Data gaps: cost/benefit analyses, how long these features last, cost??
- Need to monitor pilot projects
THANK YOU

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