

Engineering with Nature on the San Francisco Waterfront

Collaboration across disciplines and scales

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**US Army Corps
of Engineers®**
San Francisco District

In collaboration with:
Port of San Francisco's
Waterfront Resilience Program



Jacobs

Photo credit: Port of San Francisco

Agenda

- 1. Waterfront Resilience Program Adaptation Planning**
- 2. Adapting to Climate Change by Engineering with Nature**
- 3. Integrating Engineering with Nature For Multiple Benefits**
- 4. Lessons Learned**

Raise your hand if...

You work for the **federal** government

Raise your hand if...

You work for **local, state, or regional**
government

Raise your hand if...

You work for a **private company / in the industry**

Raise your hand if...

You work for a non-governmental organization

*Broadly defined -- nonprofit, academic, community-based,
and more*

PART 1.1

WATERFRONT RESILIENCE PROGRAM

Overview

PORT OF SAN FRANCISCO

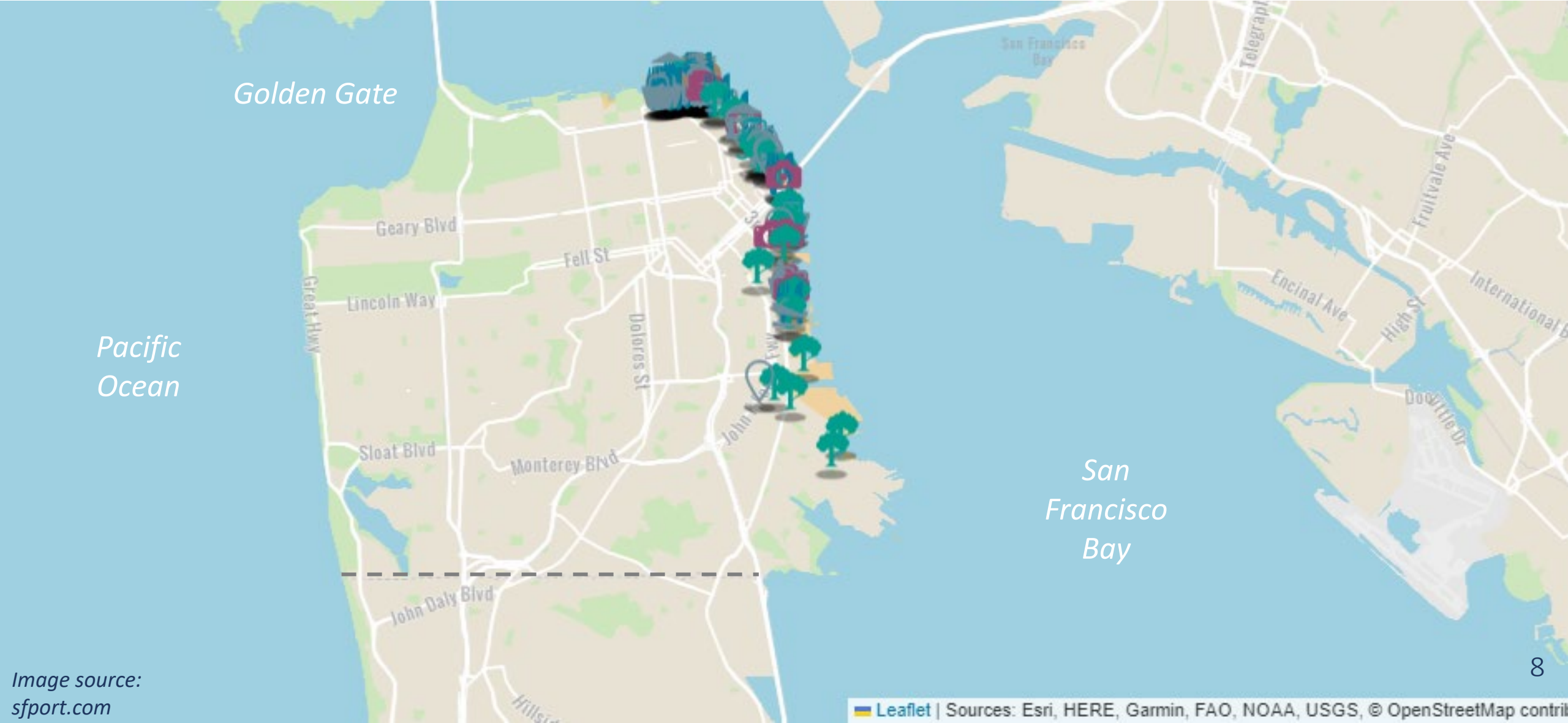


Image source:
sfport.com

WATERFRONT RESILIENCE PROGRAM

Vision Statement

The Port's Waterfront Resilience Program will take actions to **reduce seismic and climate change risks** that support a safe, equitable, sustainable, and vibrant waterfront.



PROJECT PARTNERS

Port-led, City of San Francisco Agencies, and USACE Partnered in Development Process



PROJECT PARTNERS

Working Groups



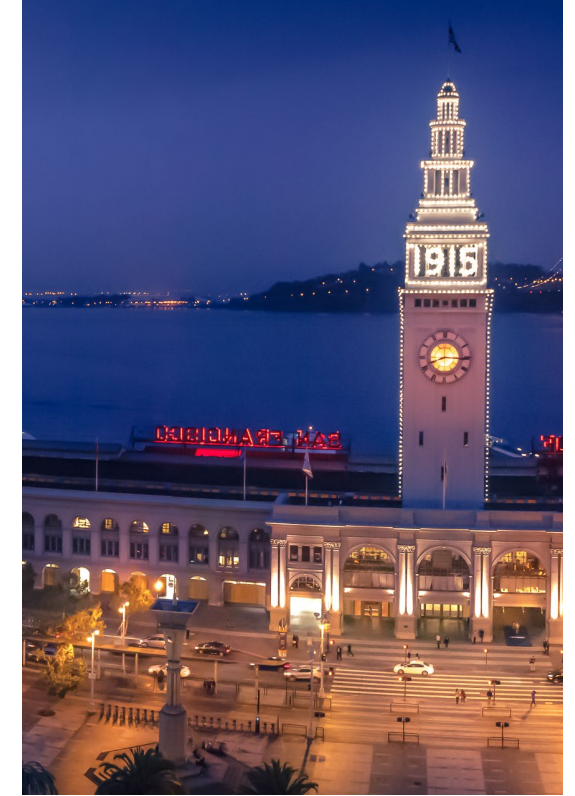
Resource Agency
Working Group



Equity Working
Group



Engineering with
Nature Working Group



Historic Preservation
Technical Advisory
Committee

PUBLIC ENGAGEMENT



PART 1.2

WATERFRONT RESILIENCE PROGRAM

Adaptation Planning

CLIMATE CHANGE HAS GLOBAL IMPACTS

Including In San Francisco



Puerto Rico, September 2022 / Alejandro Granadillo/AP



Alaska, September 2022 / adn.com



Florida, September 2022 / NYTimes.com



San Francisco Chronicle

BAY AREA / SAN FRANCISCO
S.F.'s Embarcadero needs to be raised as much as 7 feet to prepare for sea level rise, city says

John King
Nov. 5, 2021 | Updated: Nov. 7, 2021 6:25 p.m.



A car drives through floodwaters caused by large waves crashing into Pier 14 along the Embarcadero in San Francisco in 2016. The Port of San Francisco has released a report suggesting parts of the area need to be raised seven feet to avoid future flooding. [Jessica Christian/The Chronicle 2016](#)

RISING TO THE CHALLENGE

San Francisco Faces Urgent Seismic, Coastal, and Inland Flood Risks Today

SEISMIC RISKS



Lombard Street, 1906



Marina, 1989

COASTAL FLOODING



Recology, 2019



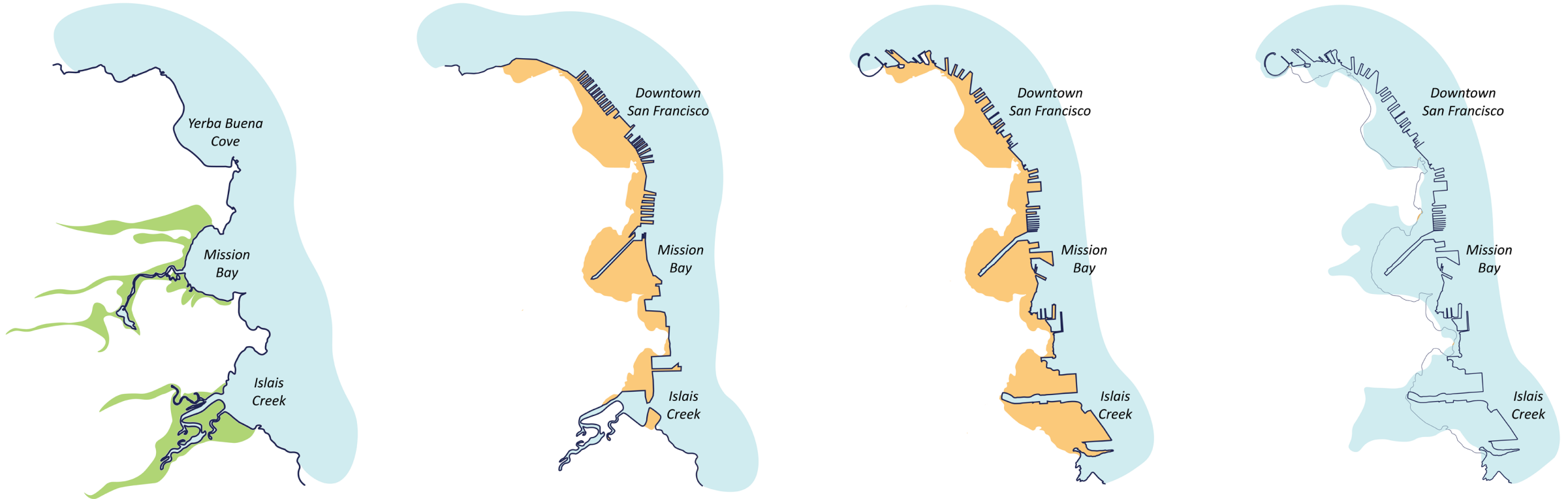
The Embarcadero, 2017

INLAND FLOODING



Islais Creek outfall and Marin St.

HISTORIC SHORELINE + BAY FILL



~1800

Pre-Bay Fill Shoreline

~1900

Downtown and Mission
Creek Bay Fill

~2000

Islais Creek Bay Fill

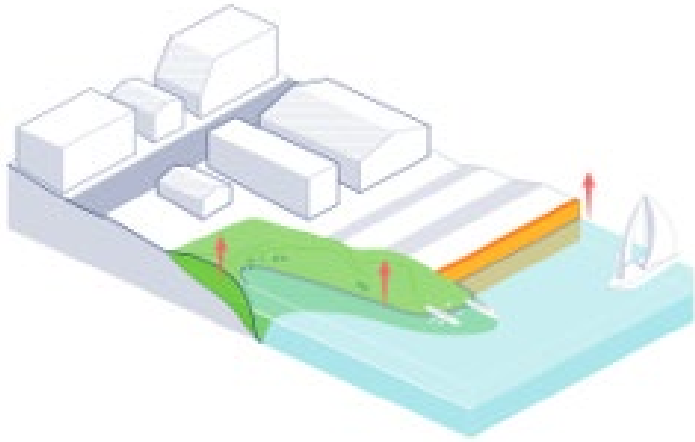
~2100

No Action: 7' of SLR +
1% annual chance flood

Marsh

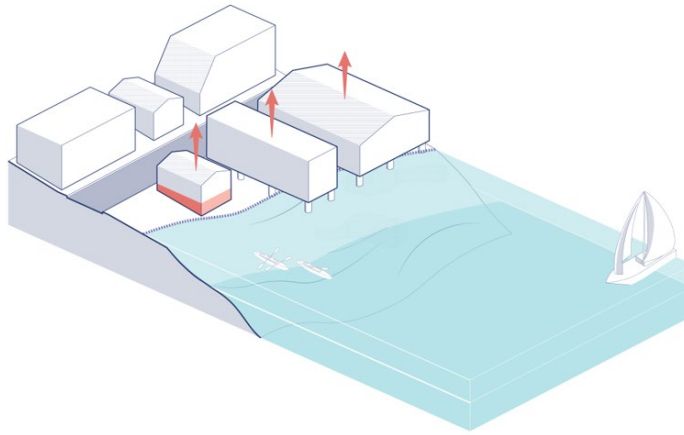
Bay Fill

ADAPTATION APPROACHES



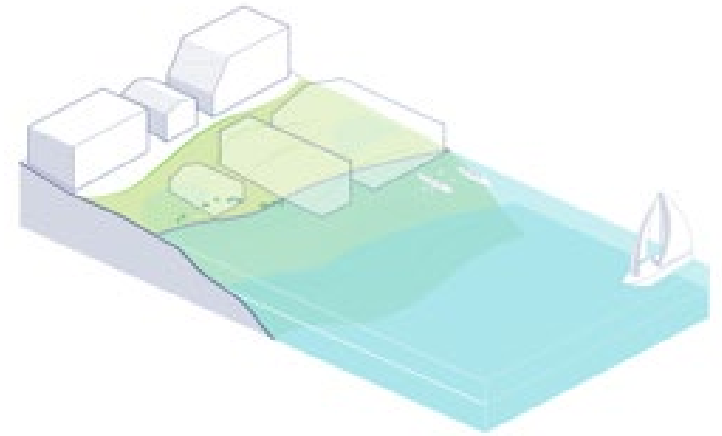
DEFEND

Keep coastal water out,
stay in place



ACCOMMODATE

Let coastal water in,
stay in place



RETREAT

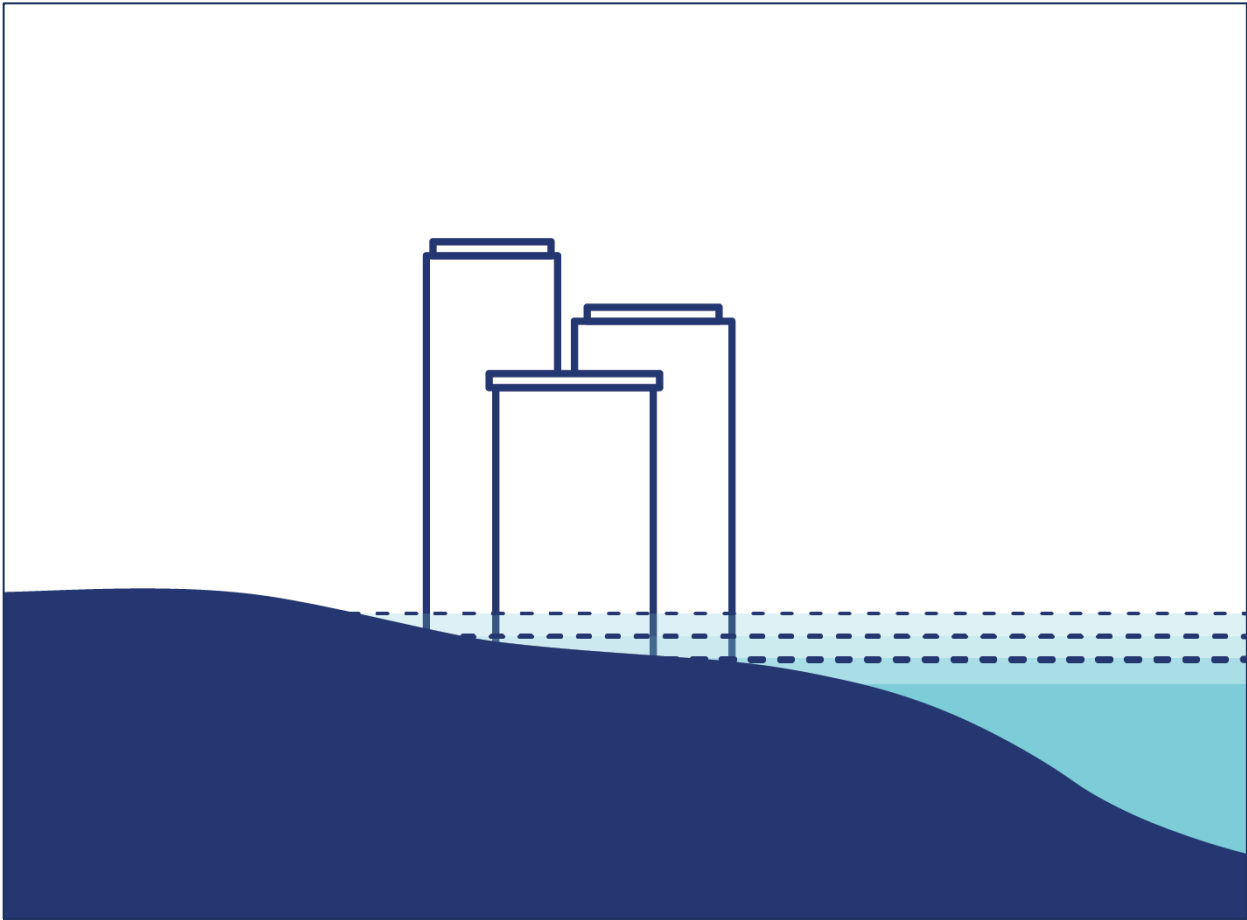
Move out of the area
over time

COASTAL AND INLAND FLOODING



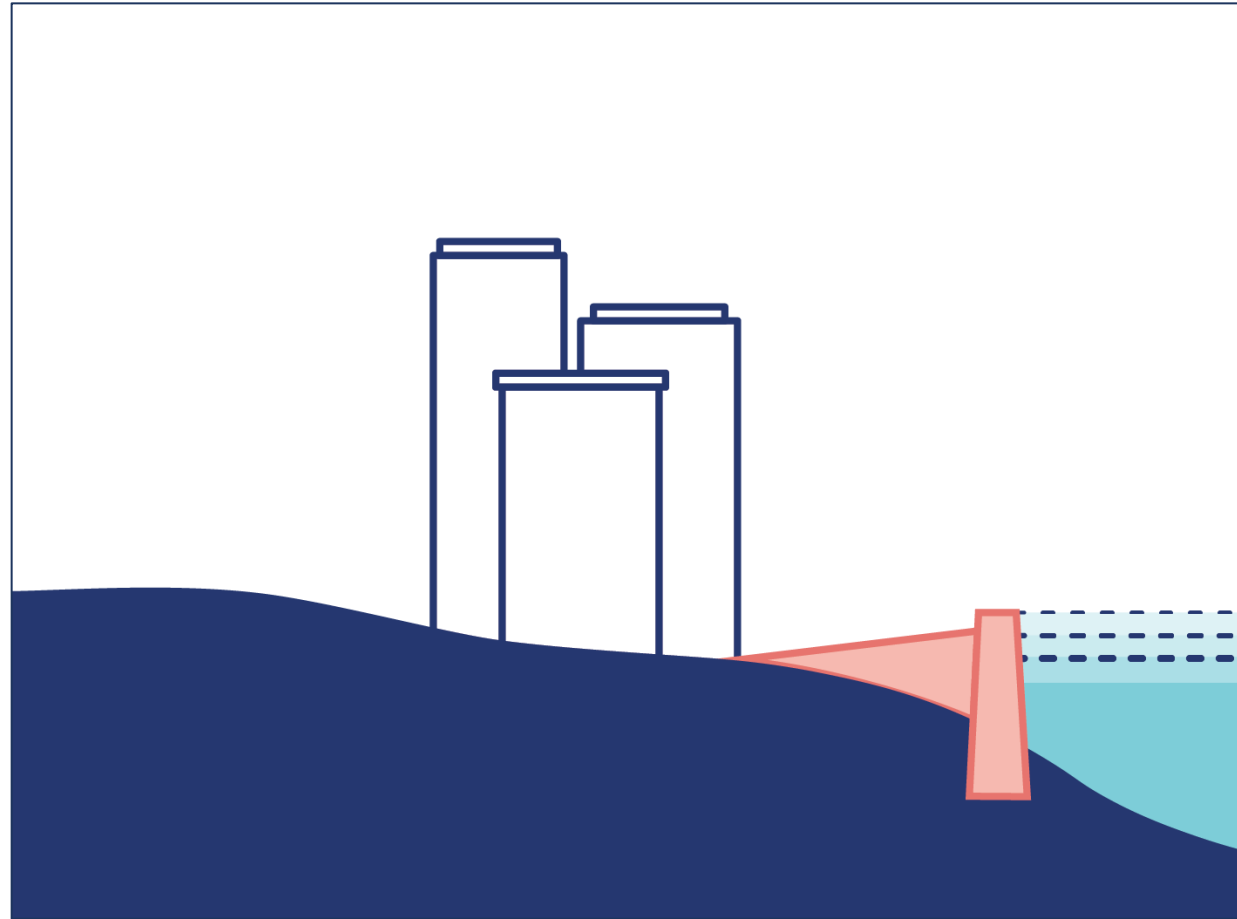
Existing conditions

COASTAL AND INLAND FLOOD RISK



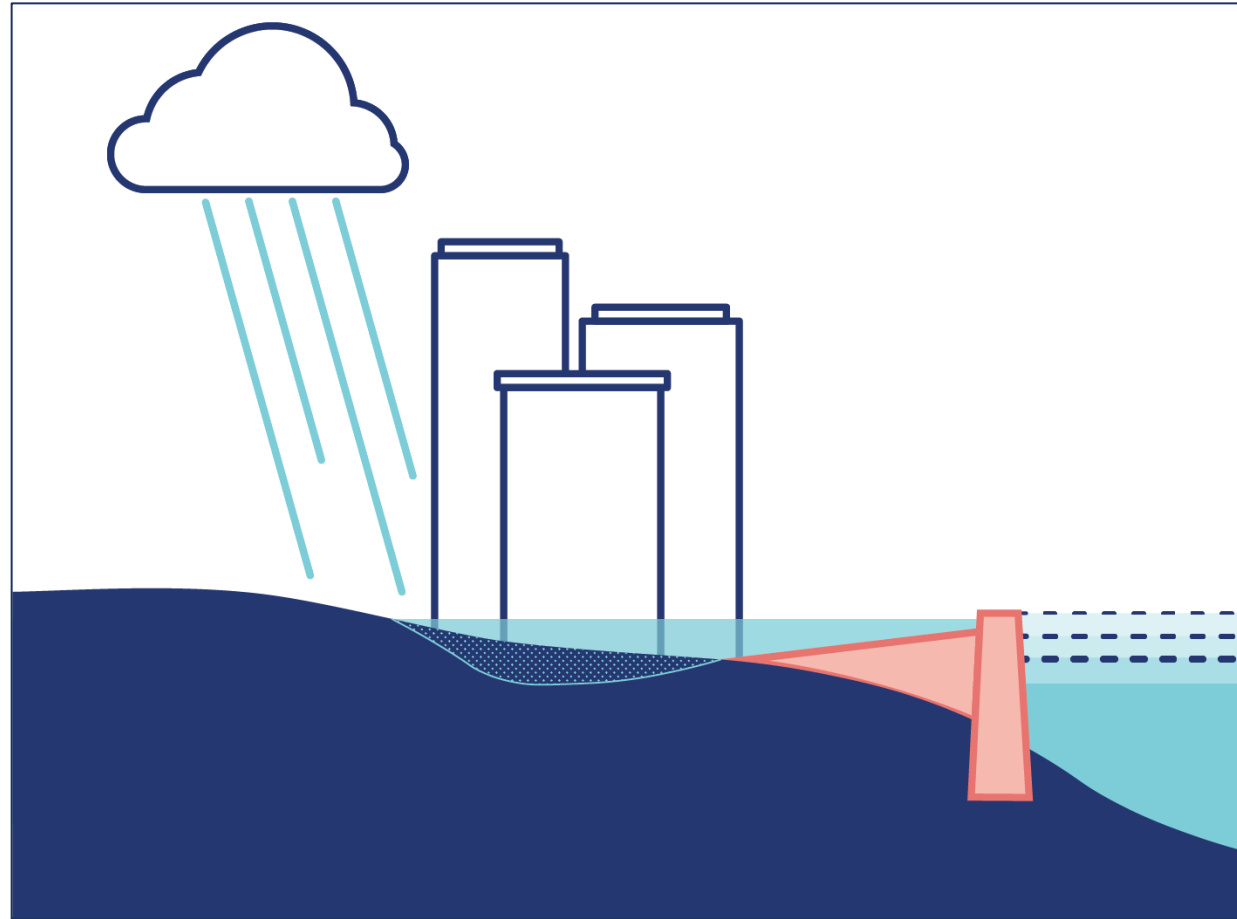
Sea levels rise

COASTAL AND INLAND FLOOD RISK



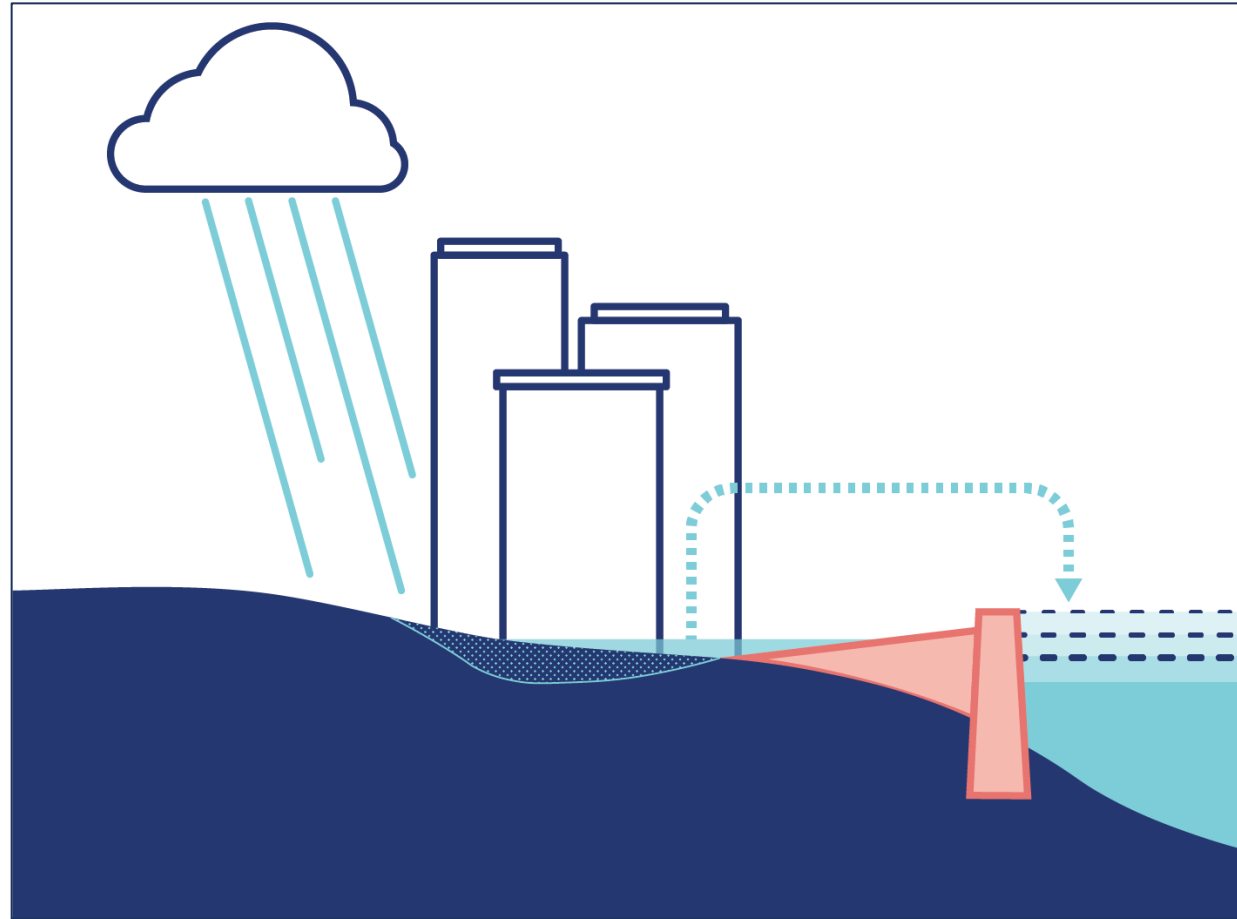
Raise shoreline to defend against sea level rise

COASTAL AND INLAND FLOOD RISK



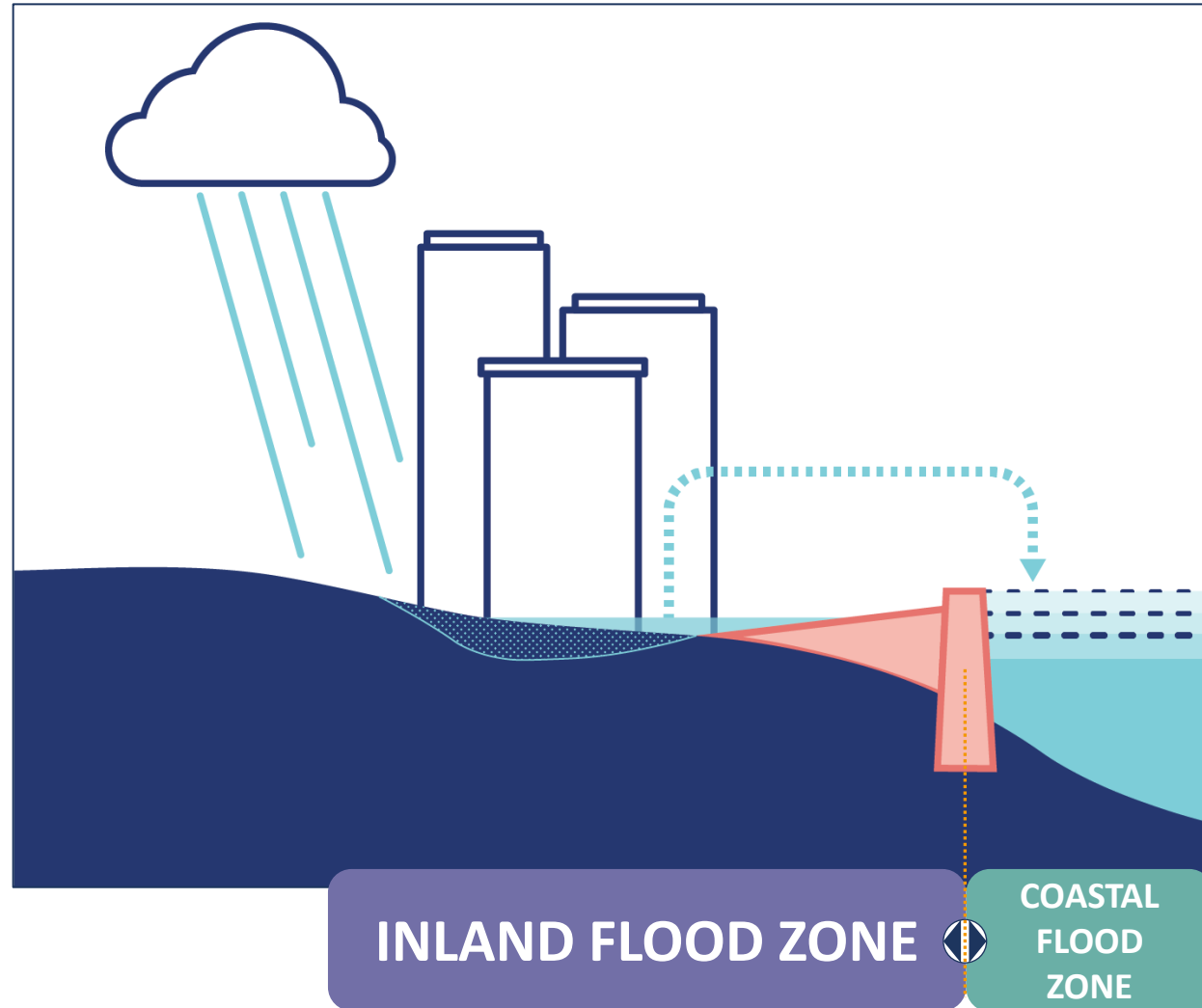
**Groundwater
and stormwater
flooding behind
raised shoreline**

COASTAL AND INLAND FLOOD RISK



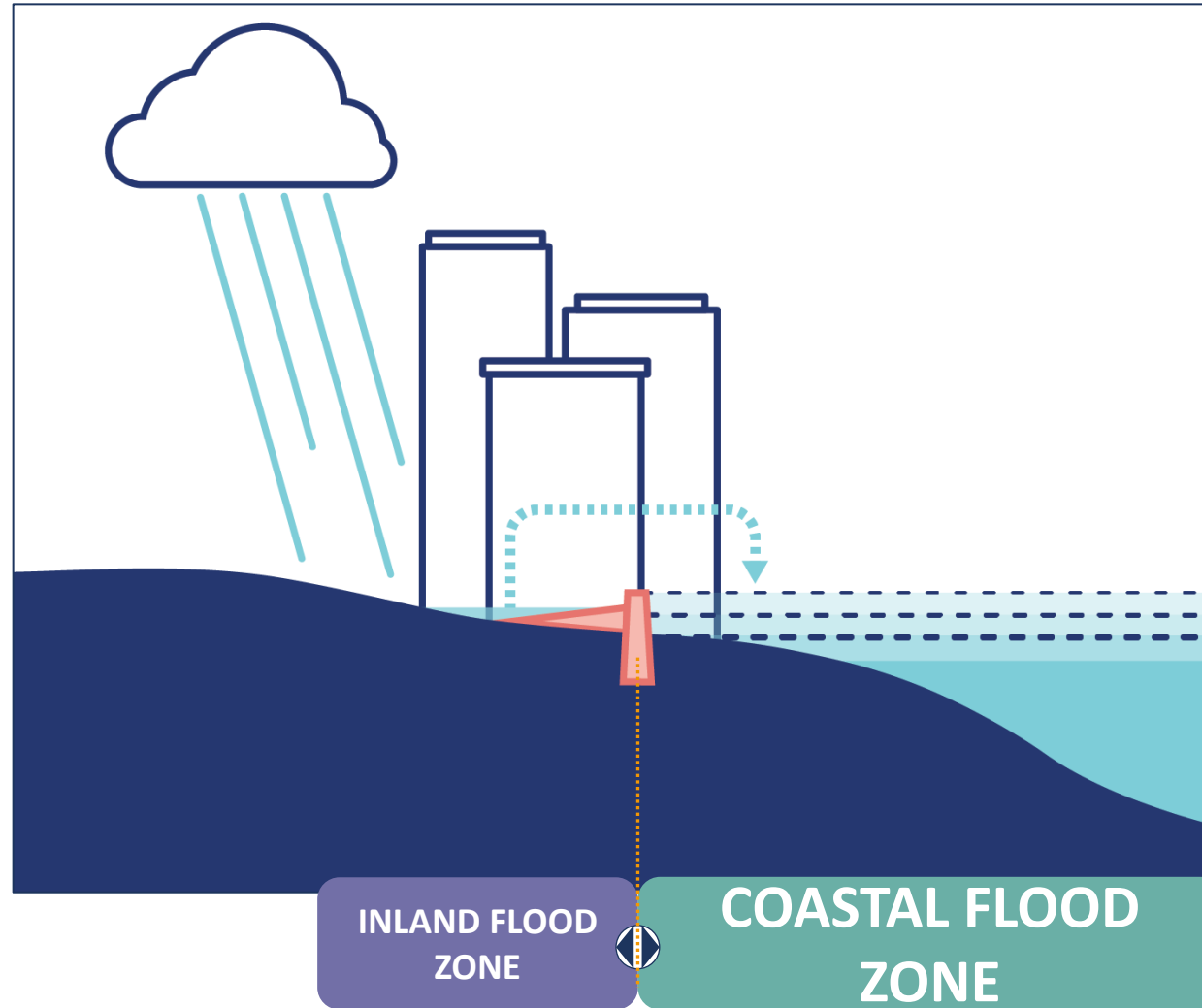
**Pumping reduces
flooding behind
raised shoreline**

COASTAL AND INLAND FLOOD RISK



Two related forms
of flooding

COASTAL AND INLAND FLOOD RISK



Shift based on the location of flood defenses

7 DRAFT WATERFRONT ADAPTATION STRATEGIES

What if...
we **did not adapt**
to mitigate the
risks?

What if...
we adapted by
floodproofing
and **moving**
buildings and assets,
without coastal flood
defense structures?

What if...
we address flooding
at a **lower rate** of
sea level rise?

What if...
we address flooding
at a **higher rate** of
sea level rise,
as recommended by
CA and SF guidance?

COMMUNITY FEEDBACK ON NATURE-BASED FEATURES

Oct 2022 - Feb 2023

We heard...

Nature-based approaches and improved public access to the waterfront remain high priority for community members, no matter the strategy.



STRATEGY EXAMPLE 1

Representative site in 2100



Redesign for a narrower roadway

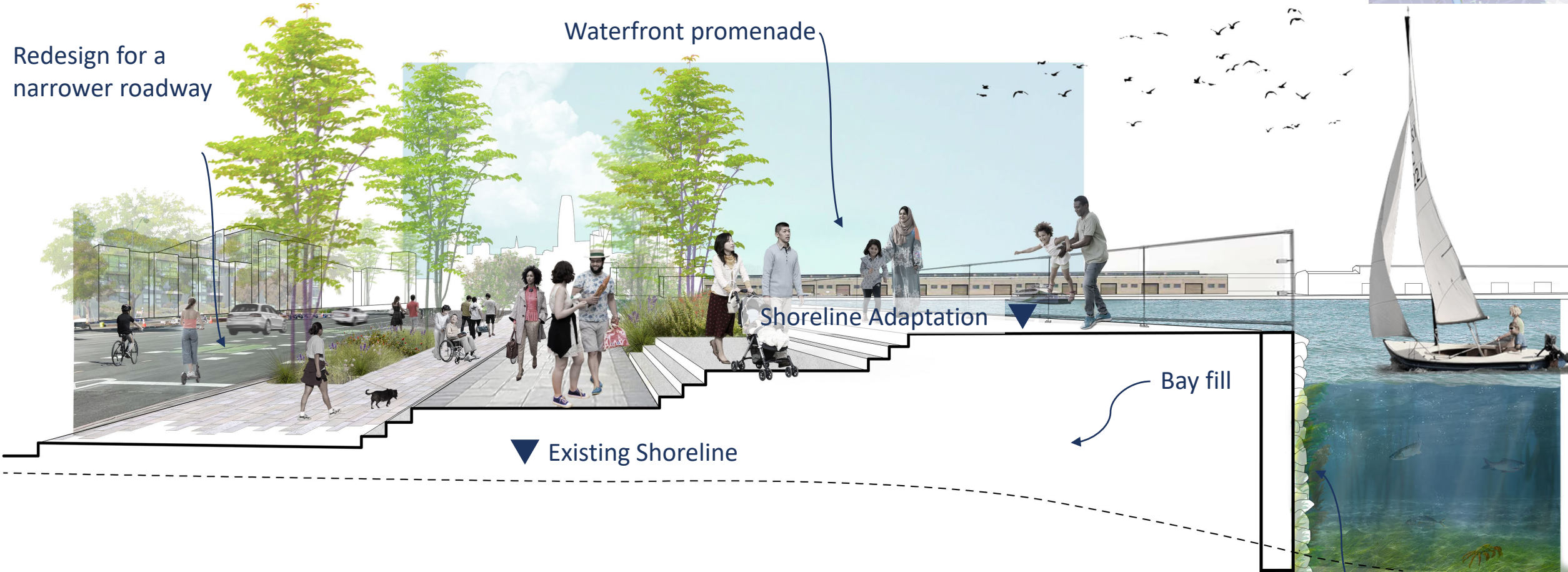
Waterfront promenade

Shoreline Adaptation

Bay fill

Existing Shoreline

Living seawall

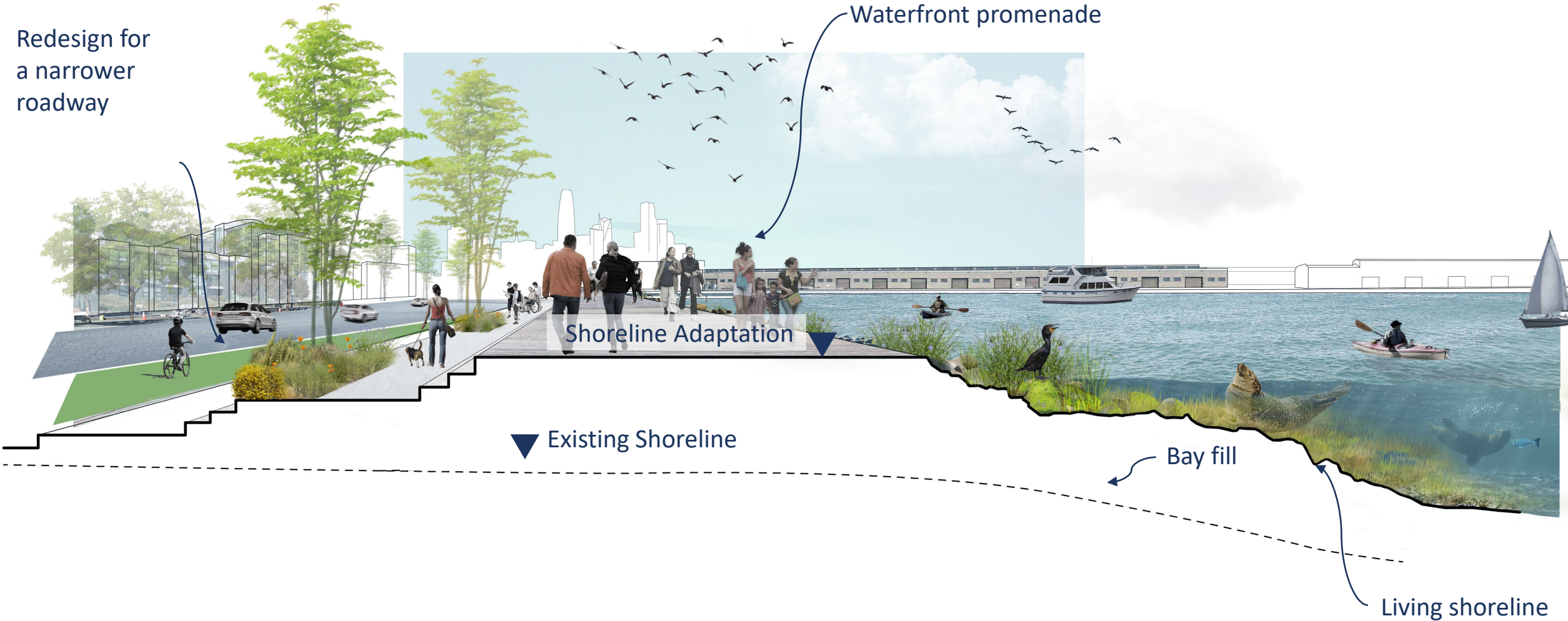


STRATEGY EXAMPLE 2

Representative site in 2100

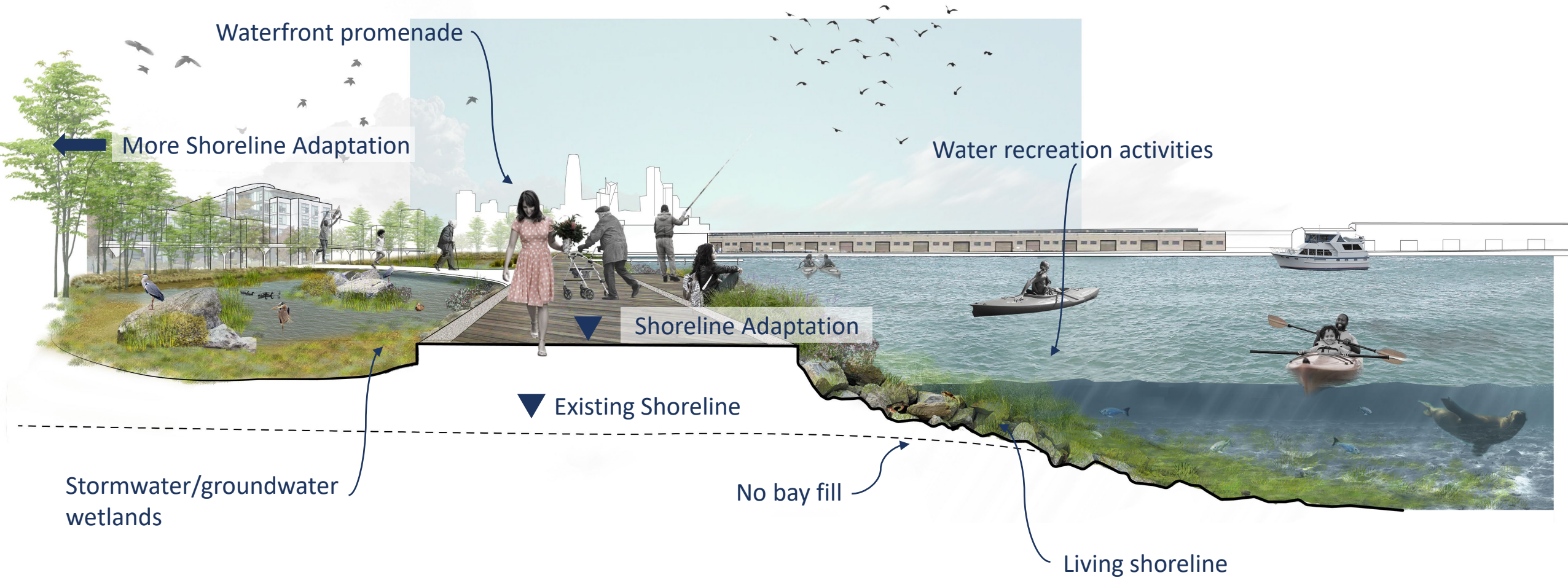


Redesign for a narrower roadway

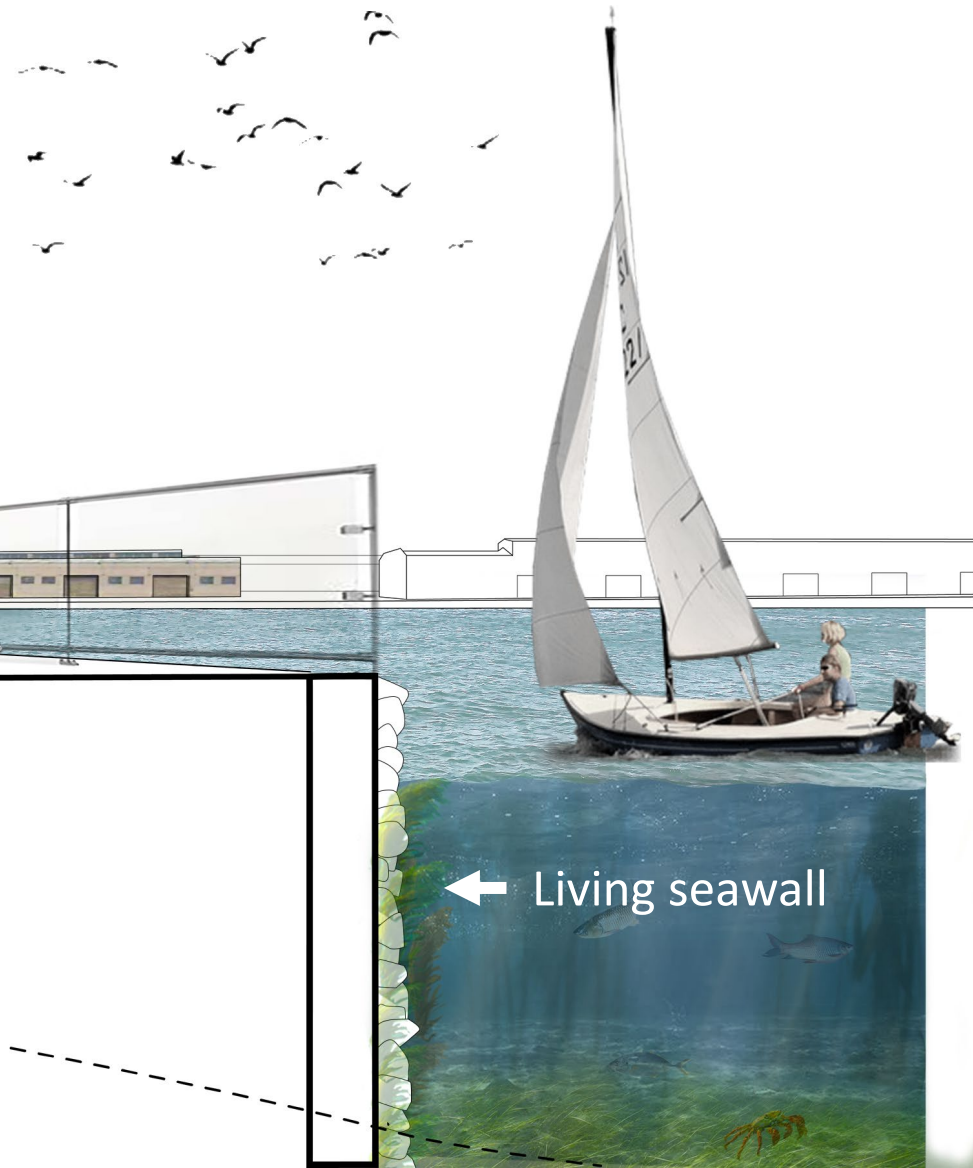


STRATEGY EXAMPLE 3

Representative site in 2100



GLIMPSE OF THE FUTURE!



PART 2

**ADAPTING TO CLIMATE CHANGE
BY ENGINEERING WITH NATURE**

U.S. Army Corps of Engineers San Francisco District

Partner with governments, community groups, Tribes and Tribal organizations.

Fed \$ to **plan, design, and construct** local water resource projects:

- Ecosystem Restoration
- Flood Risk Management
- Navigation

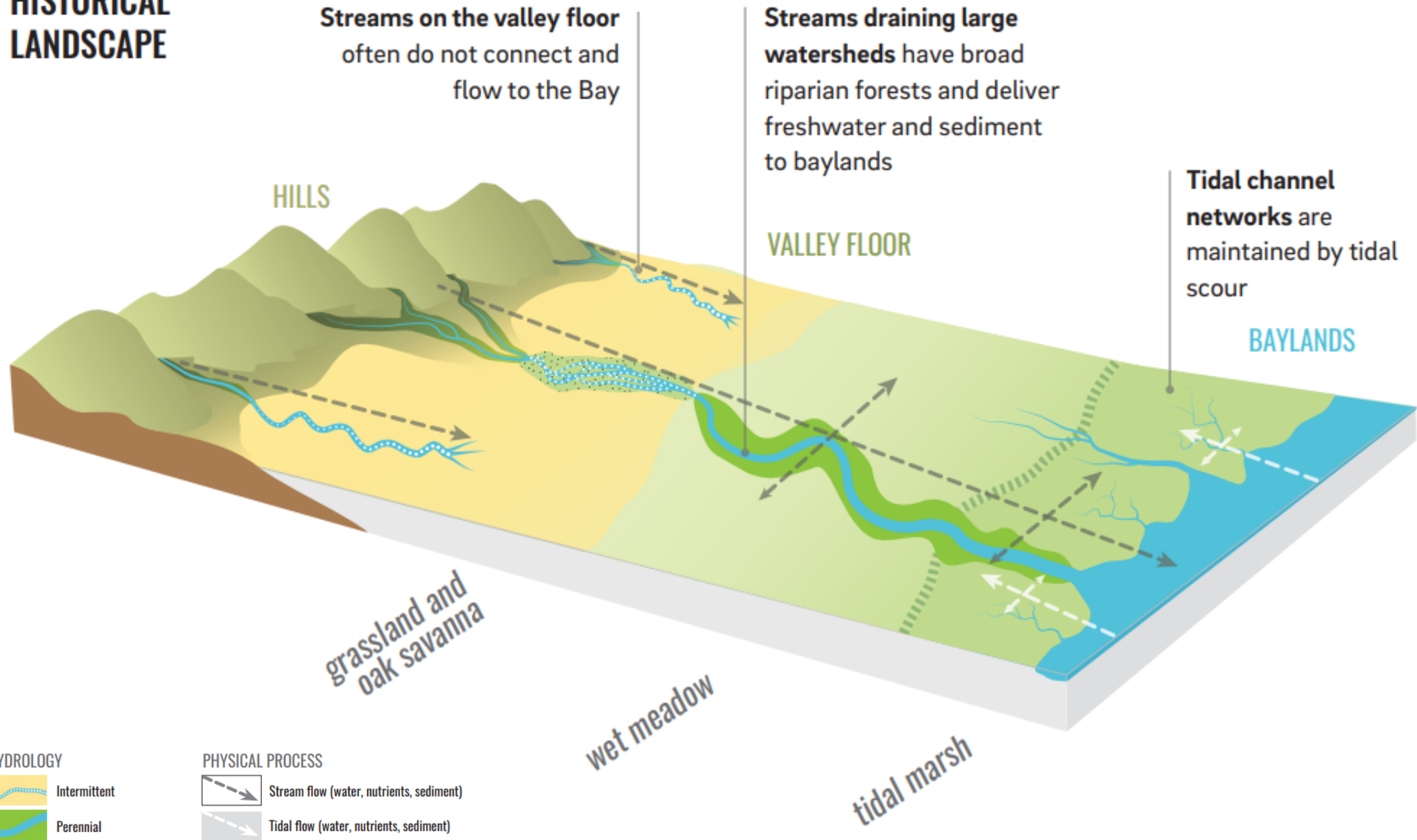
Policy-driven.

Congressionally authorized.

Project funded.



HISTORICAL LANDSCAPE

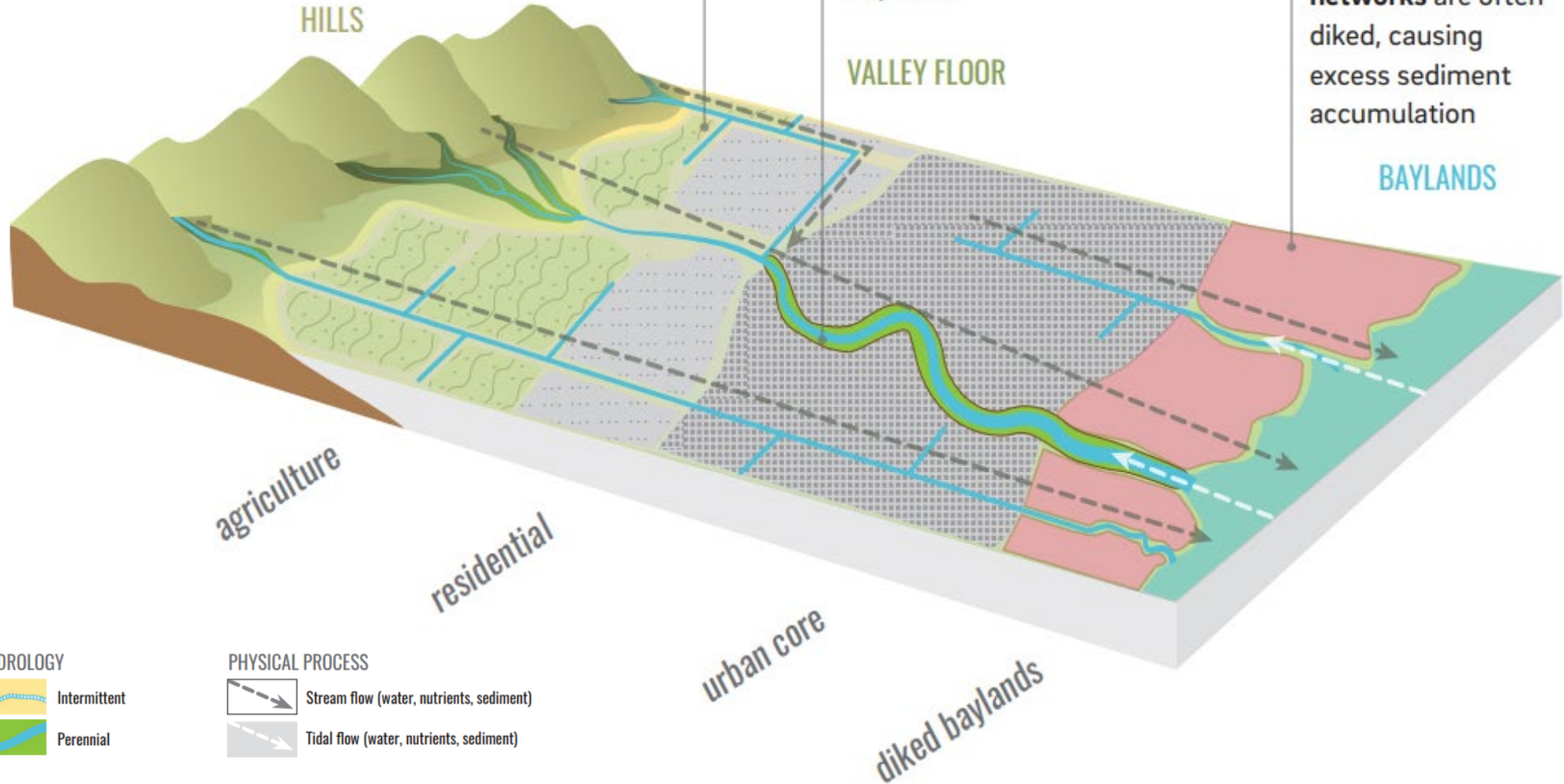


MODERN LANDSCAPE

Many streams on the valley floor are channelized and incised

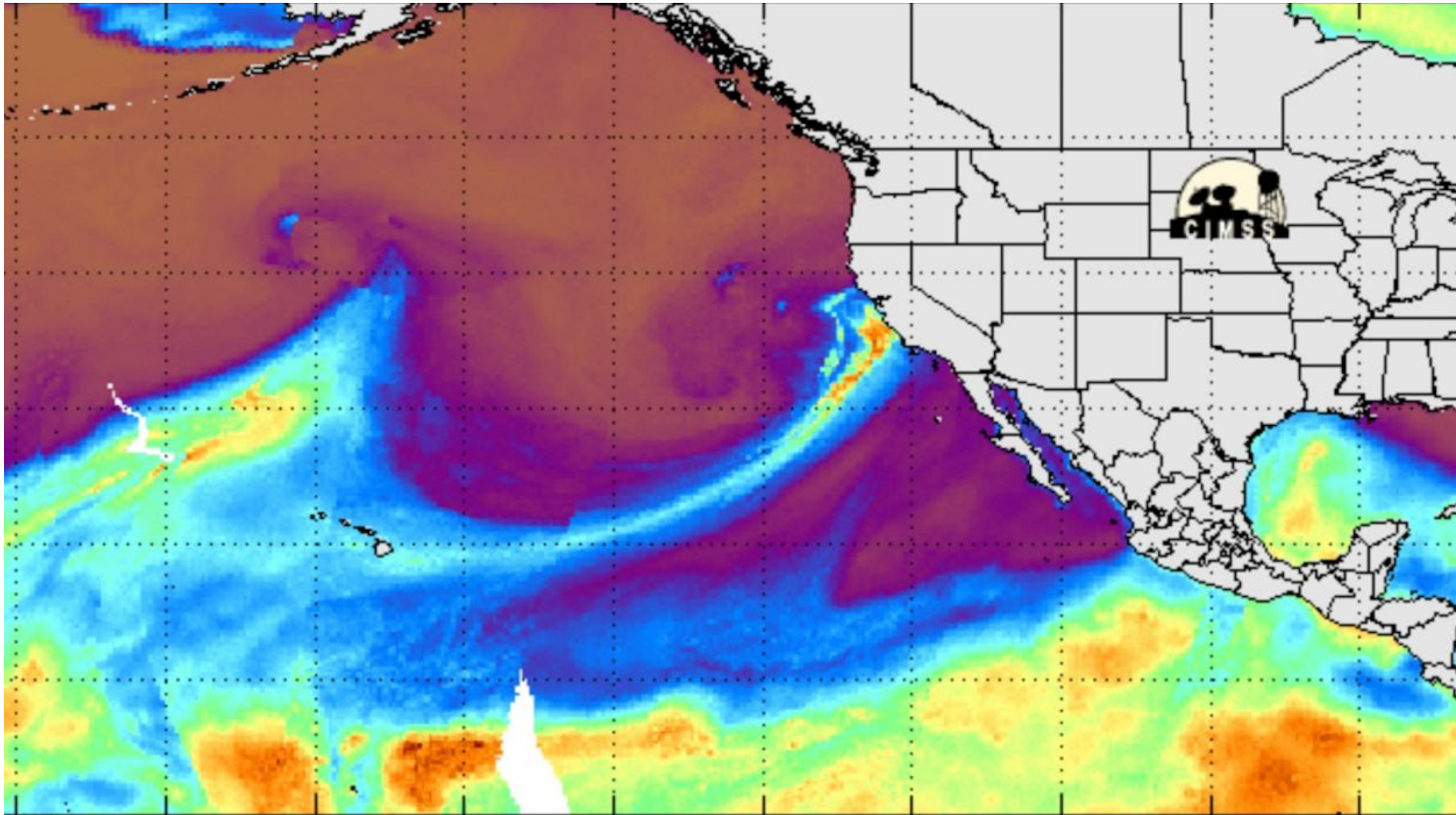
Streams draining large watersheds often have levees and no longer flow onto floodplains and baylands

Tidal channel networks are often diked, causing excess sediment accumulation

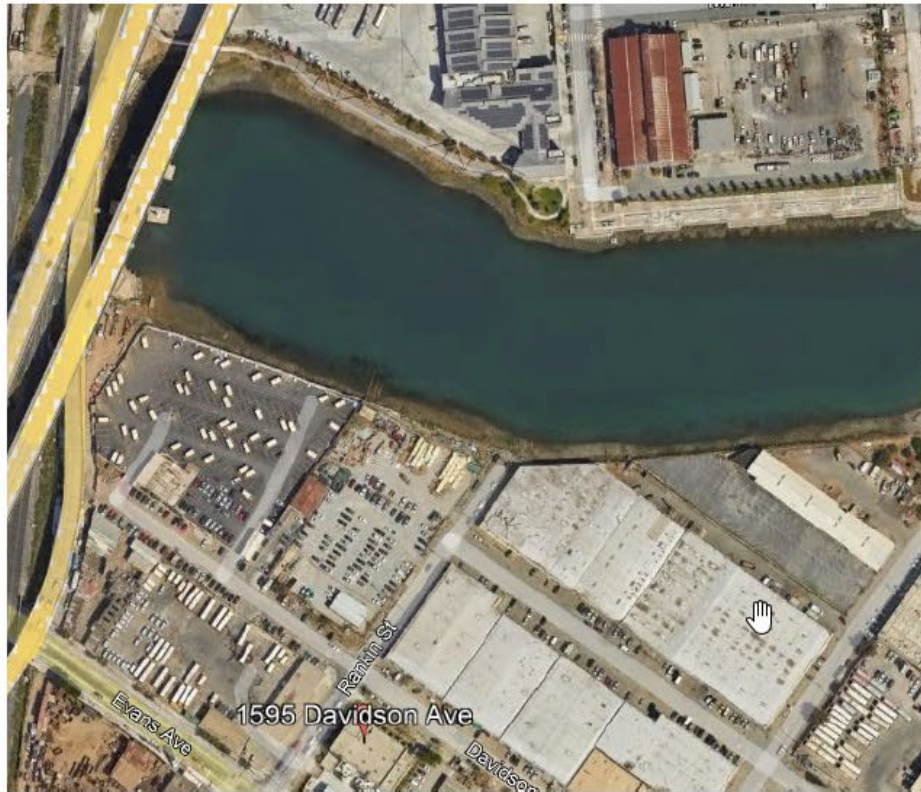


Our Gray Legacy

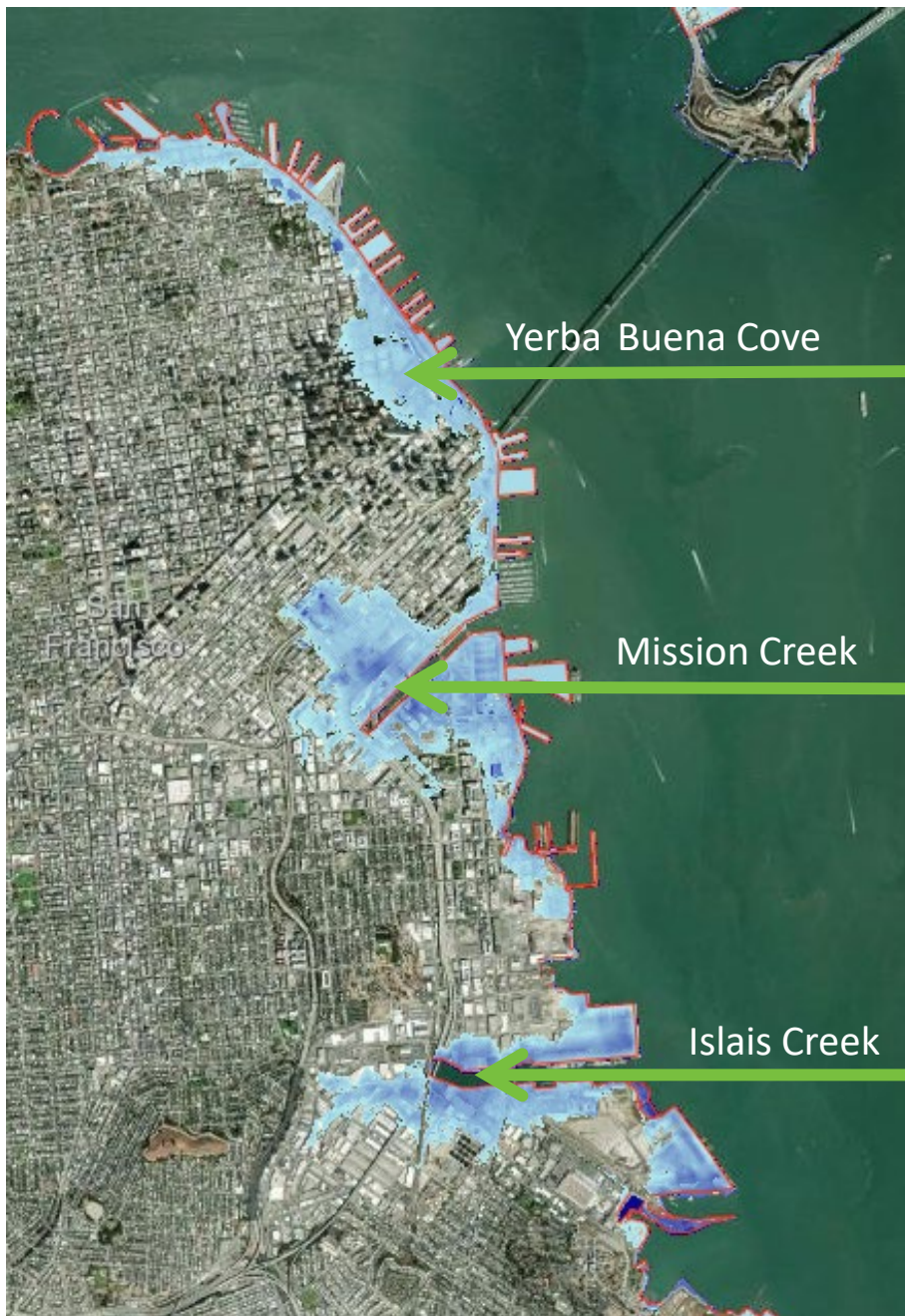








BCDC shoreline explorer. Approx 2090 High Curve USACE

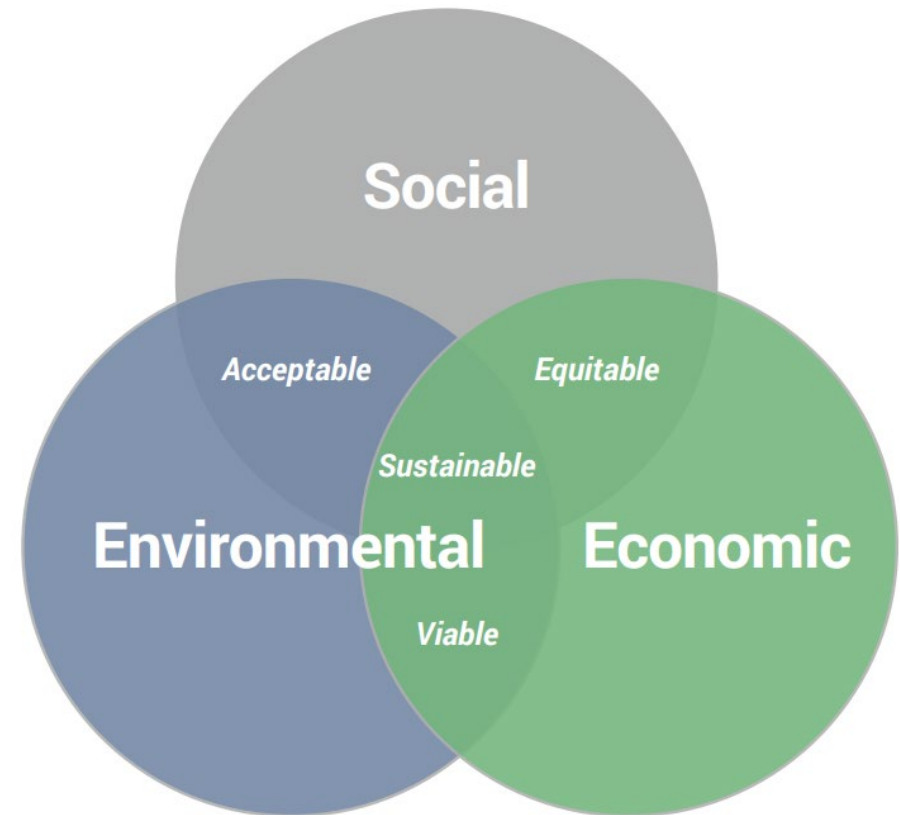


Historical Baylands c1800 EcoAtlas.org



Engineering with Nature

“Engineering With Nature[®] (EWN) is the intentional **alignment of natural and engineering processes** to efficiently and sustainably deliver economic, environmental, and social benefits **through collaboration.**”

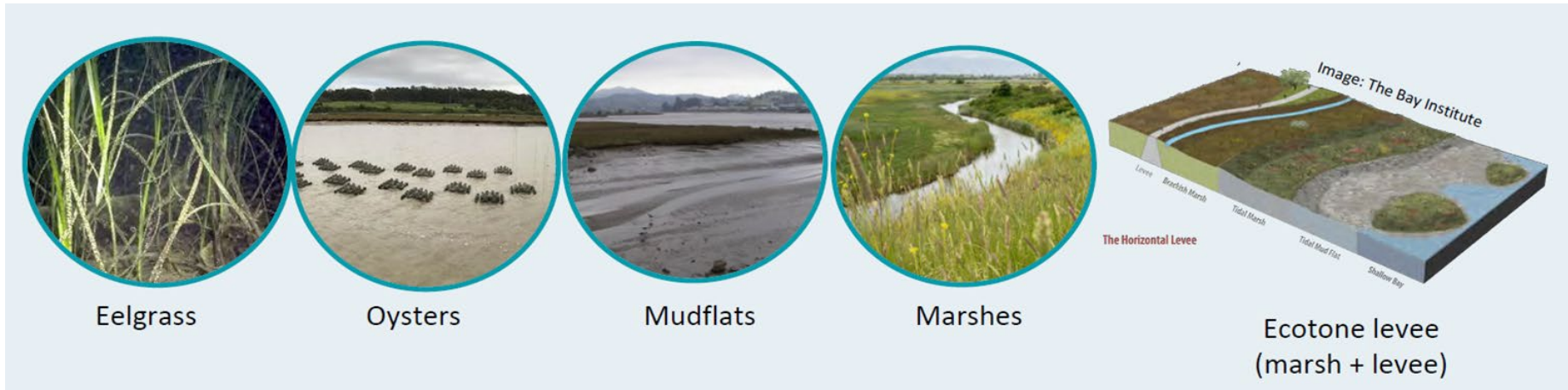


Natural and Nature-Based Features

- Use natural physical and biological processes
- Provide multiple benefits
- Can be cost effective
- Can be more adaptable over time
- Are less well understood by engineers in terms of their performance
- Need to be prioritized to where they match appropriate environmental conditions
- Can absorb energy instead of reflect



Natural and Nature-based Features in the Bay



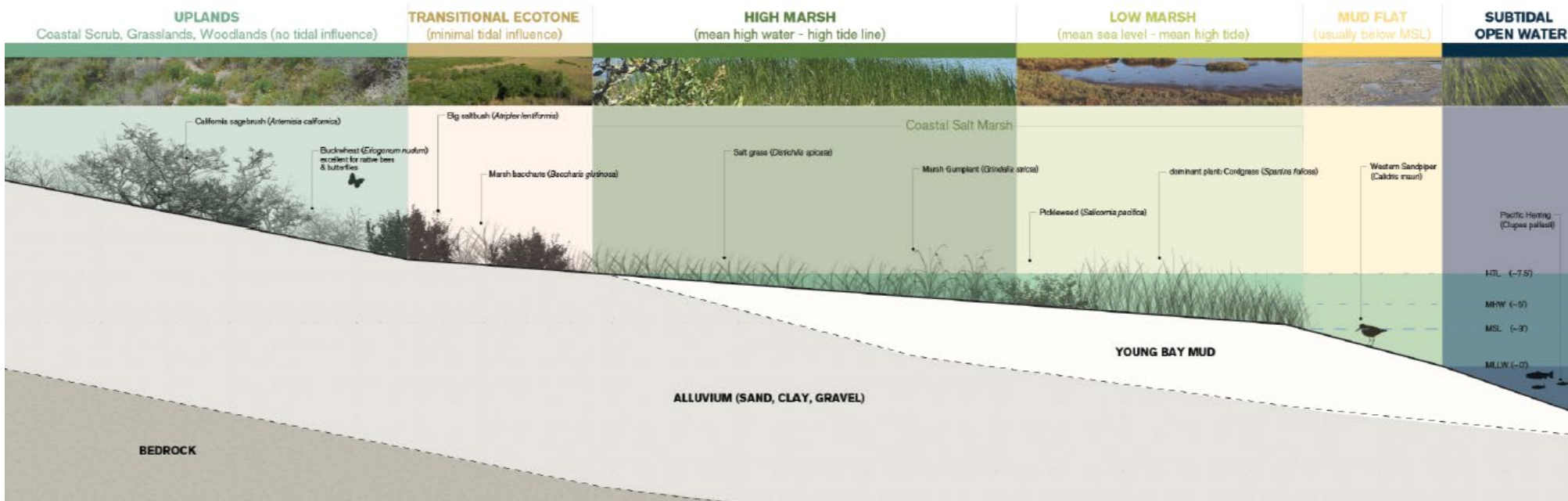
Eelgrass

Oysters

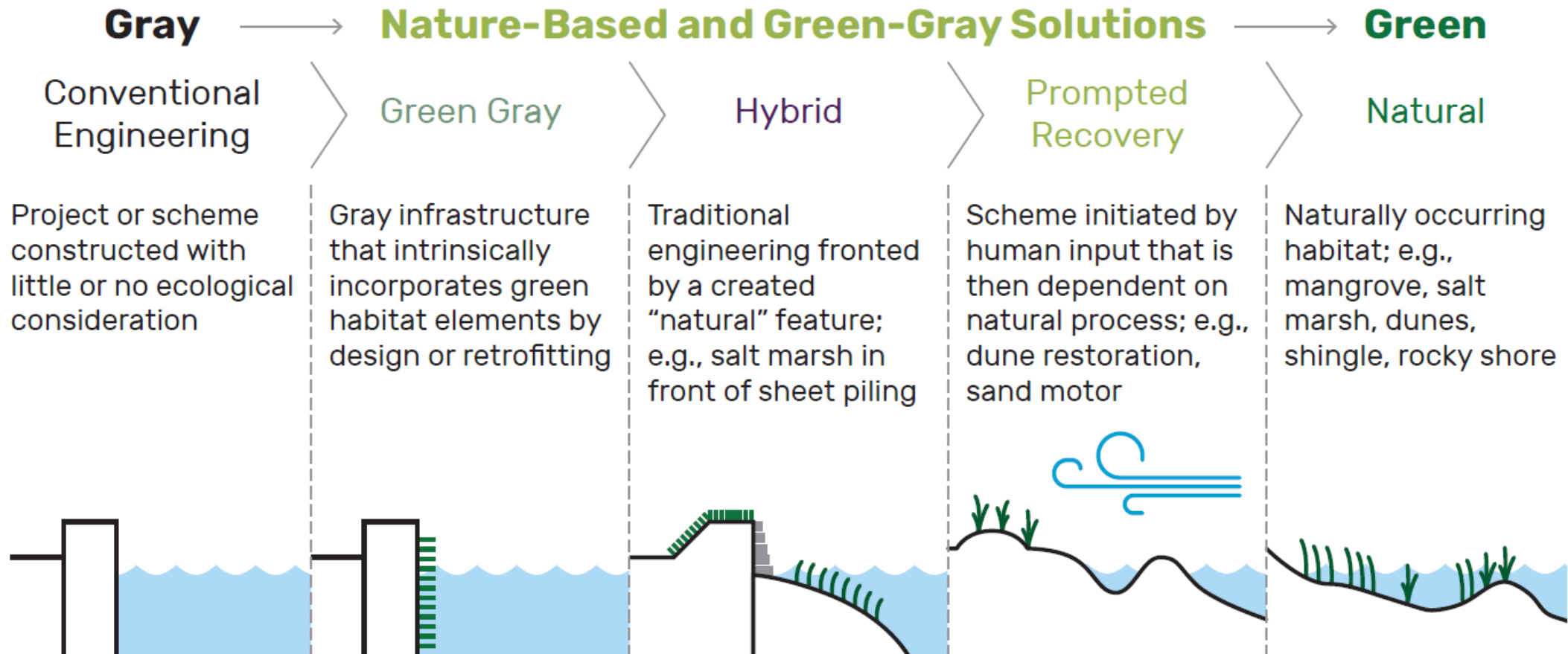
Mudflats

Marshes

Ecotone levee
(marsh + levee)



Gray to Green Spectrum





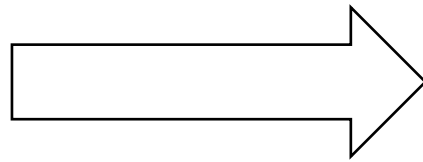
Yolo Bypass (Sacramento River Flood Control Project) 1917



Hamilton Wetlands (BUDM for wetland restoration)



**Opportunistic
Individual**



**Strategic
Systemic
Collaborative
Equity-Focused**

Challenges to Implementing EWN at USACE

- Lack of multi-benefit approaches, budgeting, planning, policies, and business lines
- Knowledge gaps and unfamiliarity with options
- Inability to measure benefits equitably
- Top-down and internally driven approaches (as opposed to community and partnership-focused)
- “We’ve always done it this way”
- Short-term impact for long-term ecological benefit

San Francisco District Proving Ground

Implement. Document. Share.

EWN Proving Grounds are USACE districts and divisions committed to the broad integration of EWN principles and practices into all business lines in the form of constructed projects. Proving grounds are places where innovative ideas are tested on the ground, throughout USACE missions. They document processes, project milestones, and lessons learned in the implementation of EWN measures so others can learn from their experience.



[Mobile District](#)

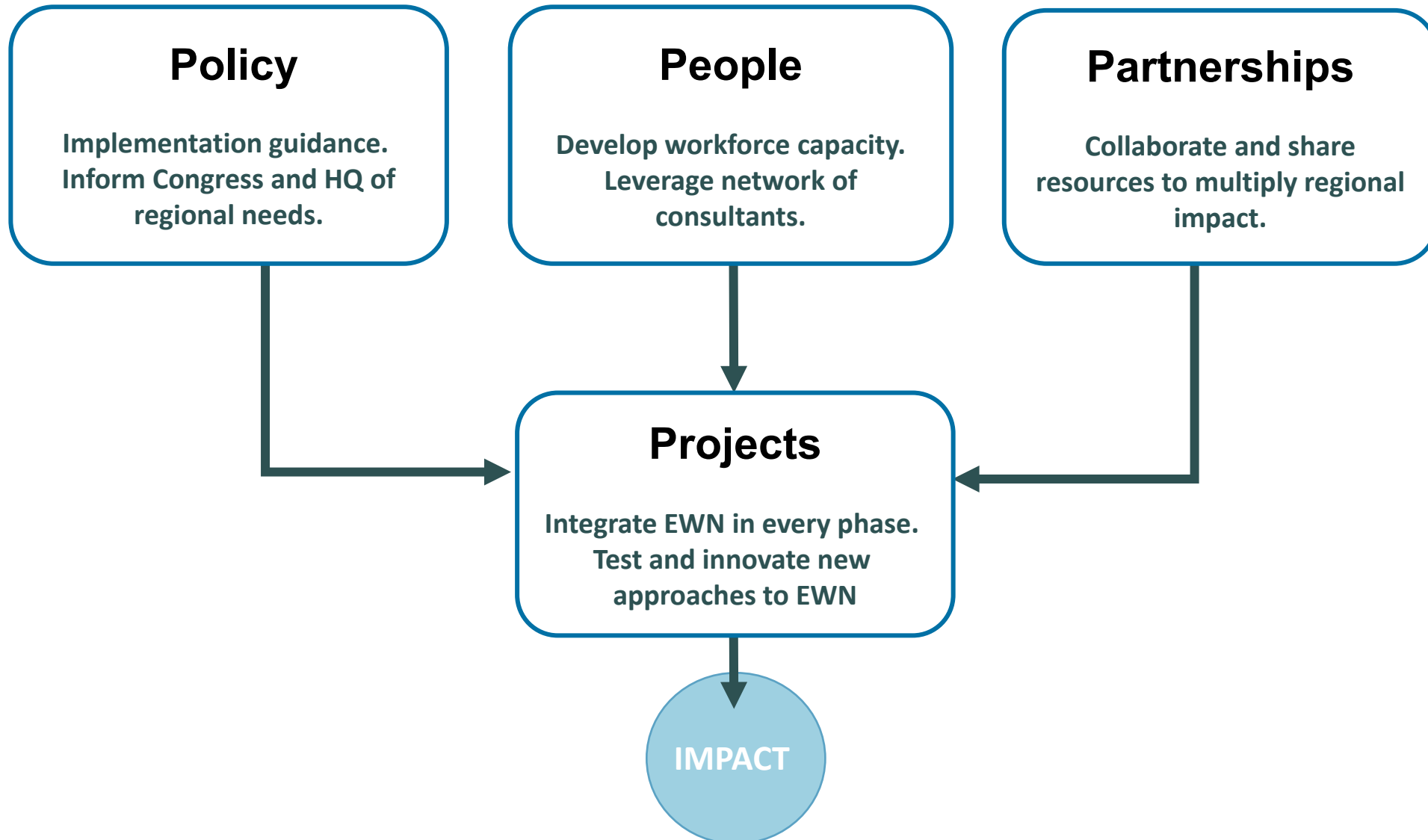


[San Francisco District](#)

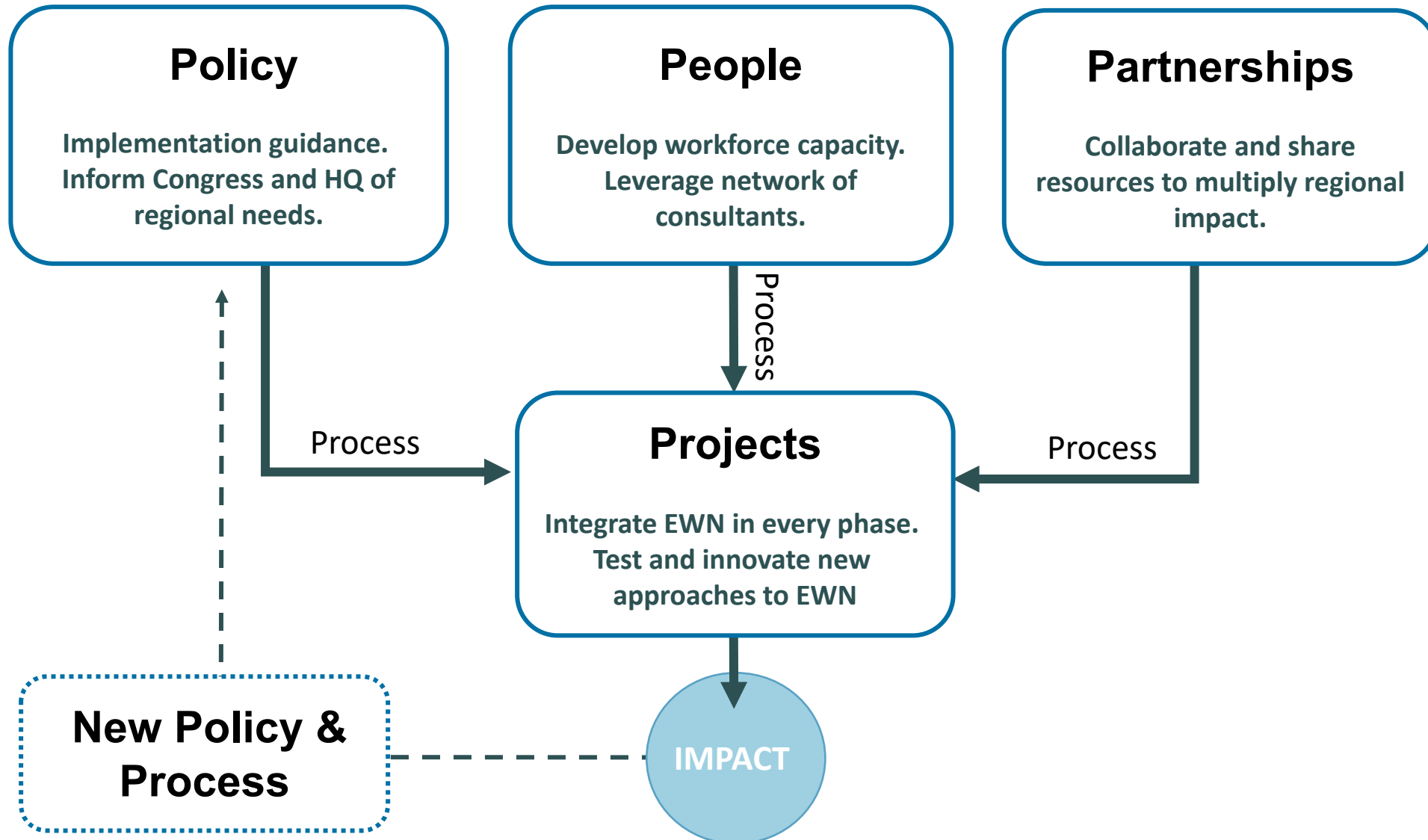


[St. Louis District](#)

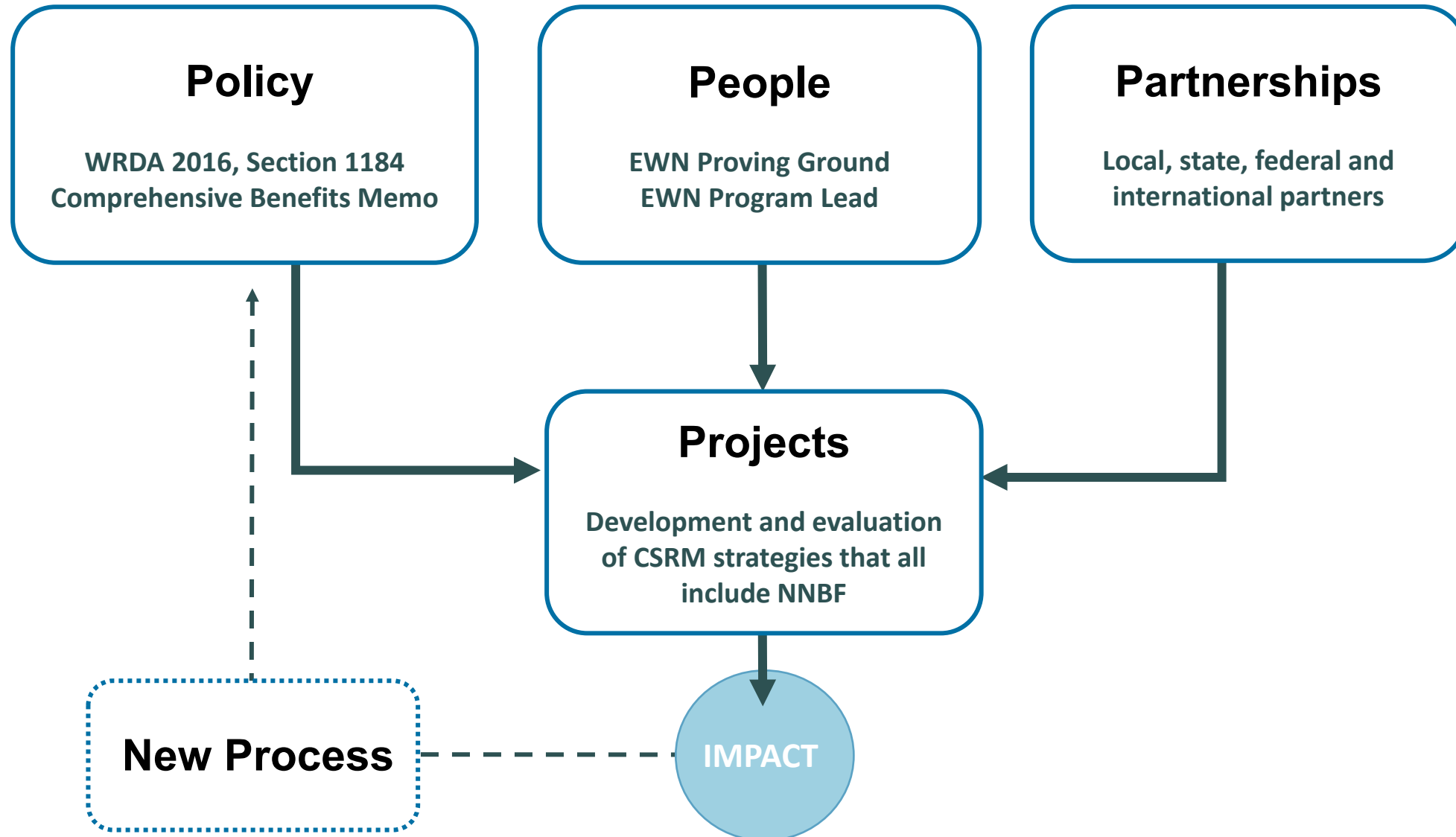
How do we deliver EWN... and transform the organization



How do we deliver EWN... and transform the organization



Applications to San Francisco Waterfront Project



PART 3

INTEGRATING EWN ALONG THE SF WATERFRONT

INTRO

Integrating EWN while balancing varied project objectives



INTRO

Varied site geography



Fisherman's Wharf
Source: Port of SF



Pier 94 + Islais Creek Backlands
Source: Port of SF

INTRO

Varied risk profiles



Inland Flooding, Fisherman's Wharf

Source: Port of SF



Waves, Rincon Park

Source: Port of SF

INTRO

Varied adaptation strategies being considered

**SHORELINE
LOD**

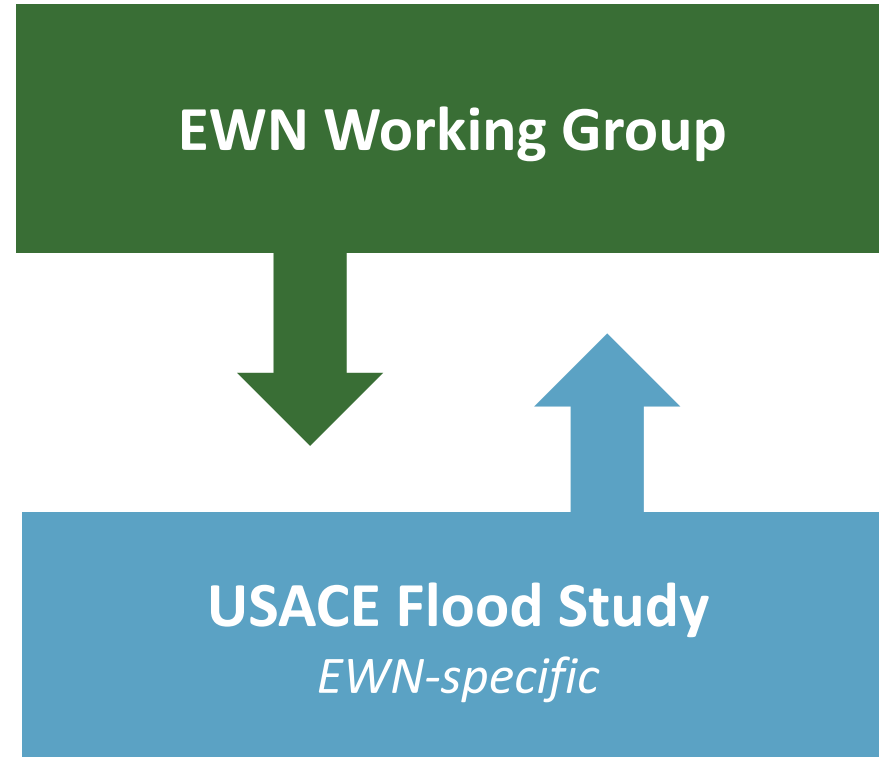
**ACCOMMODATE/
SOME RETREAT**

MOST RETREAT



PROCESS

Interconnected processes



PROCESS

EWN provides numerous co-benefits, including...

USACE focus

Coastal Storm Risk Reduction

Contribute to:

- Reducing/dissipating wave energy
- Reducing wave run-up
- Reducing erosion

Infrastructure

Contribute to:

- Extending typical lifespan
- Can reduce O&M costs

Social Benefits

Contribute to:

- Improving access to the Bay and nature
- Increasing educational opportunities

Environmental

Contribute to:

- Providing varied habitat for a range of species
- Reducing inland stormwater flooding
- Connecting existing habitat patches

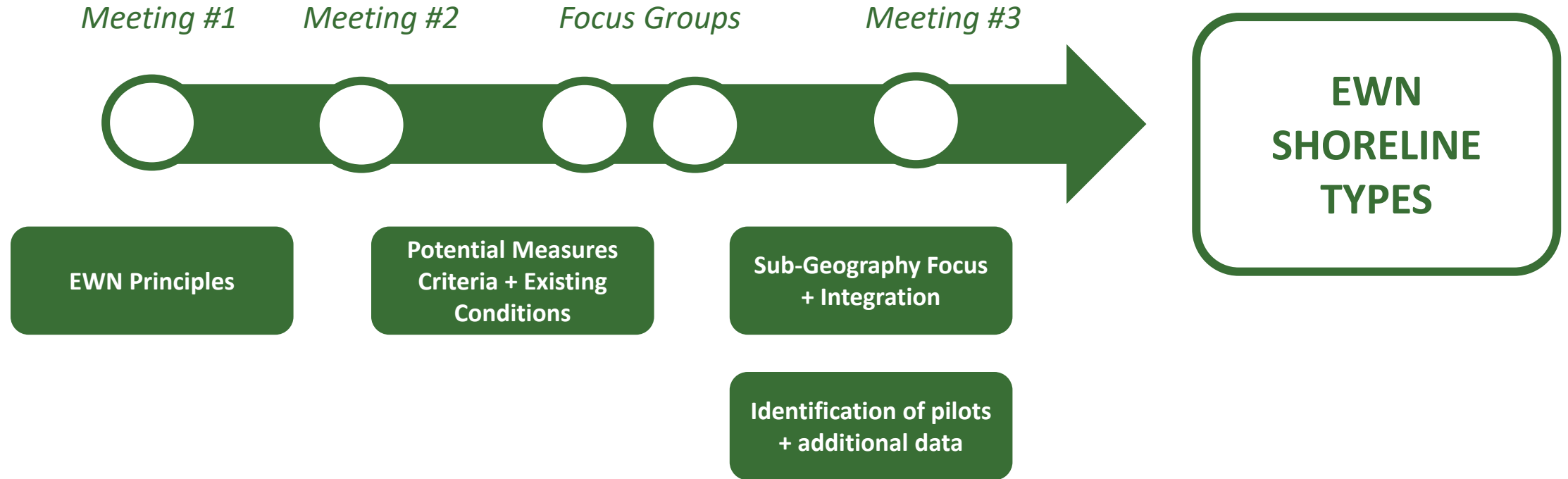
Economic Benefits

Contribute to:

- Marine economic uses (e.g., fishing)
- Coastal asset risk reduction

EWN Working Group

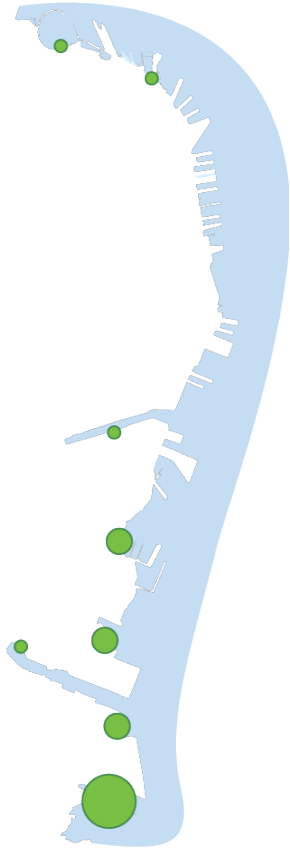
May – September 2022



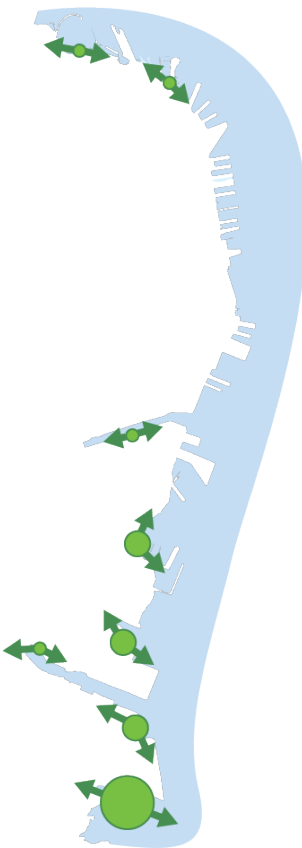
EWN Working Group

Principles: preserve, expand and connect along shoreline and inland

Protect/Conserve Existing



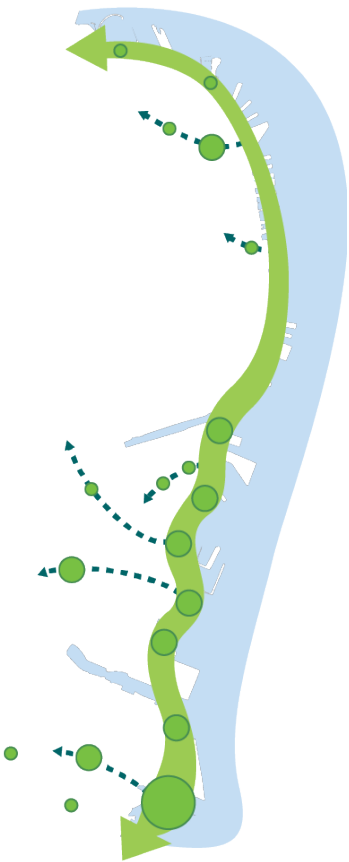
Enhance/Expand Existing



Connect along the shoreline

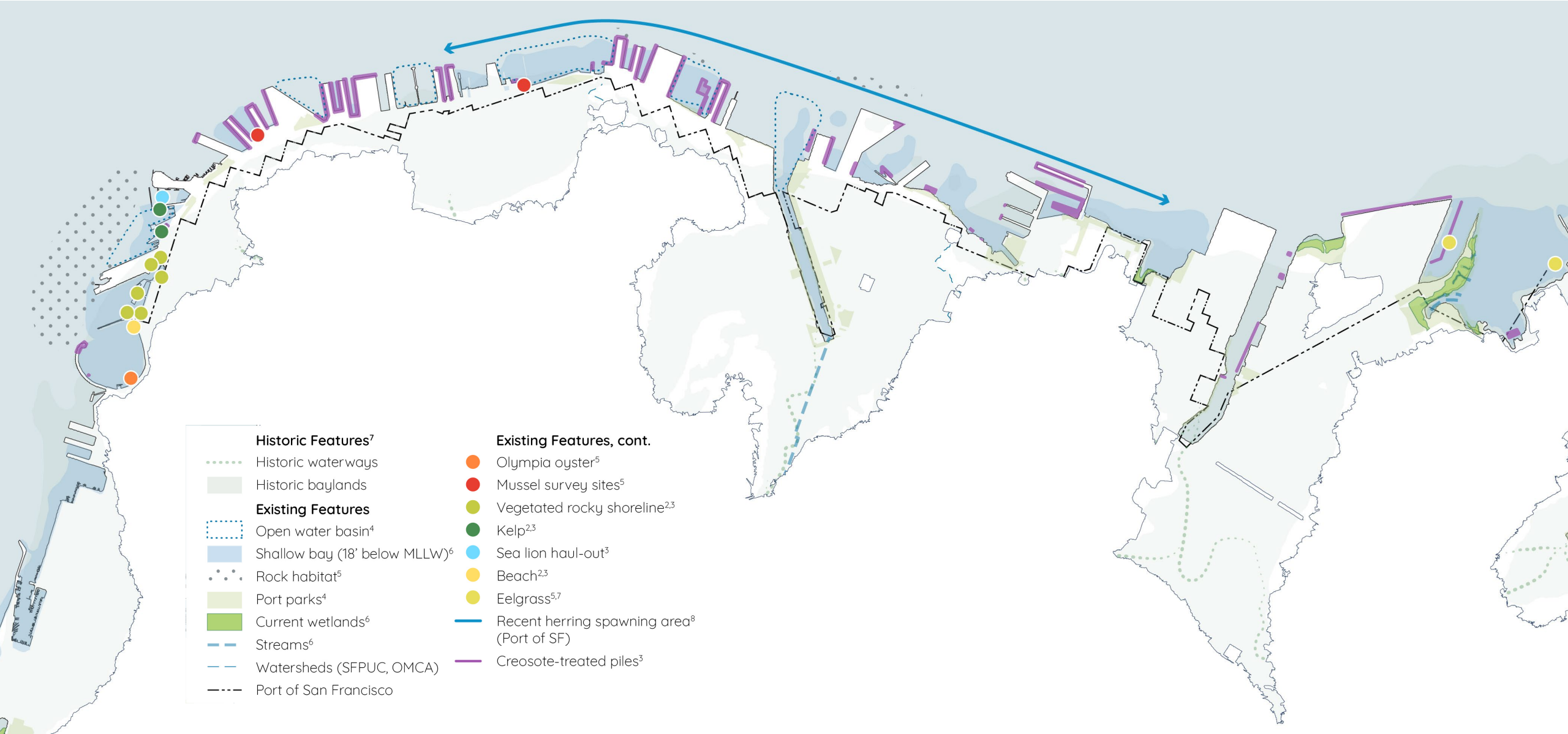


Expand inland/upland



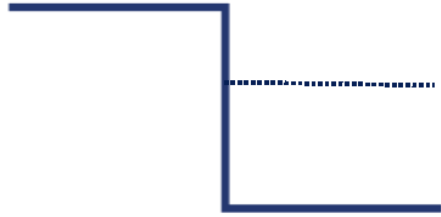
EWN Working Group

Analysis of existing conditions



EWN Working Group

Measures: Four Shoreline Types



Vertical Structure

Typical conditions:

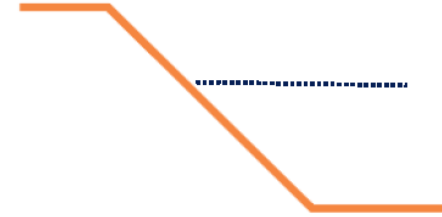
- Seawall
- Higher wave action
- Active maritime uses/access
- Deeper waters



Perched

Typical conditions:

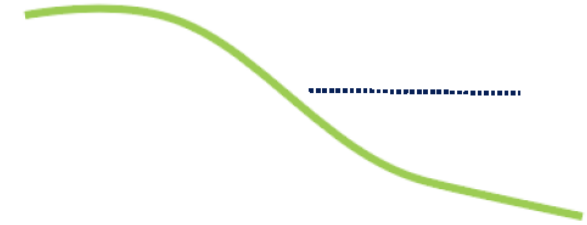
- Seawall
- Limited maritime uses/no direct access
- Shallower water



Embankment

Typical conditions:

- Structural slope
- Some maritime uses/no direct access



Naturalized Bayland

Typical conditions:

- Gentle slope
- Shallower water

EWN Working Group

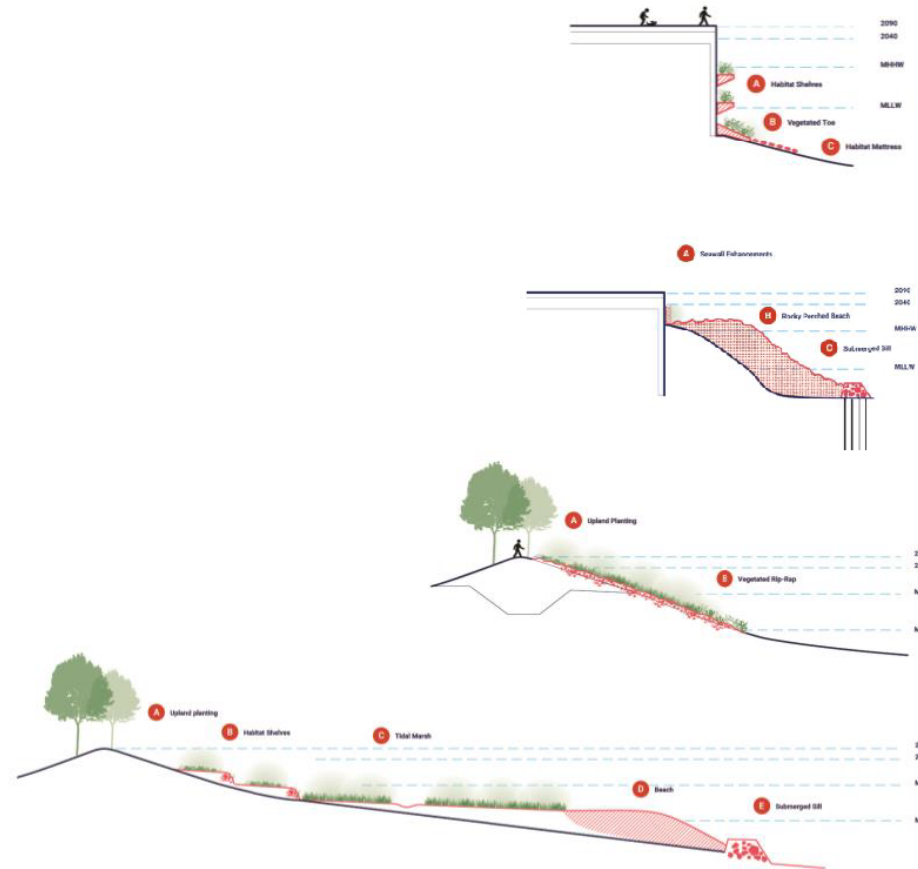
Flexibility of EWN shoreline types

Vertical Structure

Perched beach/marsh

Embankment

Naturalized Bayland



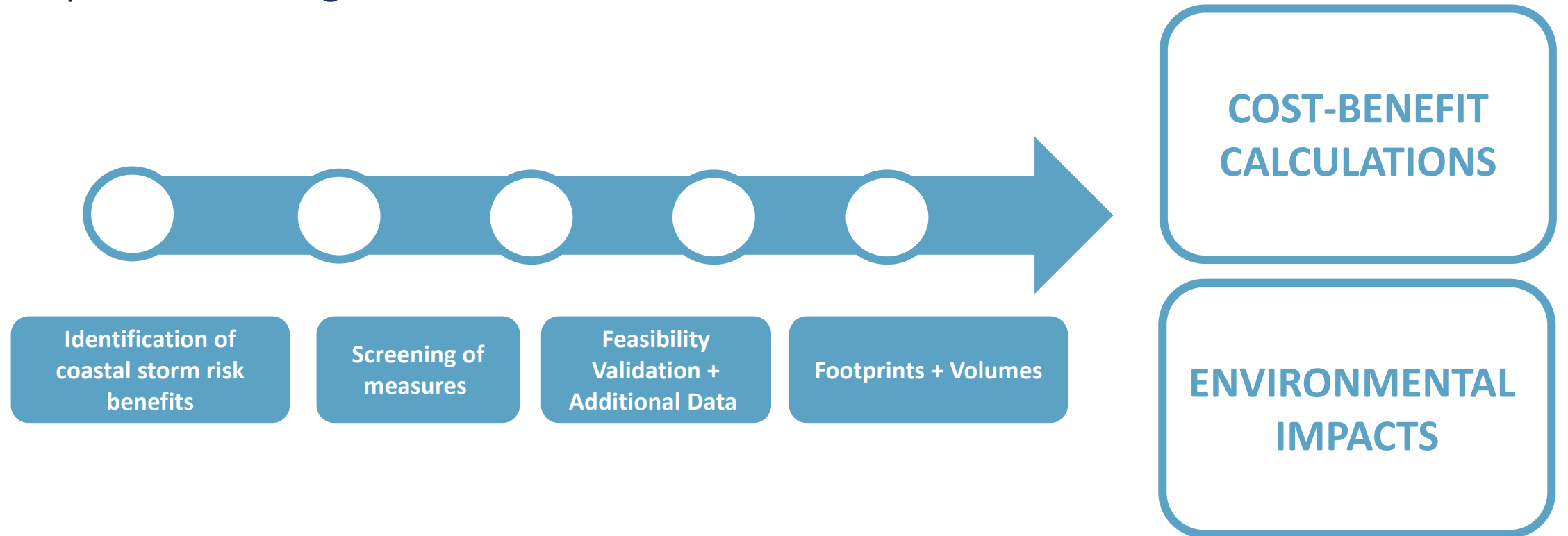
Narrower section/
more constrained



Wider section/more
opportunities

USACE FLOOD STUDY

EWN-specific meetings



USACE FLOOD STUDY

Screening Measures

- Proposed measures reflect an analysis of the sited risks, opportunities, considerations, and constraints.
- The measures proposed here all fall along a gray-green spectrum. This reflects the highly urbanized context of the study area.
- Traditional approaches predominantly provide CSRMs benefits through a single measure sited in a given location along a shoreline.
- By contrast, EWN measures can be combined across a terrestrial to aquatic transect to provide *multiple integrated* benefits in one location.

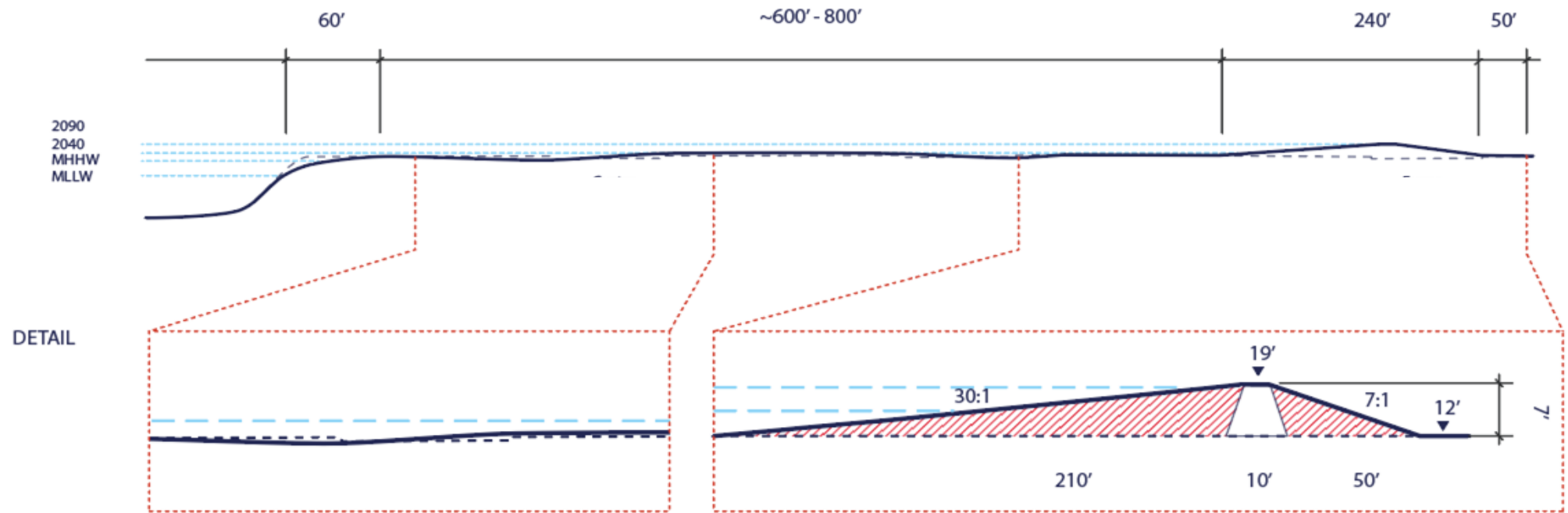
Retained Measures	Tentatively Retained	Screened
Existing coastal wetland (restoration/enhancement/inland migration)	Mudflat augmentation	Submerged breakwater
Marsh establishment/de-paving (new marsh)	Pier/piling habitat improvement	Polder Management
Ecotone levee	Wharf enhancements (light penetration)	Sandy beaches (nourishment/establishment)
Coarse beaches (nourishment/establishment)	Subtidal Habitat Improvement: Submerged aquatic vegetation, oyster beds, nearshore reef	Islands
Living Seawall	Living breakwater	Upland habitat
Ecological armoring	Green stormwater infrastructure	
	Creek to baylands reconnection	
	Afforestation/urban corridors	

DRAFT

USACE FLOOD STUDY

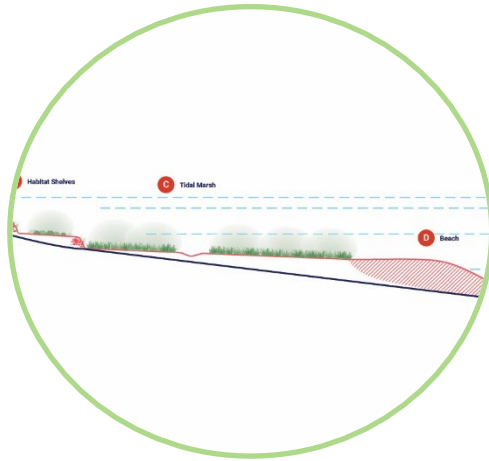
EWN-specific meetings

FULL SECTION



EWN INTEGRATION

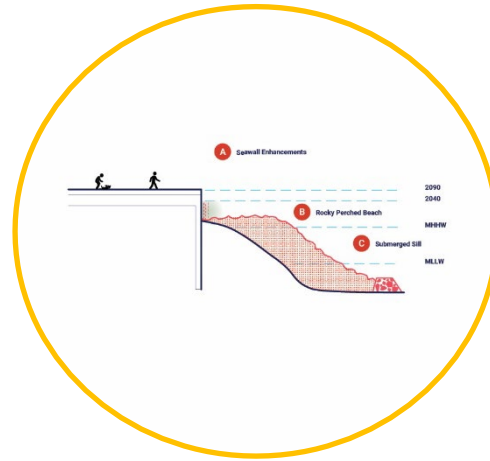
Big Moves



Wetland

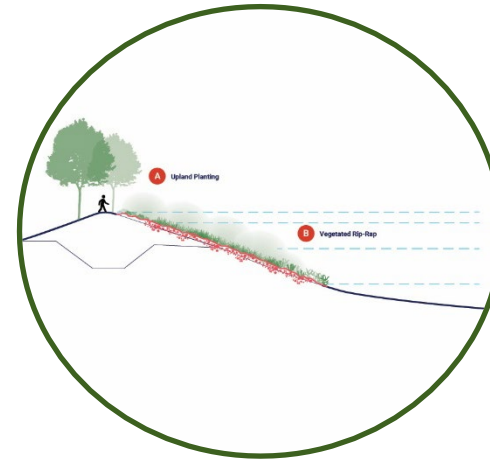
Preserving/enhancing existing vs. new (de-paving, expanding, etc.)

Range: Tidal-brackish-stormwater



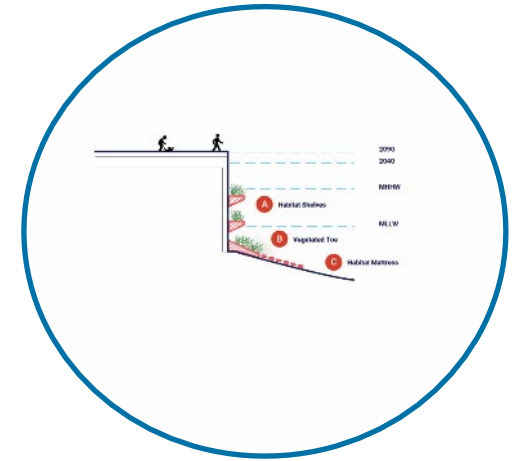
Coarse Beach

Perched, onshore, existing grade



Berm

Creeks and shoreline

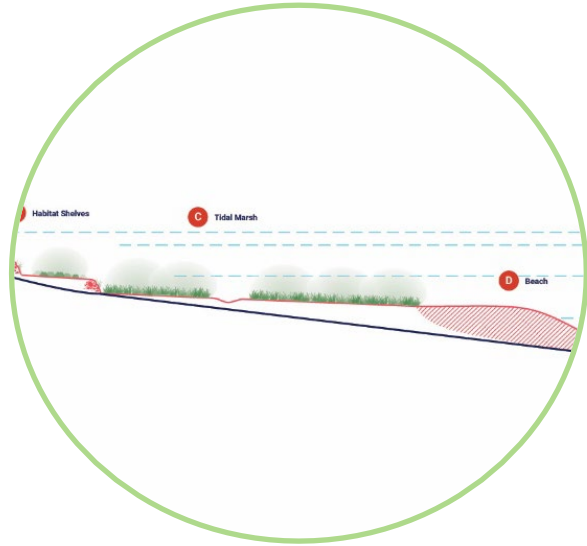


Living Seawall

With fill, without fill, stepped

EWN INTEGRATION

Big Moves: Wetlands + Ecotone Levee



Source: Port of SF

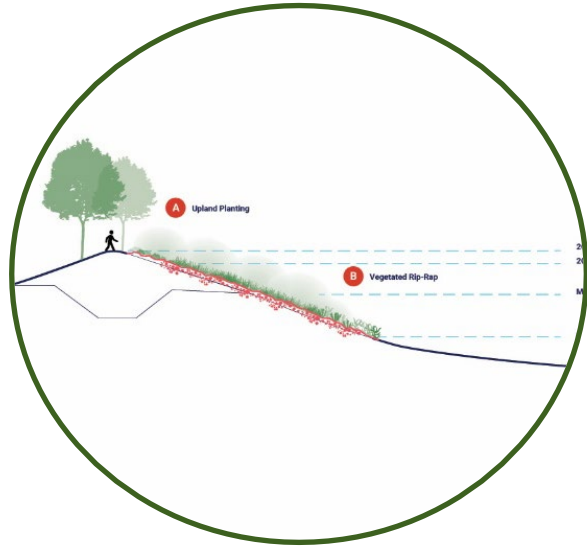
Potential Sites Analyzed



*Southern
Waterfront*

EWN INTEGRATION

Big Moves: Berms



Source: Thames Estuary Edges

Potential Sites Analyzed



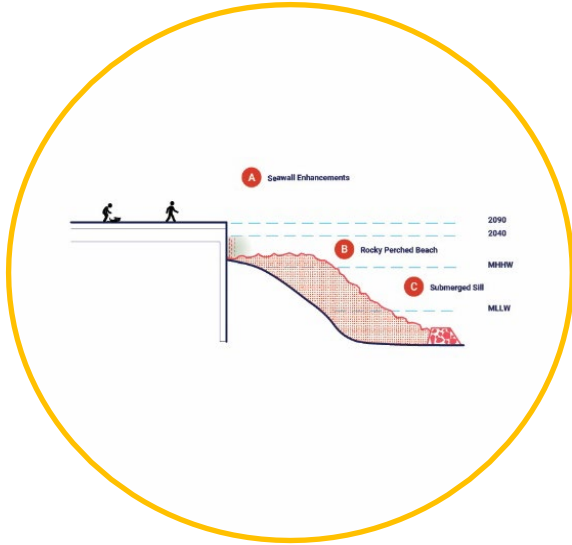
Aquatic Park

Mission Creek/Bay

*Islais Creek +
Warm Water Cove*

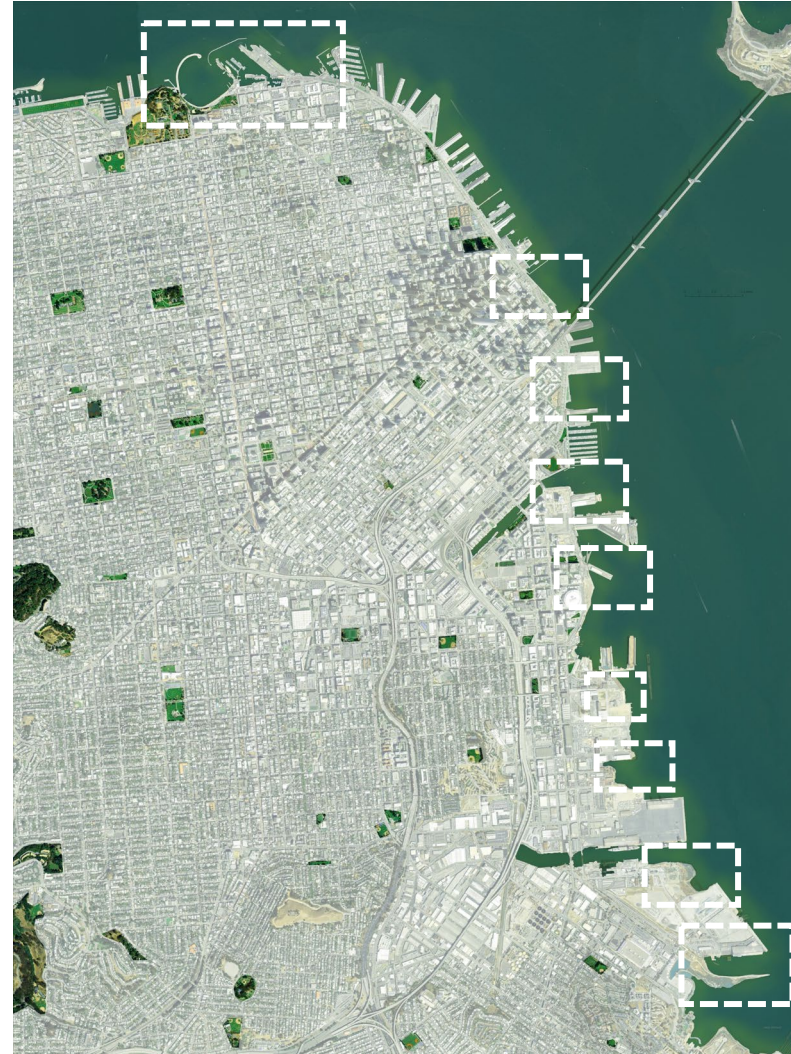
EWN INTEGRATION

Big Moves



Source: SFEI

Potential Sites Analyzed



Rincon Park

Brennan St. Wharf

China Basin

Bayfront Park

Pier 70 + Potrero PPT

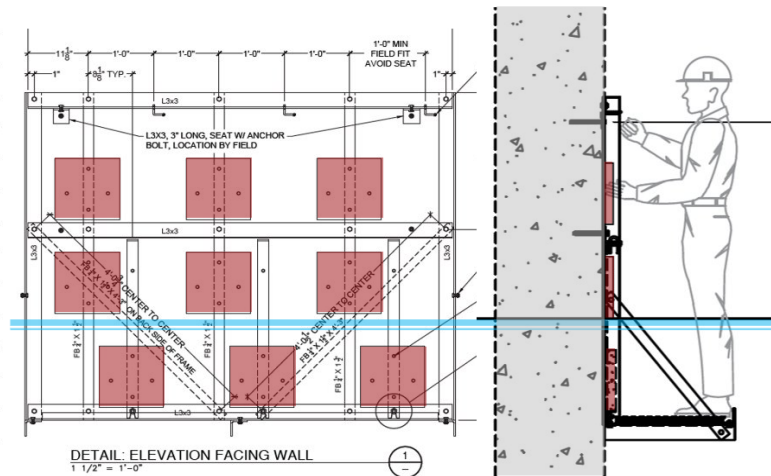
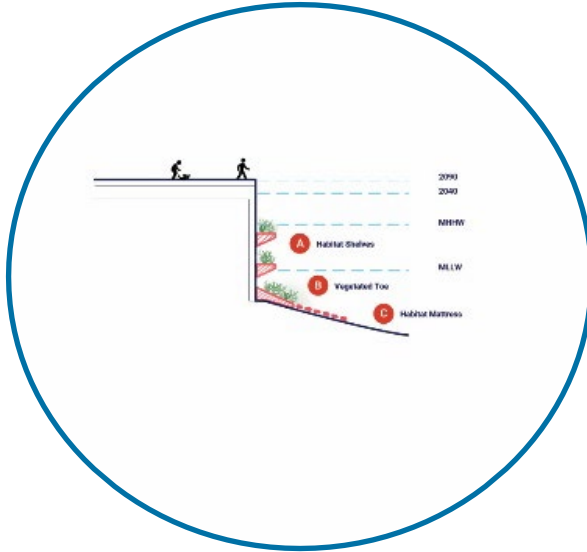
Warm Water Cove

Pier 94

Heron's Head

EWN INTEGRATION

Big Moves



Source: Port of SF

Potential Sites Analyzed



Northern Waterfront

Mission Creek (Mouth)

Mission Bay

EWN Integration

Opportunity to start to build a new relationship between the city and natural systems

Historic

Varied habitat types across interconnected coastal and riparian systems



Today

Limited patches of habitat and disconnected environmental systems



Hybrid Opportunity

Layer in naturalized edges, strategically re-connect habitats and restore natural systems



PART 4

LESSONS LEARNED

EWN is the Path Forward

- Projects are the vehicle for change..... And change takes time
- Local sponsors need to request EWN early and often
- EWN requires consistent knowledge sharing and collaboration across agencies and disciplines (and a growth mindset!)
- Deep knowledge of local context is critical
- Find shared goals, take the time to calibrate

A photograph of two children riding bicycles on a dirt path. The child in the foreground is wearing a red and white jersey and a yellow helmet. The child in the background is wearing a dark jersey with 'CUBBY 30' on the back and a black helmet. The path is surrounded by dry grass and trees, with a large ship visible in the distance under a clear blue sky.

Thank You!

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maryellen.hearn@pathwaysclimate.com