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Engineering With Nature

Engineering With Nature: A Systems Design Approach

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USACE San Francisco District (SPN)
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ASBPA, Long Beach, CA

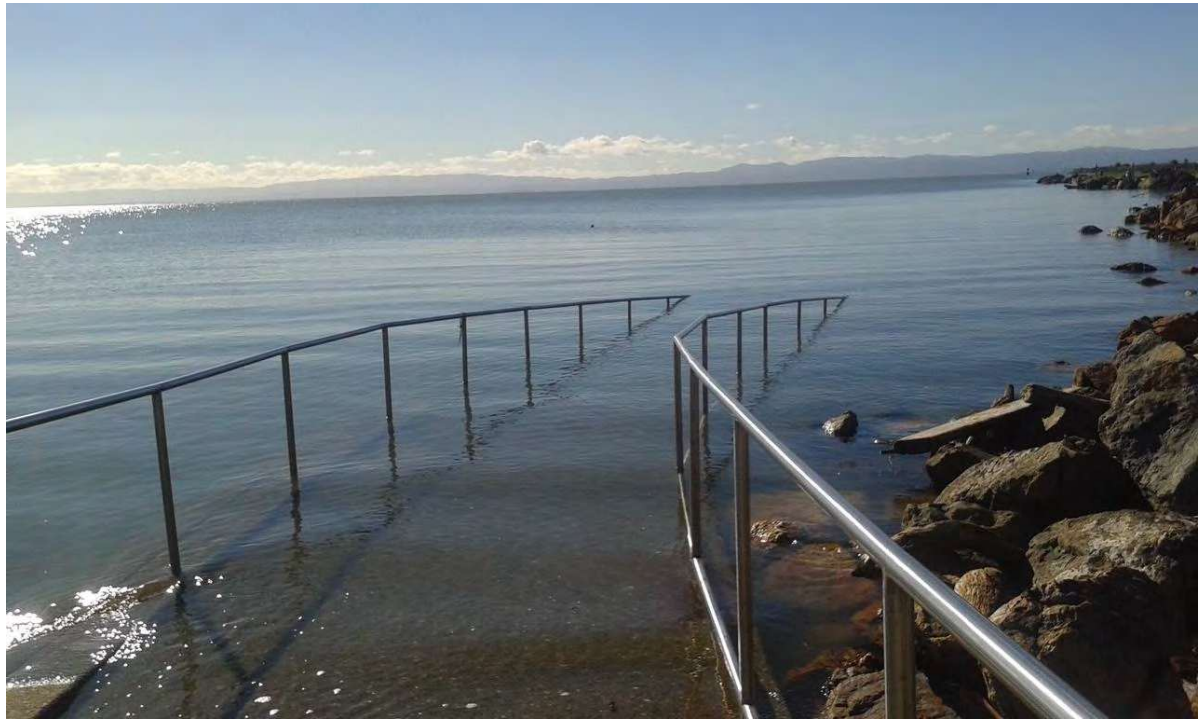
Overview

- Introduction
  - Tiffany K. Cheng, PE, Senior Coastal Engineer, USACE San Francisco District (SPN)
  - EWN Proving Ground
    - Develop and implement innovative EWN techniques in the District's civil works program

- Presentation topics:
  - Examples of NNBF
  - Engineering Design Considerations
  - Guiding Questions for the Engineer
    - Framework: Siting/suitability, key design parameters, project goals + benefits, rating function + performance
  - Wrap-up/Questions

Shifting Baselines … Shifting Approaches

- Early coastal engineering and management motivated by transportation, commerce and military advantage → traditional, armored structures
- Natural and nature-based features (NNBF) can deliver multiple co-benefits to coastal projects
  - More adaptive and cost-effective than traditional armoring, when deployed appropriately
- Goal: Not just minimizing P(Failure) … Engineer the conditions for dynamic equilibrium



Examples of Natural and Nature-Based Features

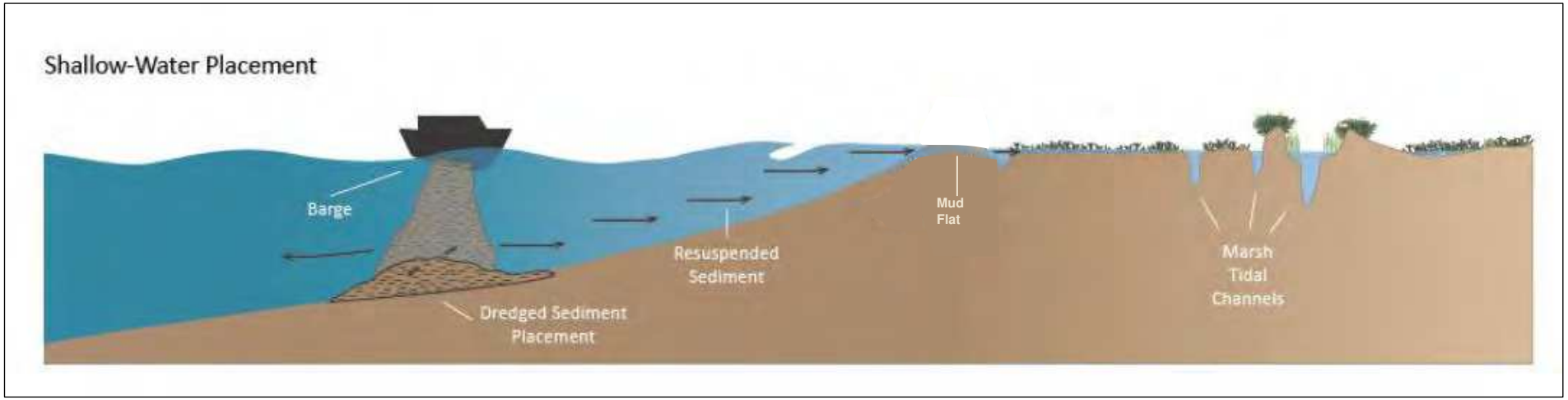
- Vegetated Dunes
- Dynamic Revetment/Cobble Berm
- Native Oyster Reefs
- Eelgrass Plantings
- Tidal Bench/Horizontal Levee
- Marsh Sill
- Nature-based solutions can also include working with natural processes

Open Coast

Estuarine

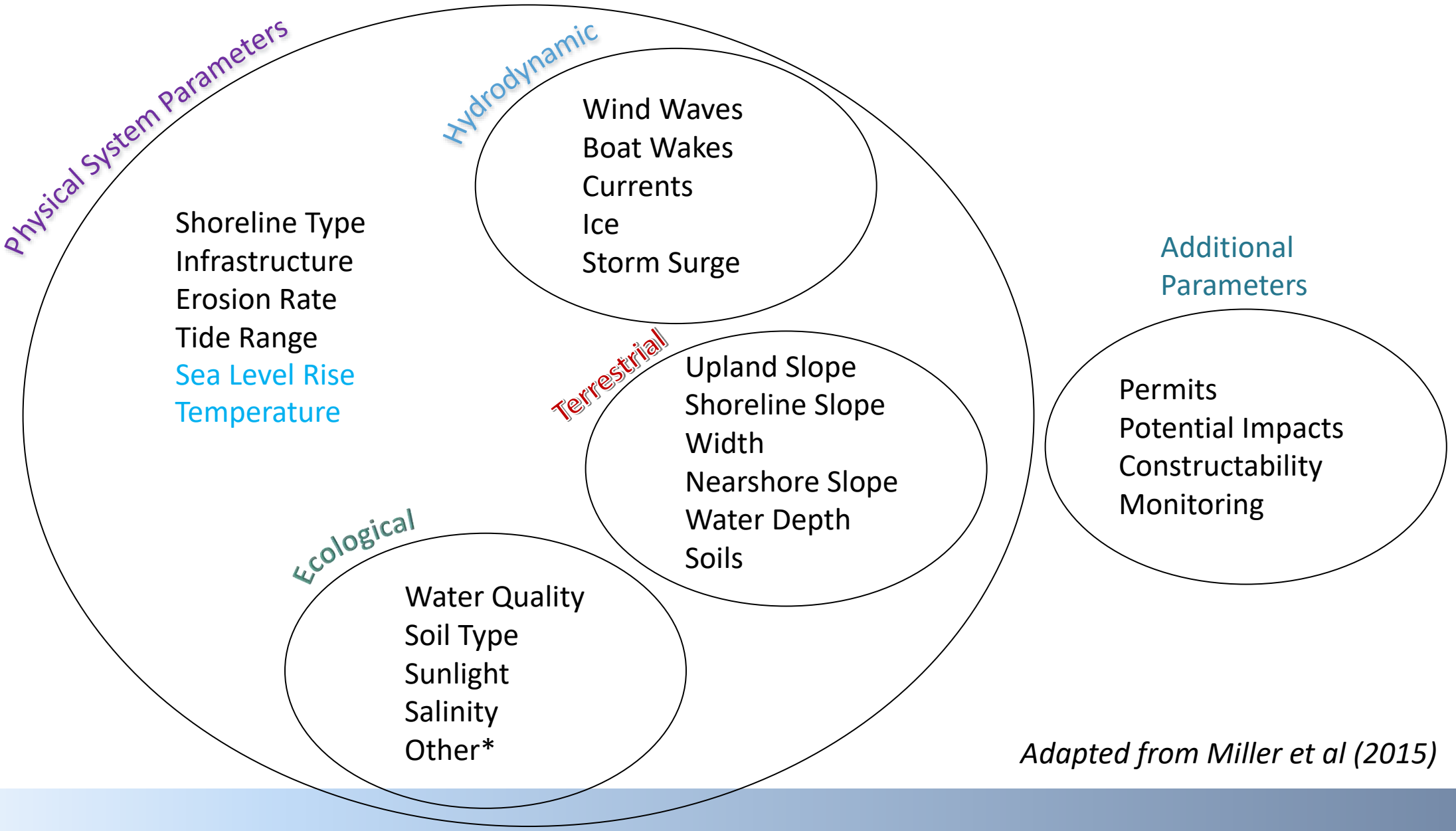
Ex.) Strategic sediment placement - USACE Section 1122 Pilot Study

Surfer's Point Managed Shoreline Retreat



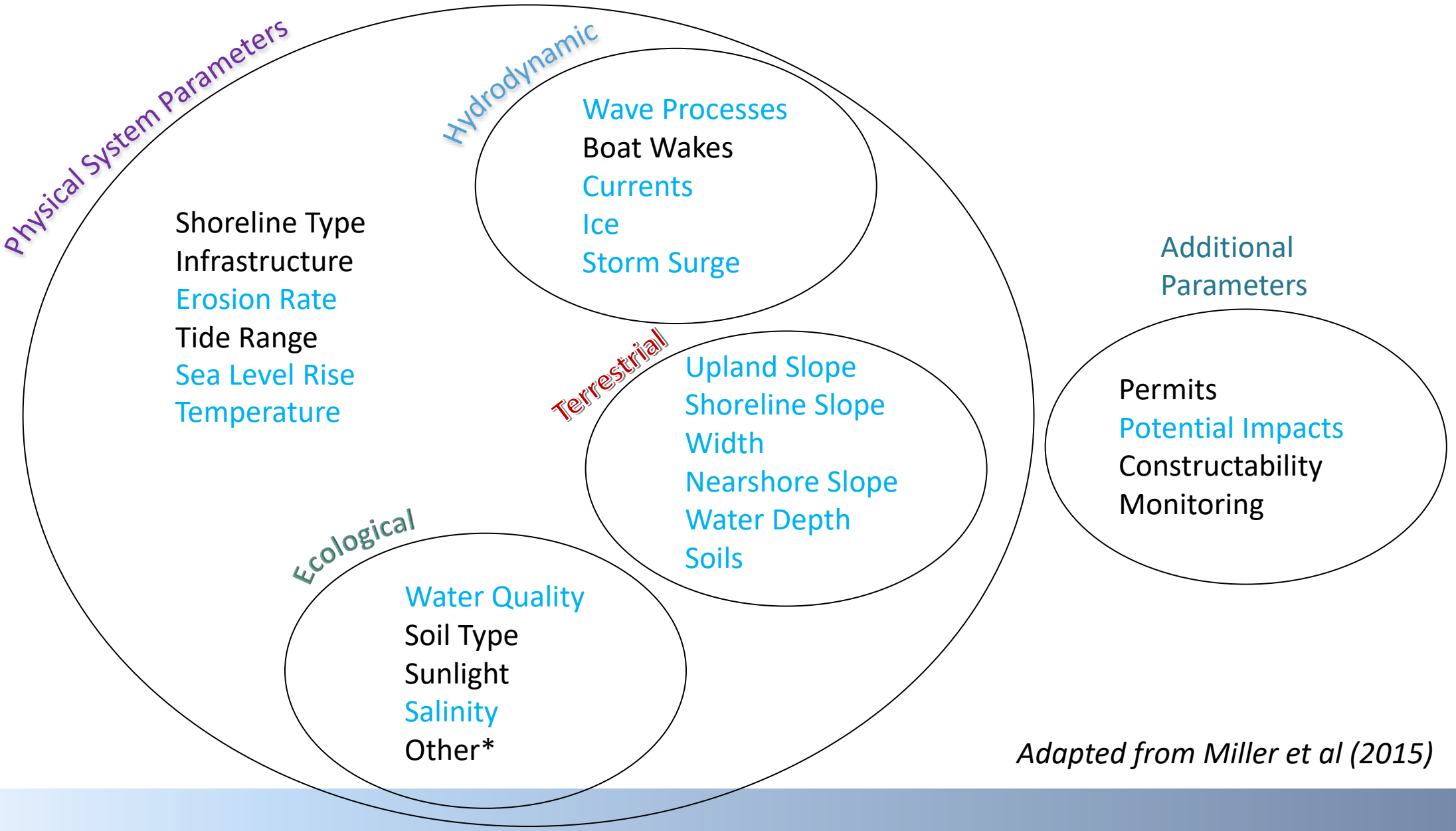
San Francisco Estuary Institute (2017)

Engineering Design Considerations



Adapted from Miller et al (2015)

Engineering Design Considerations

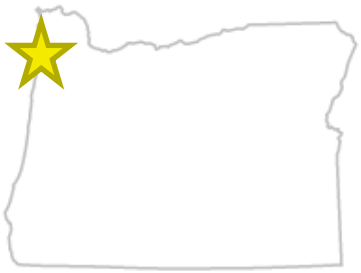


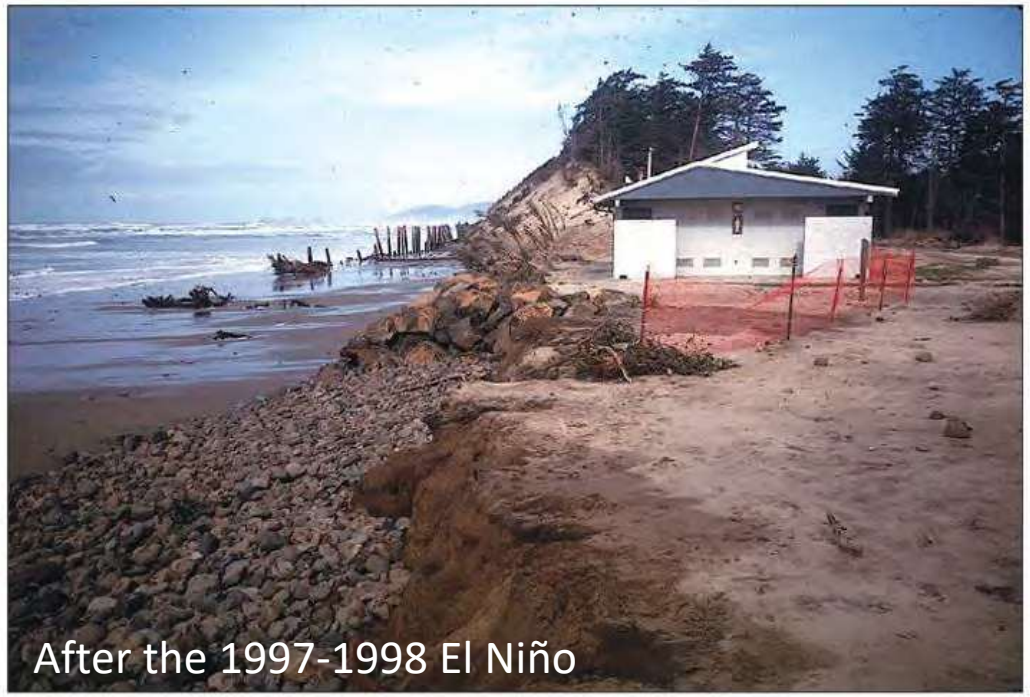
Adapted from Miller et al (2015)

Case Study #1: Cape Lookout State Park

Cape Lookout State Park, Tillamook, OR
Site Characterization:

- Open coast, high wave energy exposure
  - Winter wave heights ~ 20+ ft
  - ~45 ft wave heights during March 1999 storm
- Project location is an erosion "hot spot", due to El Niño winter storm patterns and location north of a headland



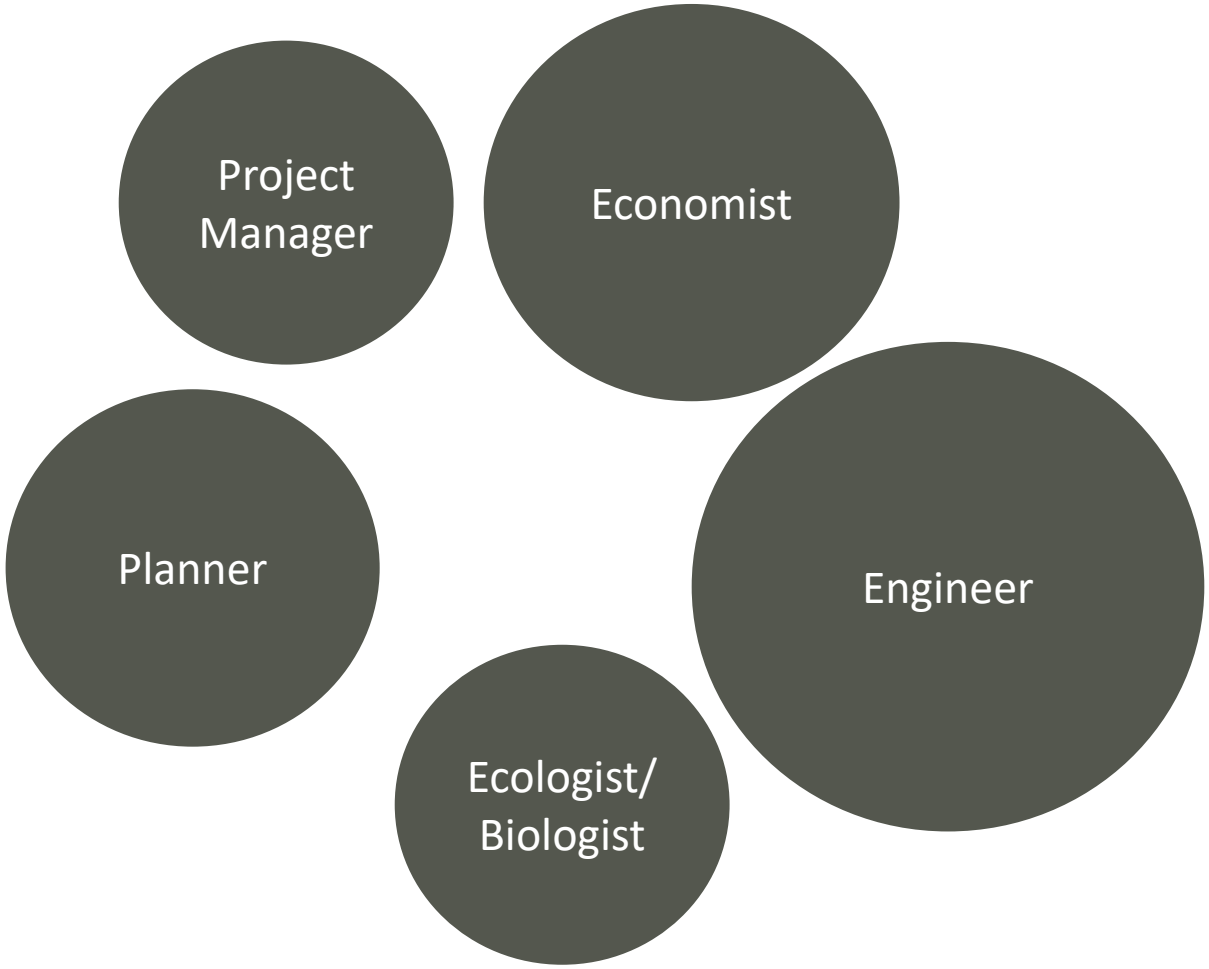


Komar and Allan (2010)

Drivers	Physical Processes	Physical Shore Response	Functional Response
Sea Level Rise Extreme Weather (El Niño + winter storms)	Alongshore sediment transport to the north Storm surge Wave breaking at sea cliffs and foredunes	Erosion of sandy beach and adjacent property	Loss of public access and recreation; Loss of habitat function

Intervention

Guiding Questions for the Engineer



Keep It Simple Stupid ☺:

1. Are NNBF **suitable** at my site?
2. How much **space** and **materials** are needed?
3. Will NNBF **work** (and how well)?
4. And **for how long**?

Siting and Suitability

- Appropriate siting of nature-based solutions is a major factor in their longevity/effectiveness
  - Available fetch → Wave energy exposure at site
  - Space for landward migration
  - Sediment supply
- Regional tools – local and landscape-scale opportunities
  - NOAA Coastal Flood Exposure Mapper
  - The Nature Conservancy Coastal Resilience (state-level)
  - San Francisco Bay Adaptation Atlas
  - Others …

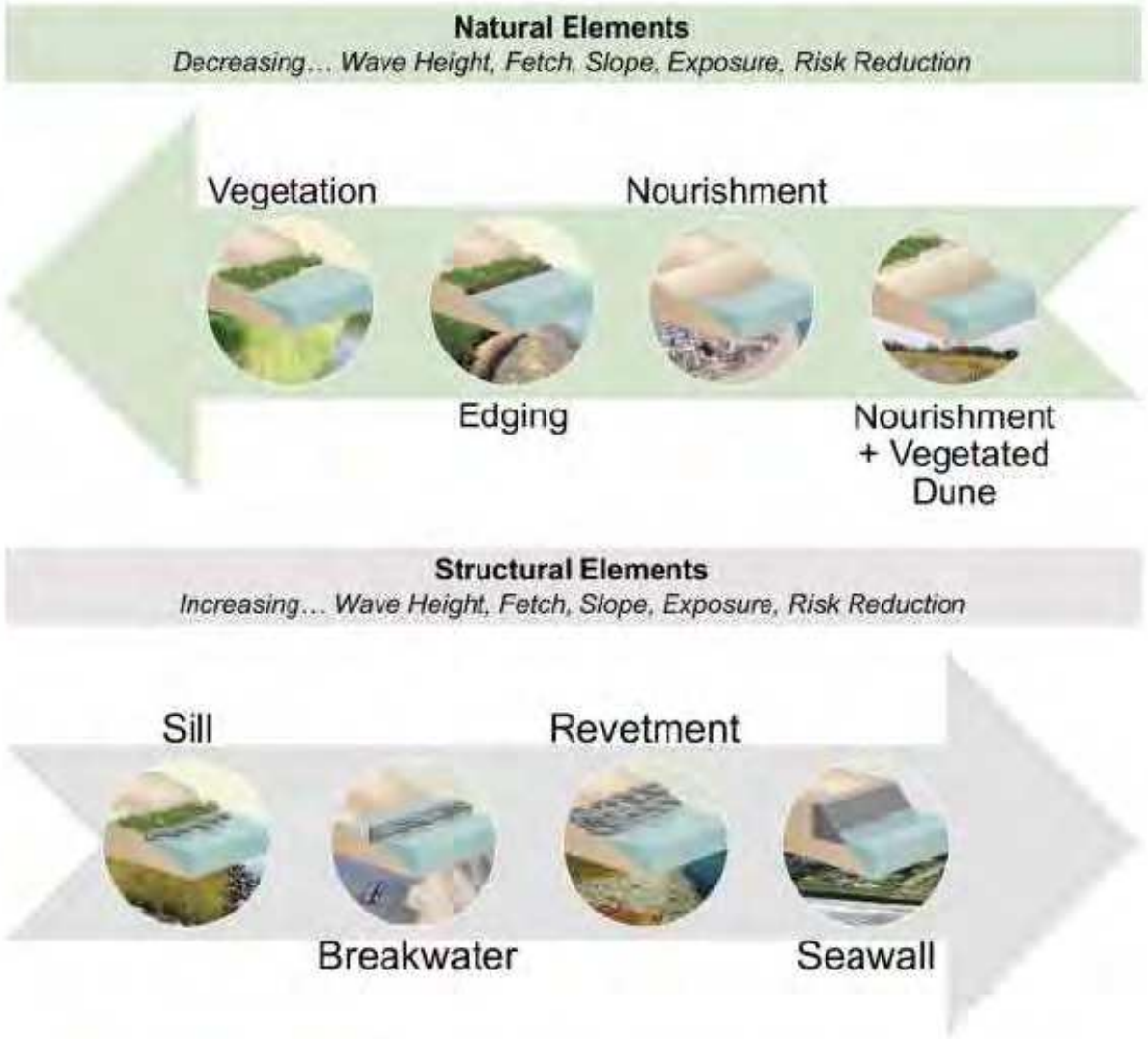


Figure 1-1. Nature-based solutions consist of varying degrees of natural, nature-based, and structural elements depending on the setting, exposure to wave action, and resilience needs (adapted with modifications from SAGE 2017).

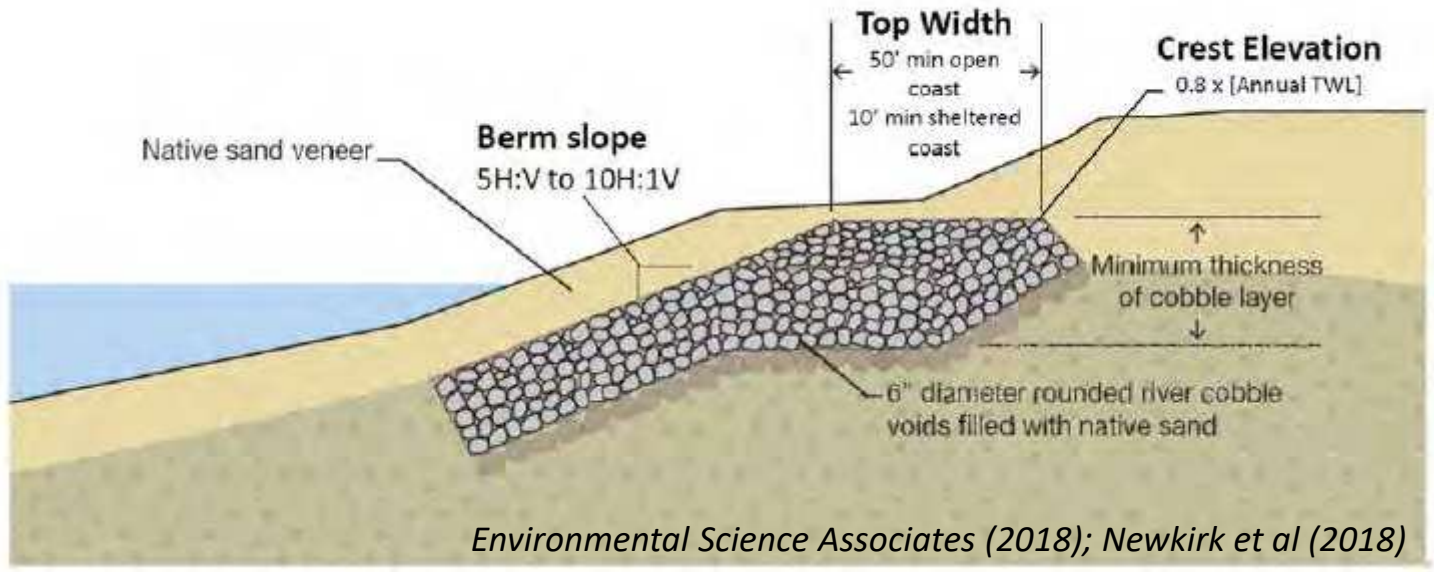
TABLE 3
SUITABILITY MATRIX OF NATURE-BASED ADAPTATION MEASURES FOR EAST BAY SHORE TYPES

	Shore Type / Nature-Based Adaptation Measure	*Dune*	*Coarse-Grained Berm*	*Marsh Sill*	*Tidal Bench*	*Oyster Reef*	*Eelgrass Bed*
Sheltered Water (Wind-Waves)	*Tidal Marshes*	Low	Low	High	High	High	High
	Coarse-Grained Beaches	Medium	High	High	High	High	High
	Armored Shorelines	Low	Medium	Low	Low	Medium	Medium
	Filled Reclaimed Areas	Low	High	Medium	Medium	Medium	Medium
	*Earthen Levees and Dikes**	Low	Medium	Medium	High	Medium	Medium
	Tidal Flats and Mudflats	Low	Low	High	High	High	High
	Estuaries and Baylands	Low	High	High	High	High	High

SF Bay Trail Risk Assessment and Adaptation Prioritization Plan (RAAPP) (2021)

Key Design Parameters

- Relate key design parameters to site-specific physical parameters
  - Location in nearshore/tidal profile
  - Planform space, e.g. minimum alongshore and cross-shore dimensions to provide benefits
  - Volume of materials required
- Example: Dynamic revetment/cobble berm – flood protection
- Because water levels control both flooding and wave exposure, design of coastal engineering solutions require evaluating the total water level (TWL)
- TWL = Regional Mean Sea Level + Astronomic Tides + Non-Tidal Residuals + Wave Runup



Environmental Science Associates (2018); Newkirk et al (2018)

SPATIAL REQUIREMENTS AND LOCATION WITHIN TIDAL PROFILE BY ADAPTATION MEASURE

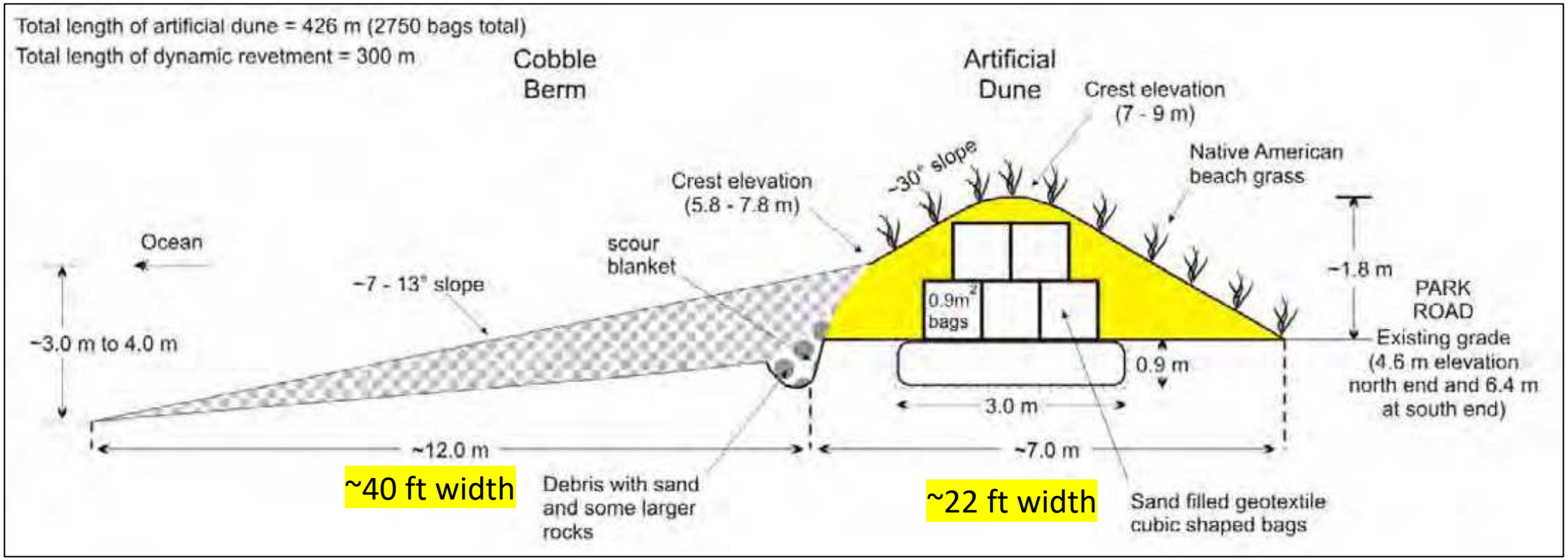
Nature-Based Adaptation Measure	Slope Range	Min. Alongshore Dimension (ft)	Min. Cross-shore Dimension (ft)	Location within tidal profile
Dunes	-	100 ft	100-200 ft for dune footprint, +50 ft behind dune footprint	Backshore
Coarse-Grained Berm	5H:1V to 10H:1V on bayward side, 3H:1V or flatter on landward side	10 ft	45 ft	Foreshore – 0.8 x TWL (crest elev.)
Marsh Sill	8H:1V to 10H:1V	30 ft	10 ft	
Tidal Bench	Minimum 7H:1V slope or gentler		30 ft	MLLW to 10-yr TWL
Native Oyster Reefs	-	-	-	+/- 2 ft of MLLW
Eelgrass Beds	-	-	-	Low intertidal (+1 ft MLW) to subtidal (< MLLW)

SOURCE: ESA, 2018; Newkirk et al., 2018

Newkirk, Sarah, Sam Veloz, Maya Hayden, Walter Heady, Kelly Leo, Jenna Judge, Robert Battalio, Tiffany Cheng, Tara Ursell, Mary Small. (The Nature Conservancy and Point Blue Conservation Science). 2018. Toward Natural Infrastructure to Manage Shoreline

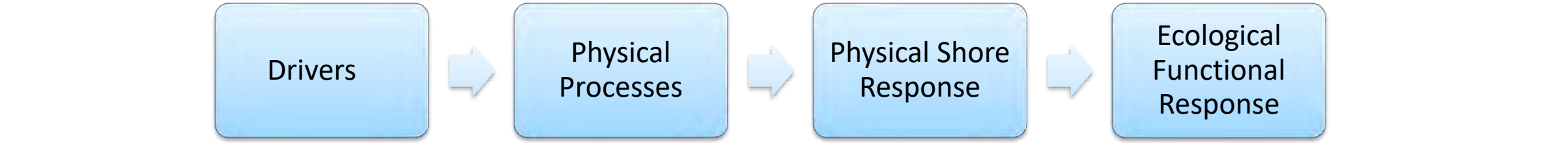
Example: Dynamic Revetment + Dunes at Cape Lookout State Park

- **Project Goals:** Protect park recreational assets from flooding and preserve recreational use and aesthetic character of shoreline
- **Solution:** Hybrid nature-based solution with dynamic revetment and restored foredune
- "Coupling" the measures allowed for downscaling of footprint



Komar and Allan (2010)

Case Study #2: SF Bay Living Shorelines Project



San Francisco Bay Living Shorelines Project (SF Bay Subtidal Goals); Photo: Michael Short

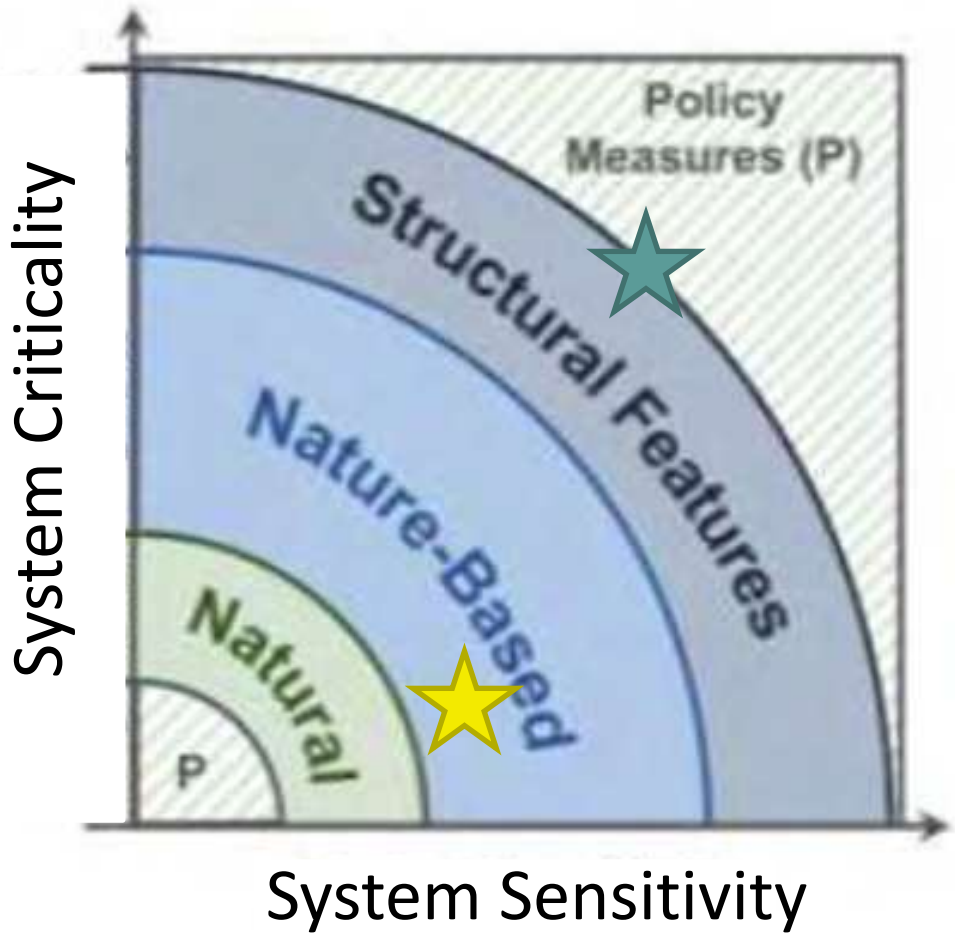
Some coastal projects have enhancing system ecology as the primary goal and objectives.

Example:

- SF Bay Living Shorelines Project (part of the Subtidal Habitat Goals Project)
- Use of oyster reefs and eelgrass plantings to increase habitat value and ecosystem resilience
- NNBF provide wave calming and sediment trapping functions
- “Estuary rollover” – buffer tidal wetlands and habitat migration

NNBF – Rating Function and Performance

- Estimate level of protection or risk reduction provided by NNBF
  - Empirical formulas for smaller, standalone features (e.g. marsh sill, cobble berm)
  - Landscape-scale features/processes can and should be evaluated with more sophisticated tools e.g. hydrodynamic modeling
- NNBF – one component in adaptation strategy for a shore segment, can be hybrid
- Define thresholds (e.g. amount of SLR) along adaptation pathway that may trigger policy measures (e.g. relocate, elevate)



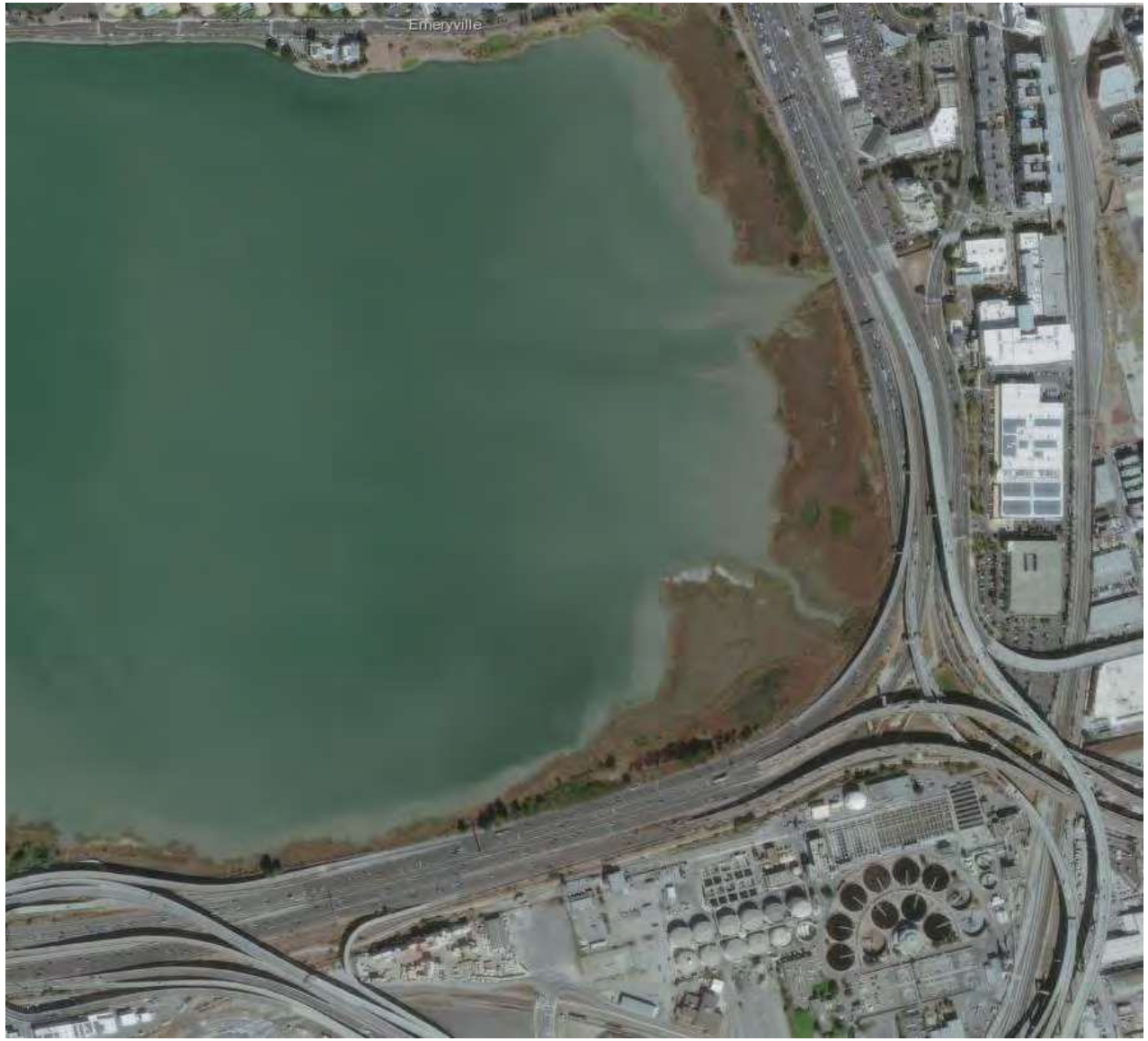
Wastewater Treatment Plant
High Criticality, Moderate-High Sensitivity
Retrofit and elevate infrastructure, and eventually relocate entire system

Recreational Trail
Low Criticality, Moderate Sensitivity
Use nature-based solutions to provide wave attenuation and erosion mitigation for trail shoreline; determine threshold for setting back and elevating trail
Example: SF Bay Trail Risk Assessment and Adaptation Prioritization Plan (RAAPP) (2021)

Adapted from FHWA Nature-Based Solutions for Coastal Highways (2022)

Looking Ahead

- EWN is still a young field (< 40 years), with emerging tools and guidance
  - New and existing place-based tools are actively being developed and refined
- Challenges at organizational level in developing protocols around adaptive management and benefits quantification
- Long-term monitoring information is key to evaluating project success and outcomes in their specific contexts
  - Pre-construction - baseline
  - Construction (as-built)
  - Post-construction (performance)



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THANK YOU!

Questions/comments/feedback are welcome.

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Acknowledgments:

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