Natural Shoreline Infrastructure:

Adapting to the Future with Innovative Approaches to Shoreline Resiliency for Flood Risk Reduction

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The National Conference On Beach Preservation Technology

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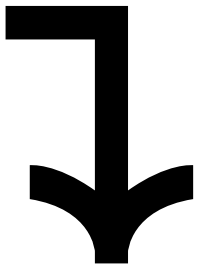
AI-generated image, Microsoft Copilot, 2025

Driving Question

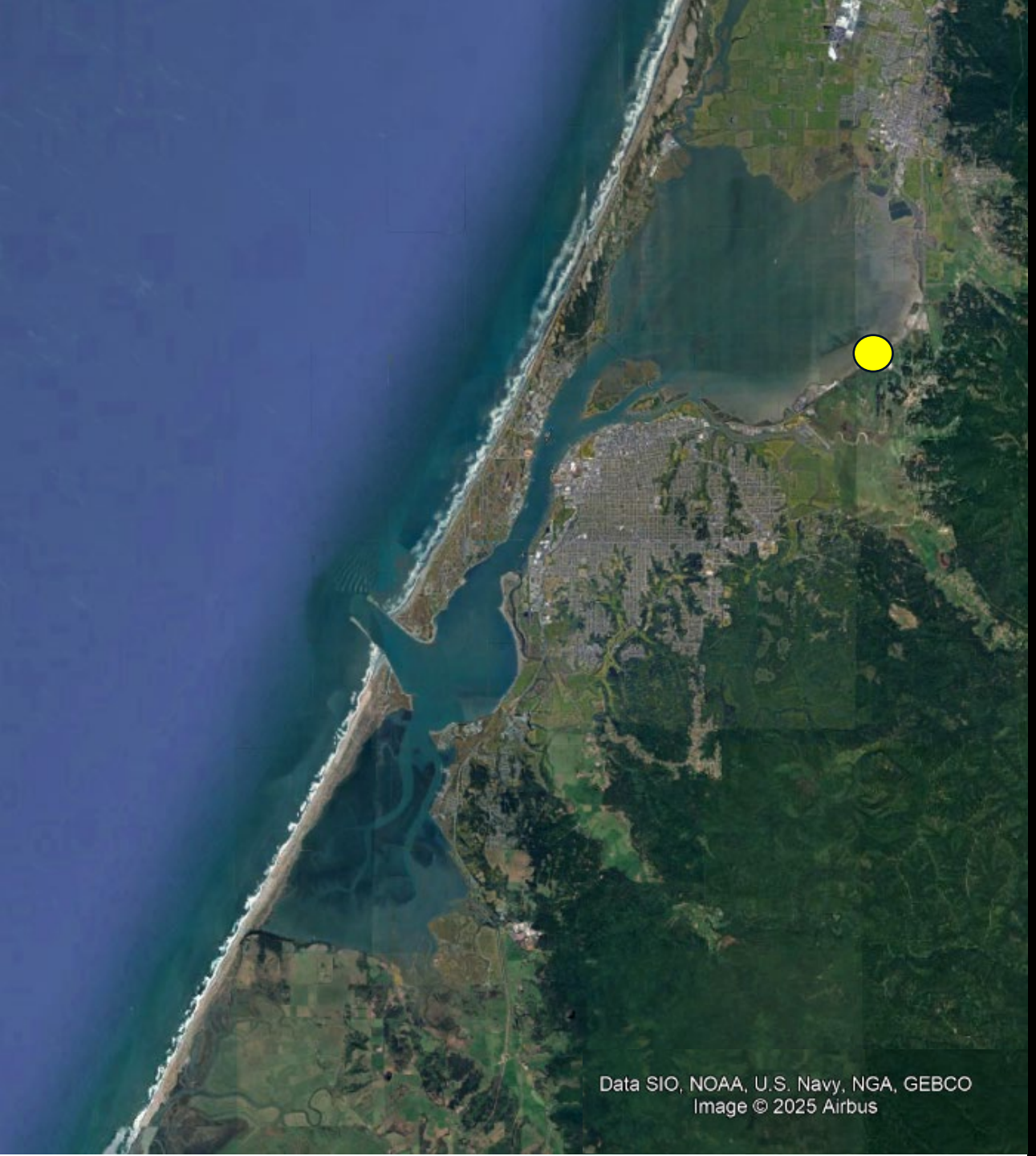


What can we learn from observing existing and constructed natural shorelines to improve our understanding of their ability to mitigate flood risk?

Humboldt Bay:
Natural Shoreline Infrastructure

Pillar Point West trail Living Shoreline Project

Cardiff Living Shoreline Project

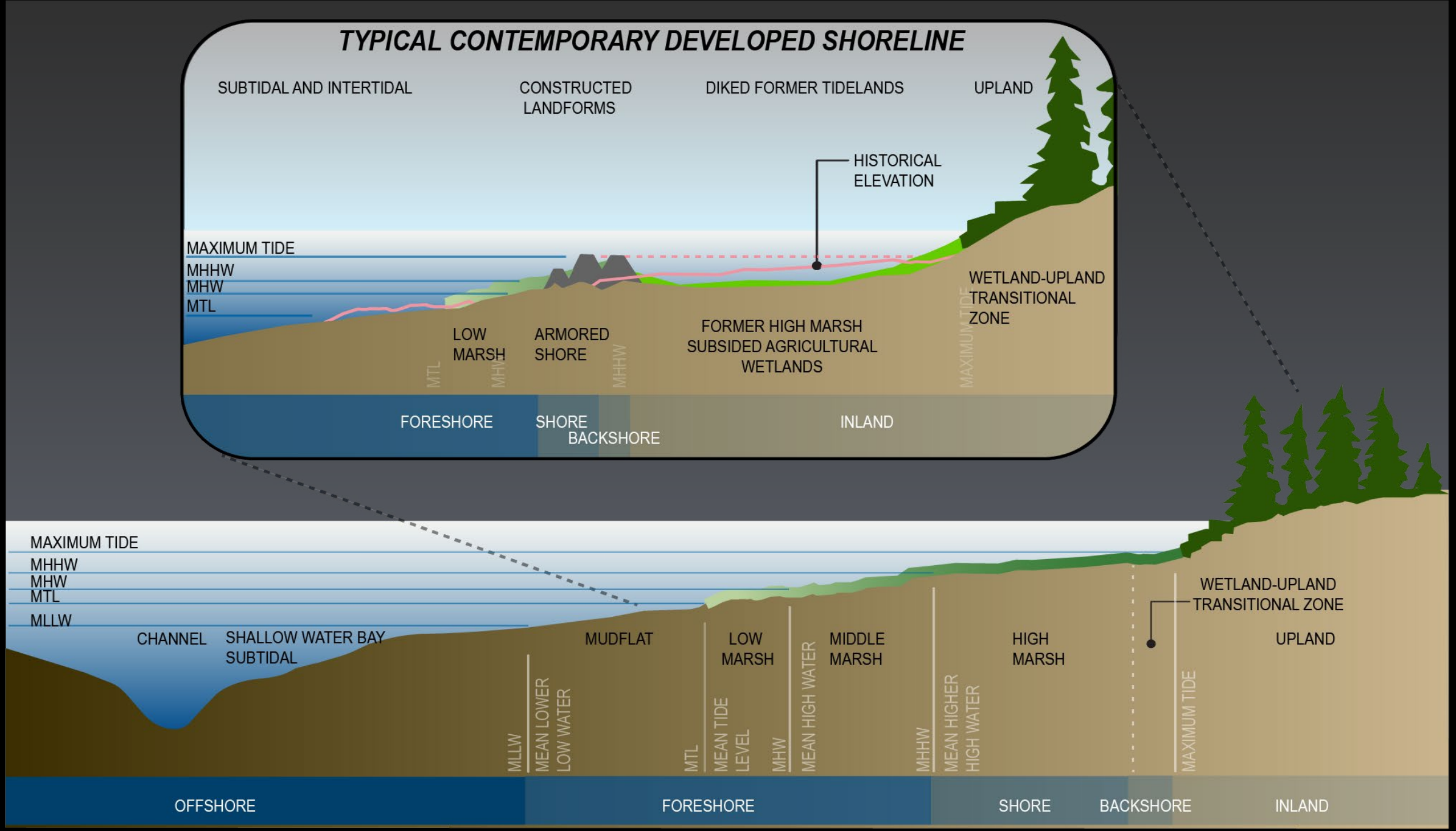


Humboldt Bay

Northern California

- Enclosed Bay
- Tides & Currents
- Storm Surge
- Wind Waves
- Sea Level Rise
- Highway 101

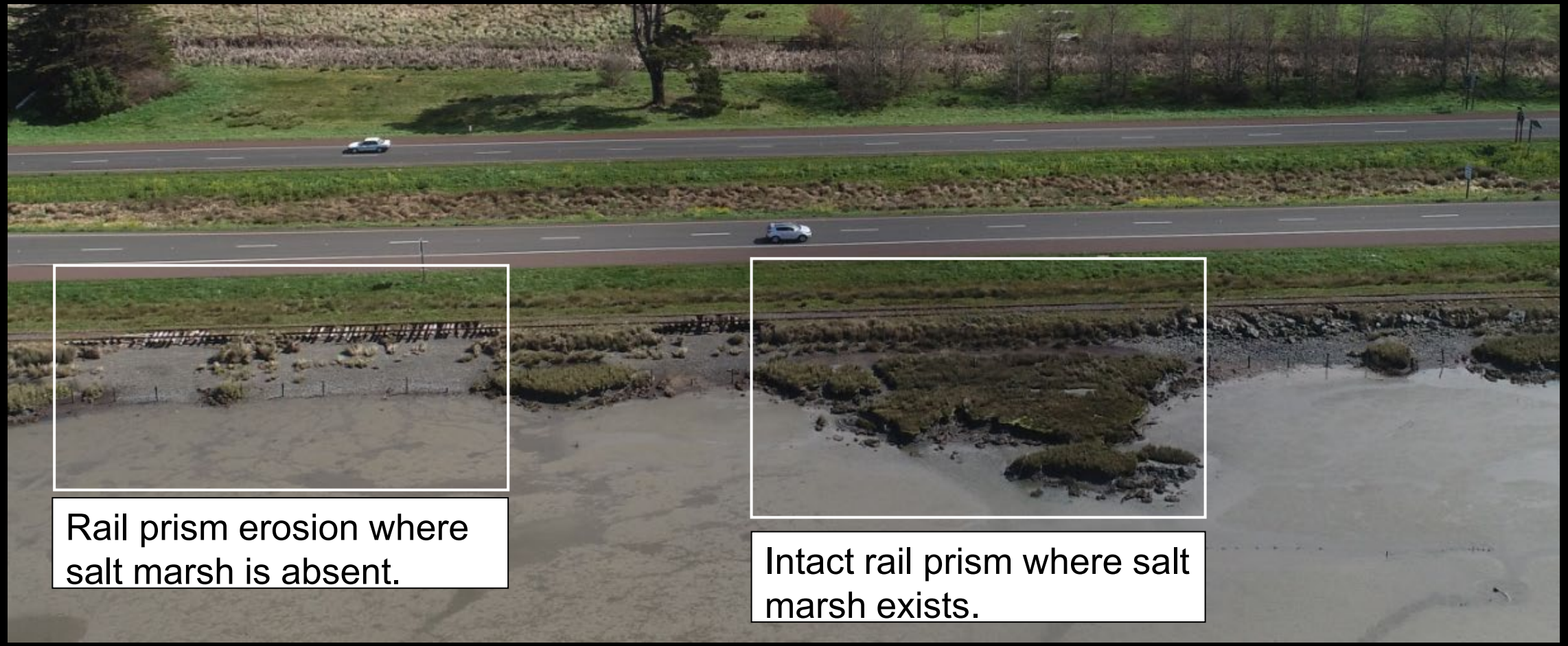

Mudflat
Salt Marsh
Subtidal Channel


TYPICAL CONTEMPORARY DEVELOPED SHORELINE
SUBTIDAL AND INTERTIDAL
CONSTRUCTED LANDFORMS
DIKED FORMER TIDELANDS
UPLAND
HISTORICAL ELEVATION
MAXIMUM TIDE
MHHW
MHW
MTL
LOW MARSH
ARMORED SHORE
FORMER HIGH MARSH SUBSIDED AGRICULTURAL WETLANDS
WETLAND-UPLAND TRANSITIONAL ZONE
MAXIMUM TIDE
FORESHORE
SHORE
BACKSHORE
INLAND
MAXIMUM TIDE
MHHW
MHW
MTL
MLLW
CHANNEL
SHALLOW WATER BAY SUBTIDAL
MUDFLAT
LOW MARSH
MIDDLE MARSH
HIGH MARSH
WETLAND-UPLAND TRANSITIONAL ZONE
UPLAND
MLLW
MEAN LOWER LOW WATER
MTL
MEAN TIDE LEVEL
MHW
MEAN HIGH WATER
MHHW
MEAN HIGHER HIGH WATER
MAXIMUM TIDE
OFFSHORE
FORESHORE
SHORE
BACKSHORE
INLAND

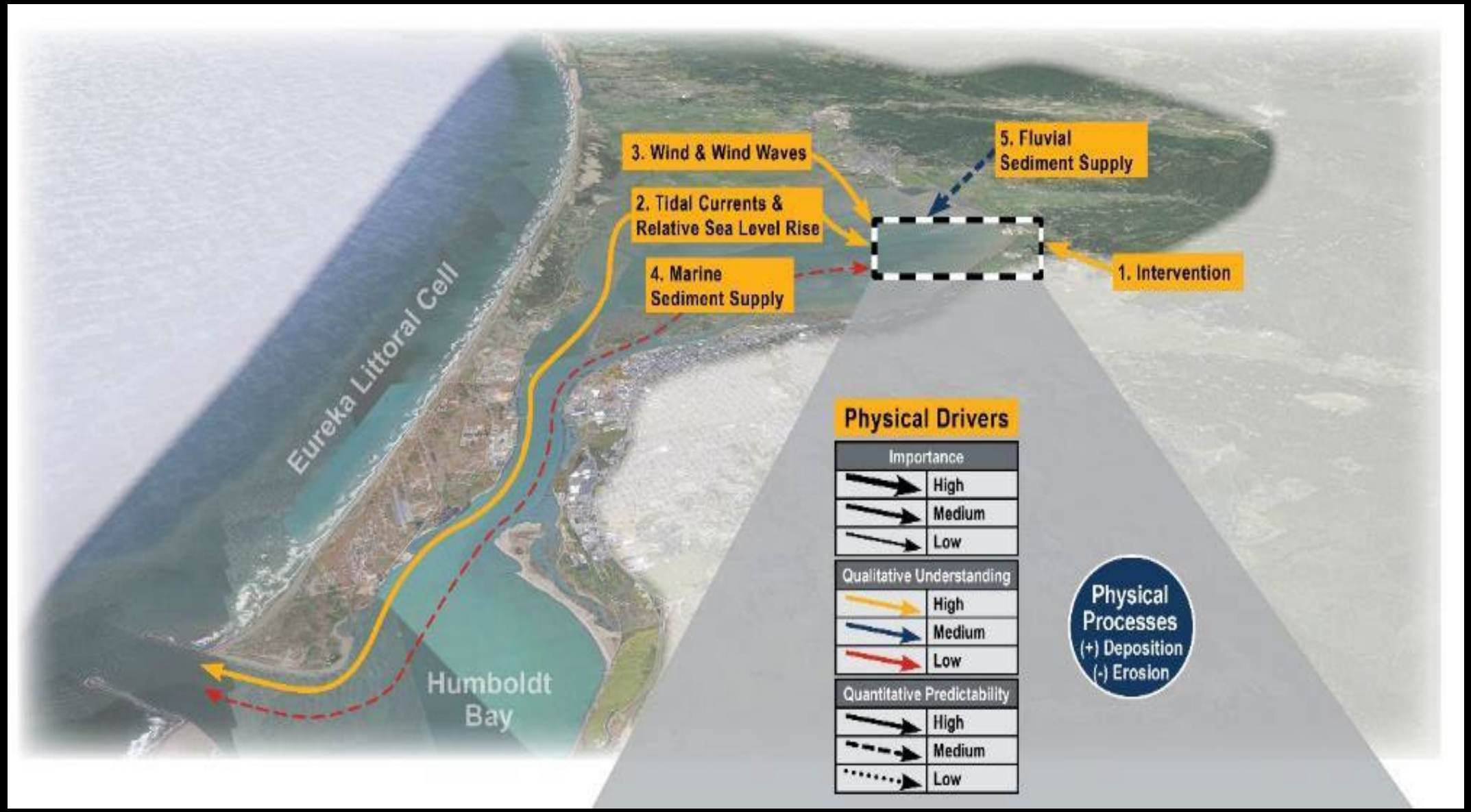
Flooding and Erosion

Differences Along the Shoreline

Differences Along the Shoreline

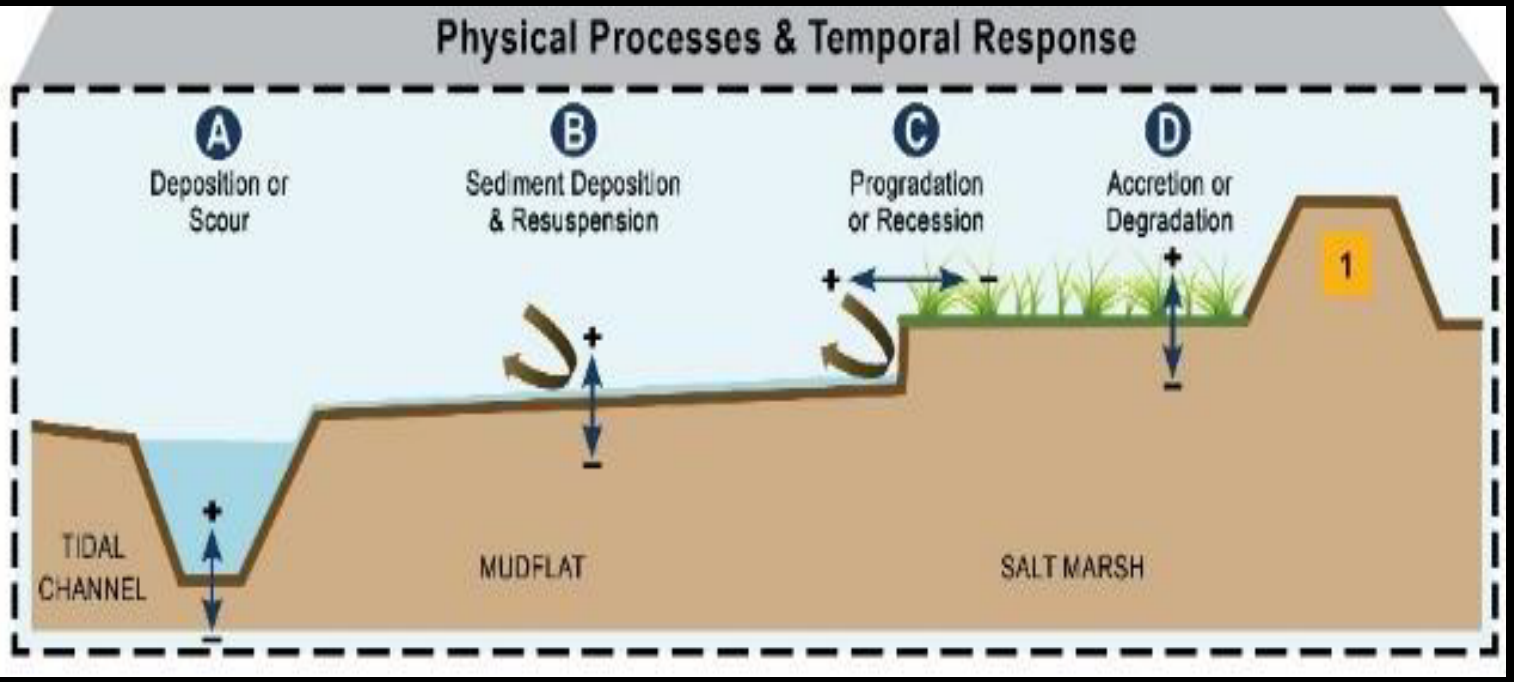


Geomorphic Drivers

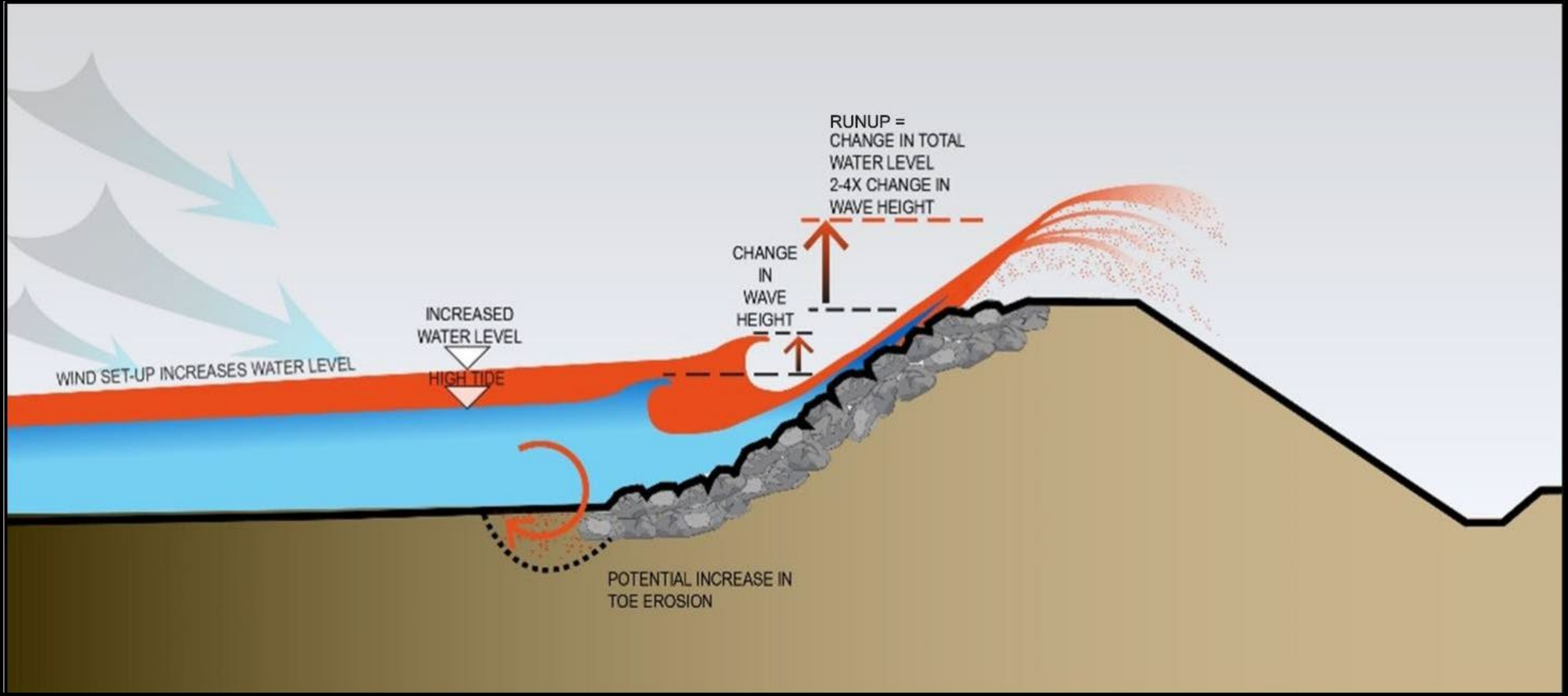


Geomorphic Drivers

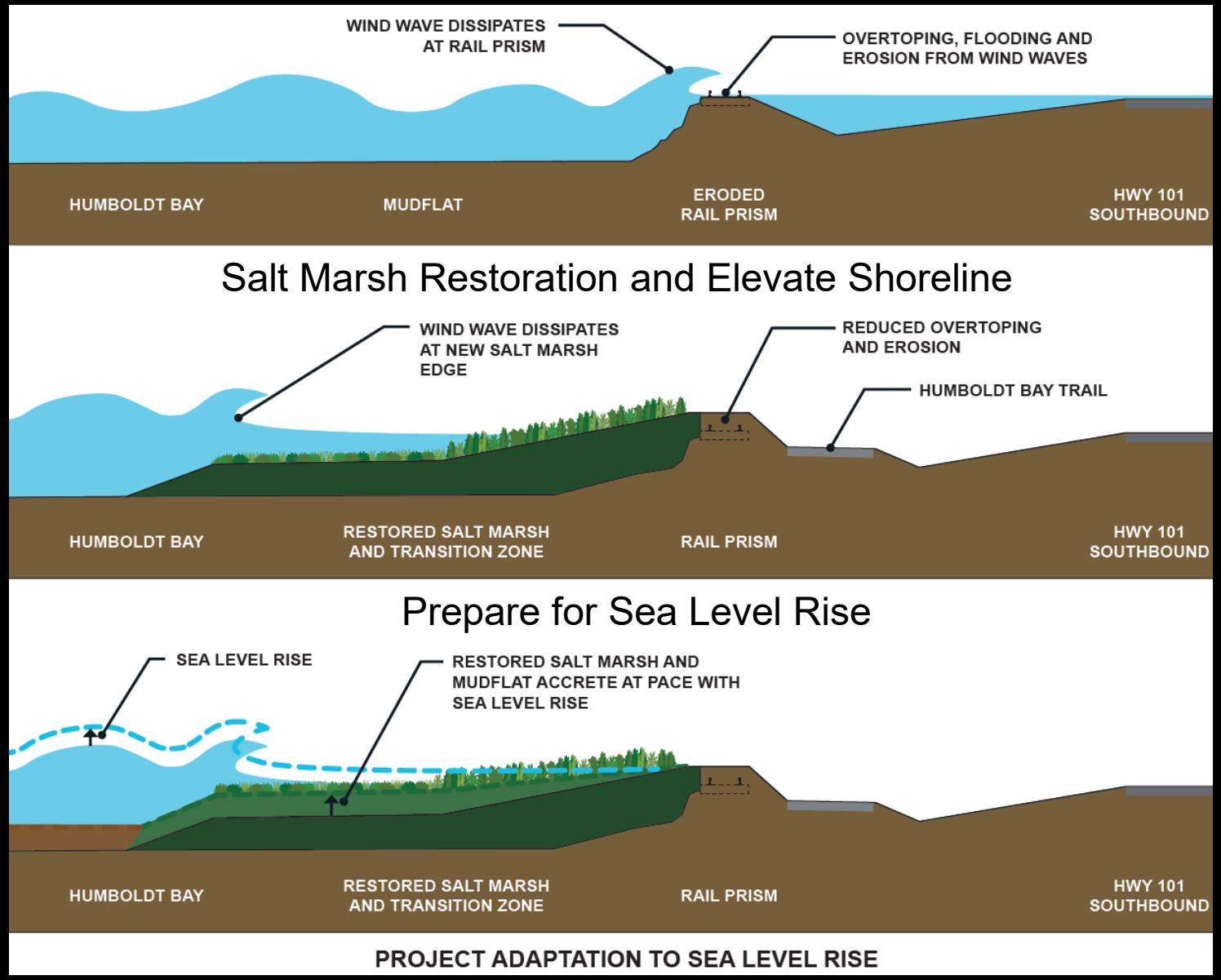
Scenario	Physical Drivers
Idealized	3. Wind & Wind Waves 2. Tidal Currents & Relative Sea Level Rise 4. Marine Sediment Supply 5. Fluvial Sediment Supply



Effects of Steepened Armoring



Explore Multiple Benefits



Explore Multiple Benefits

<table>
<tr><th rowspan="2">Water Level (RI)</th><th rowspan="2">Wind Speed</th><th colspan="2">Pre-Project</th><th>Post-Project</th></tr>
<tr><th>Flooding</th><th>Damage</th><th>Flooding/Damage</th></tr>
<tr><td rowspan="4">10.7 ft (100-yr)</td><td>48 mph (100-yr)</td><td rowspan="12">Flooding of Highway 101 South Bound Lanes</td><td>Damage to Pavement</td><td rowspan="13">No Overtopping, Flooding, or Damage with Marsh</td></tr>
<tr><td>44 mph (10-yr)</td><td rowspan="2">Damage to Rail Prism</td></tr>
<tr><td>40 mph (2-yr)</td></tr>
<tr><td>38 mph (1.053-yr)</td></tr>
<tr><td rowspan="4">10.0 ft (10-yr)</td><td>48 mph (100-yr)</td><td rowspan="2">Trail Usability Compromised</td></tr>
<tr><td>44 mph (10-yr)</td></tr>
<tr><td>40 mph (2-yr)</td></tr>
<tr><td>38 mph (1.053-yr)</td></tr>
<tr><td rowspan="4">9.4 ft (2-yr)</td><td>48 mph (100-yr)</td><td rowspan="4">No Damage</td></tr>
<tr><td>44 mph (10-yr)</td></tr>
<tr><td>40 mph (2-yr)</td></tr>
<tr><td>38 mph (1.053-yr)</td></tr>
<tr><td rowspan="4">8.4 ft (MMMW)</td><td>48 mph (100-yr)</td><td>Flooding of Trail and Highway Shoulder</td></tr>
<tr><td>44 mph (10-yr)</td><td rowspan="2">Flooding of Trail</td></tr>
<tr><td>40 mph (2-yr)</td></tr>
<tr><td>38 mph (1.053-yr)</td><td colspan="3" rowspan="5">No Overtopping, Flooding, or Damage pre- or post-project</td></tr>
<tr><td rowspan="4">7.1 ft (MHHW)</td><td>48 mph (100-yr)</td></tr>
<tr><td>44 mph (10-yr)</td></tr>
<tr><td>40 mph (2-yr)</td></tr>
<tr><td>38 mph (1.053-yr)</td></tr>
<tr><td colspan="5">EP = Exceedance Probability, RI = Return Interval</td></tr>
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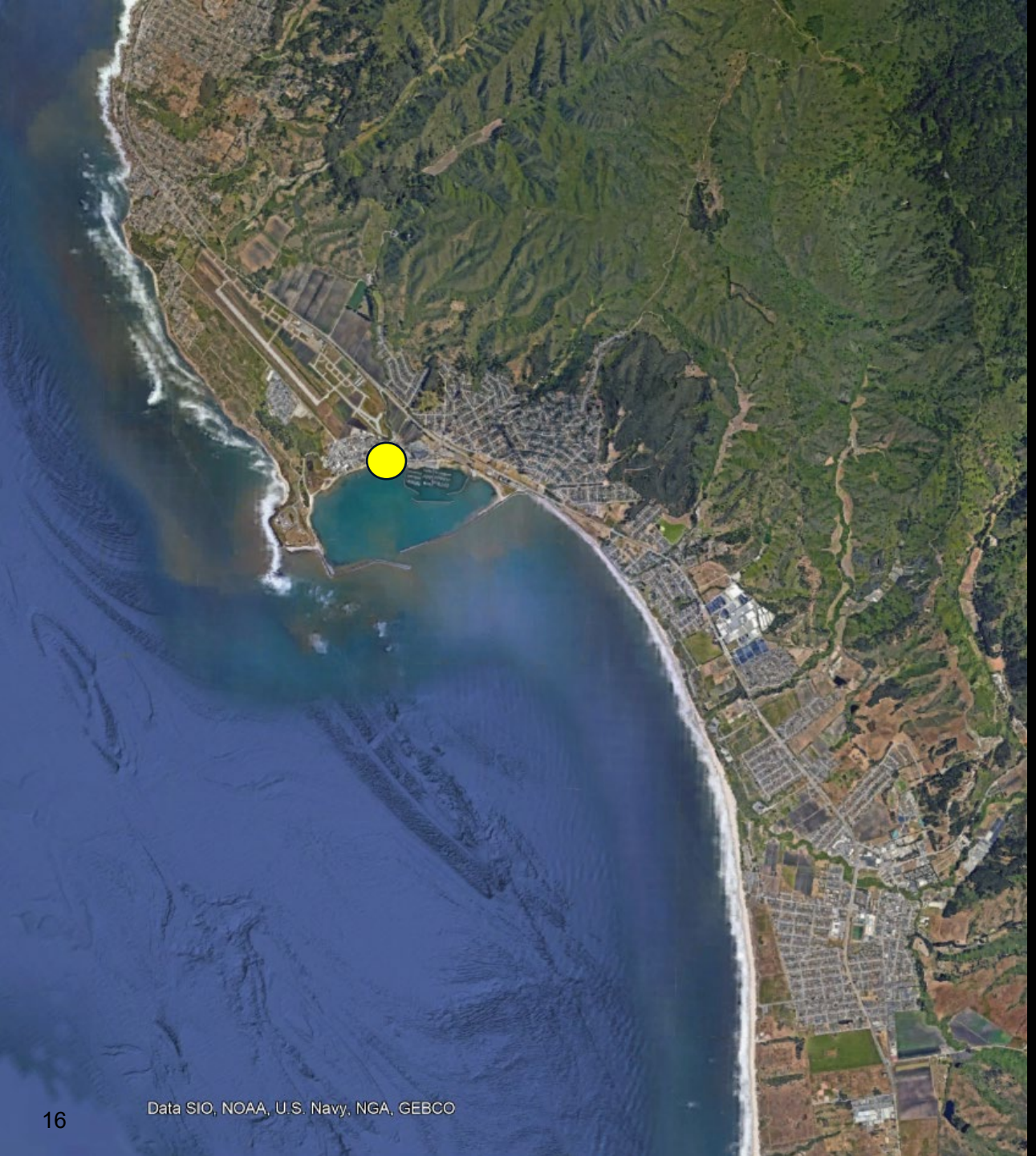
Conceptual Design

EXISTING CONDITIONS

FUTURE CONDITIONS



Pillar Point

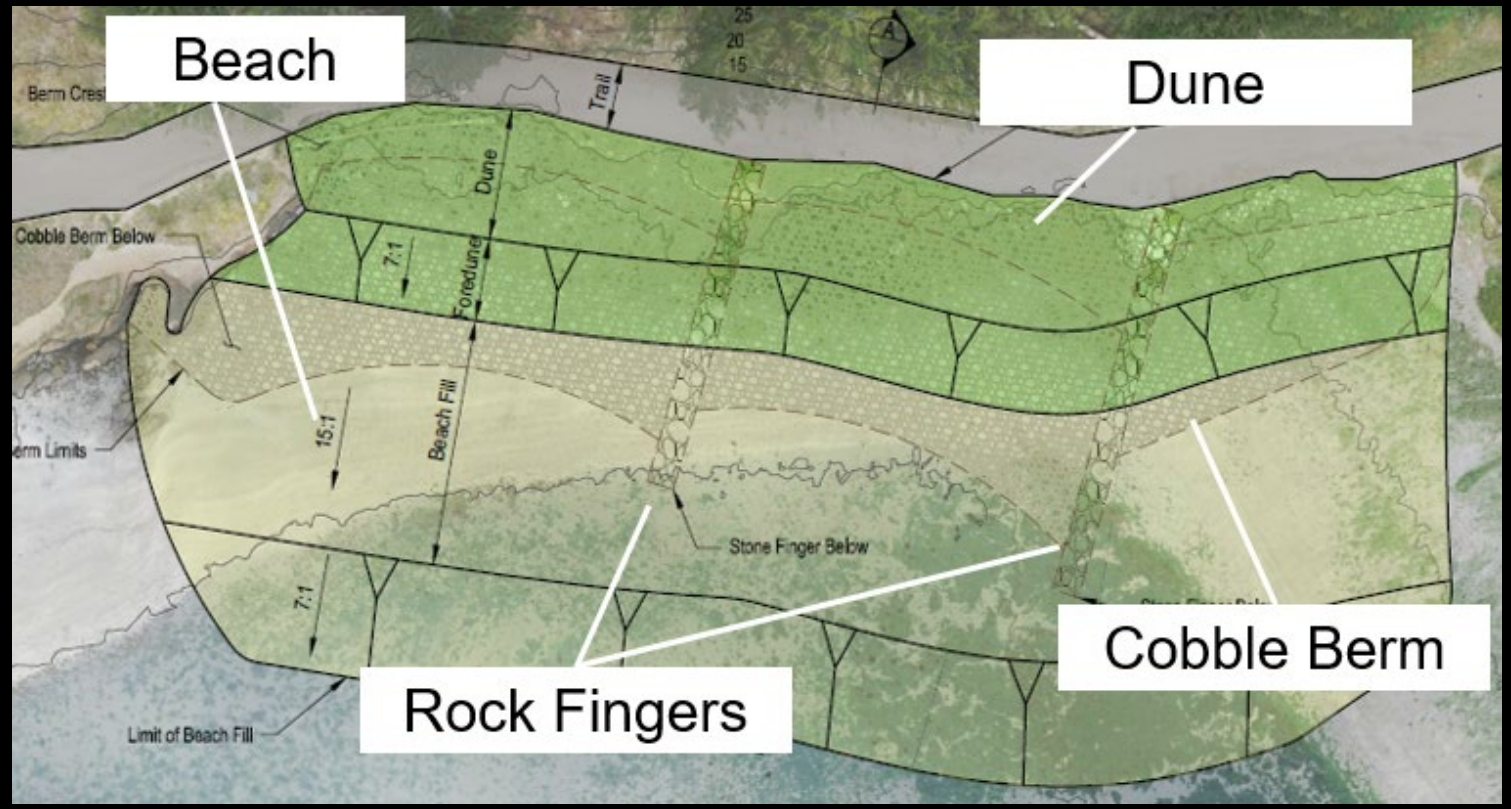
North/Central California

- Harbor with Breakwater
- Tides
- Storm Surge
- Wind Waves
- Sea Level Rise
- West Trail / Mavericks

Project Location

Design Analog - Surfer's Point, Ventura, CA

Project Design

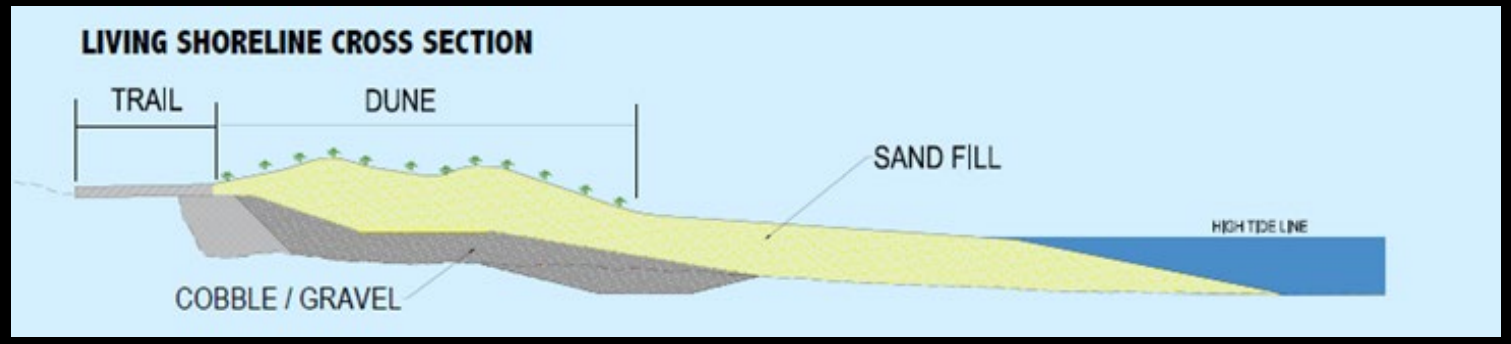


Shoreline Protection:

Protect trail from chronic erosion

Multi-benefit

Nature-based design



Project Location

Pre vs Post

Pre-Construction

Post-Construction

Environmental Compliance – Long Term Monitoring

Monitor the Project over 10-years

- Physical Performance – Adaptive Management and Monitoring Plan
- Biological Performance – Habitat Restoration and Monitoring Plan

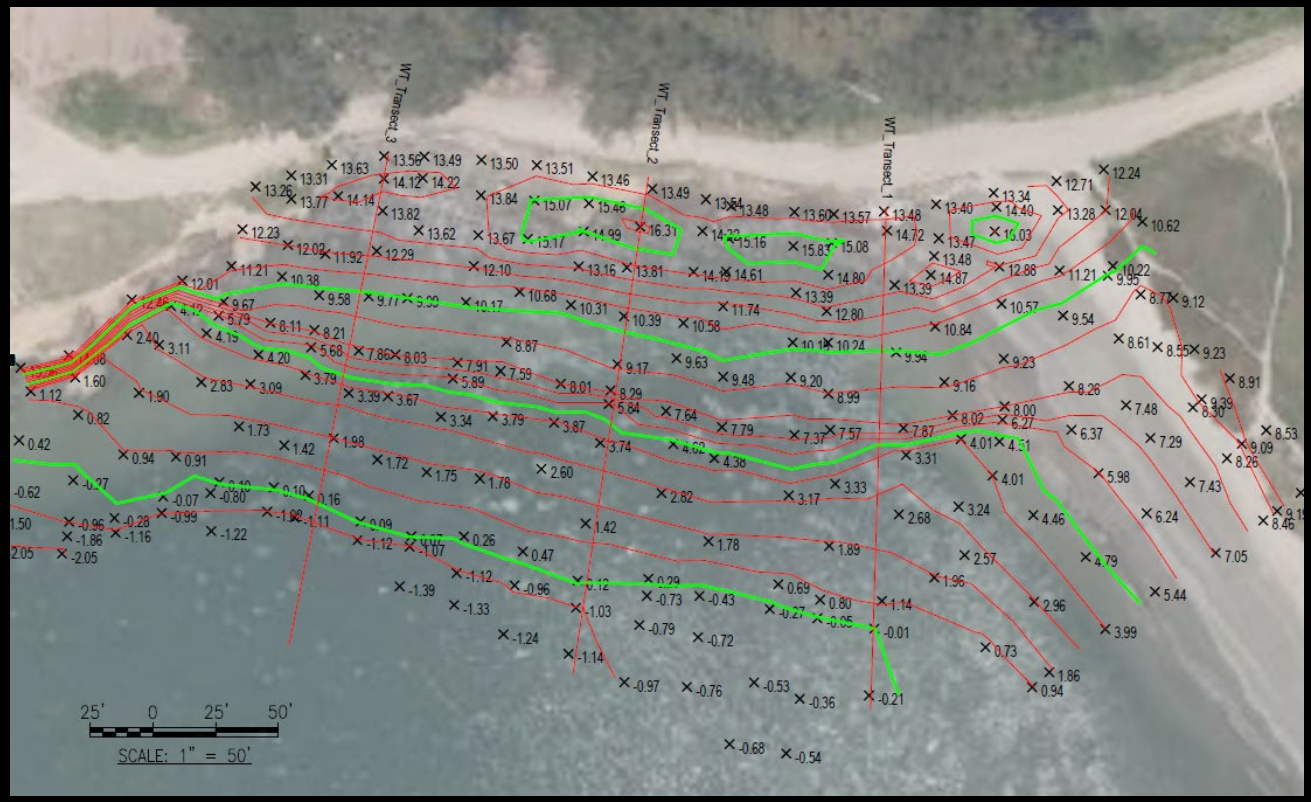
Annual reports to Coastal Commission, USACE, Water Board

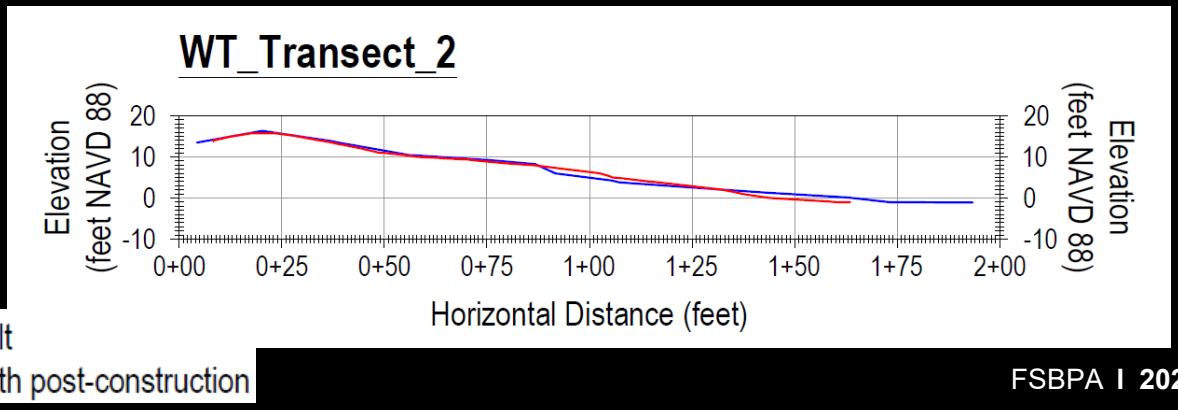
Monitoring after severe weather activity

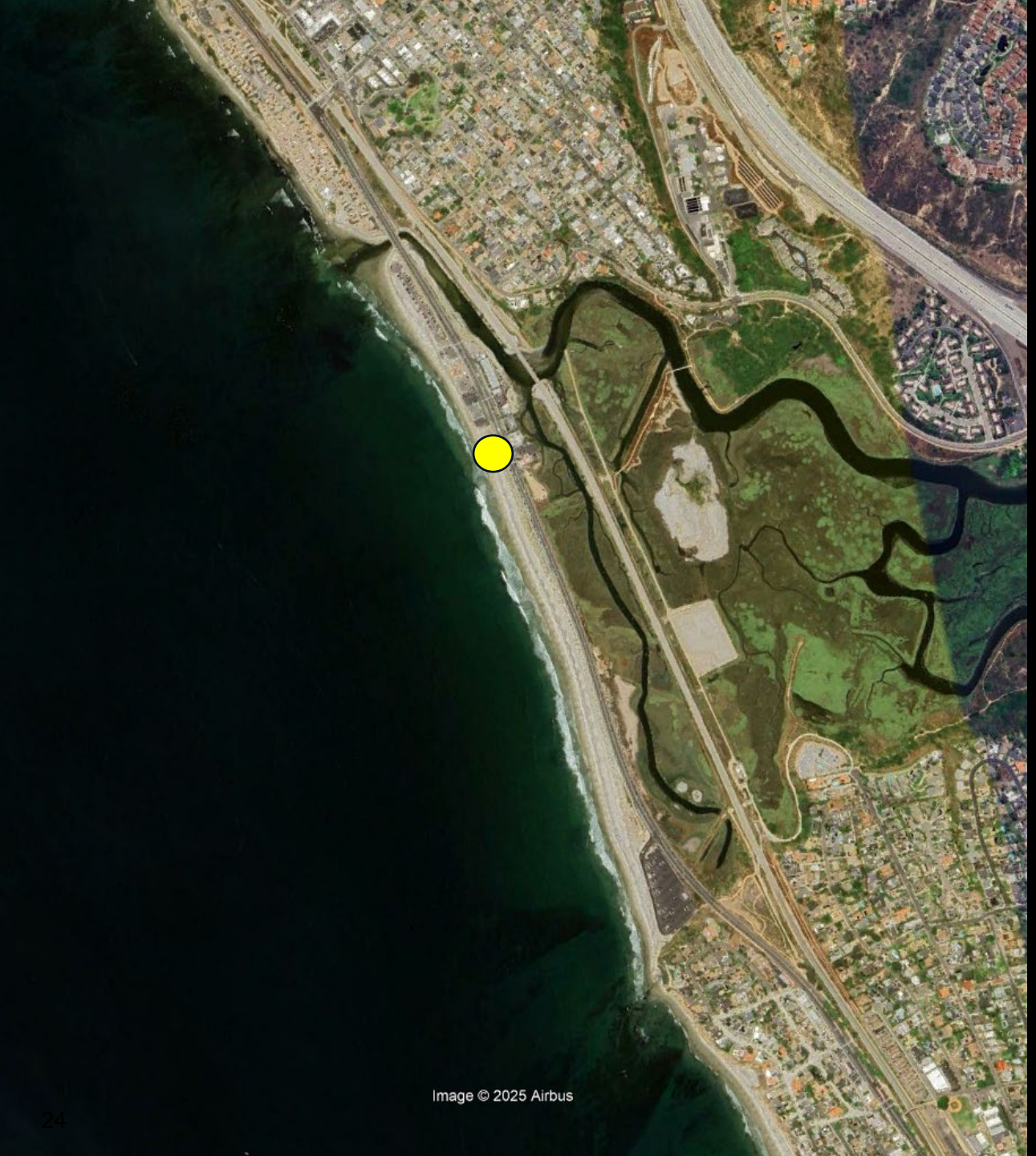
Adaptive management could be required

Post-Construction

- Dune and bioretention basin planting, Maintenance
- Physical Monitoring and Reporting
- Biological Monitoring and Reporting







Cardiff

Southern California

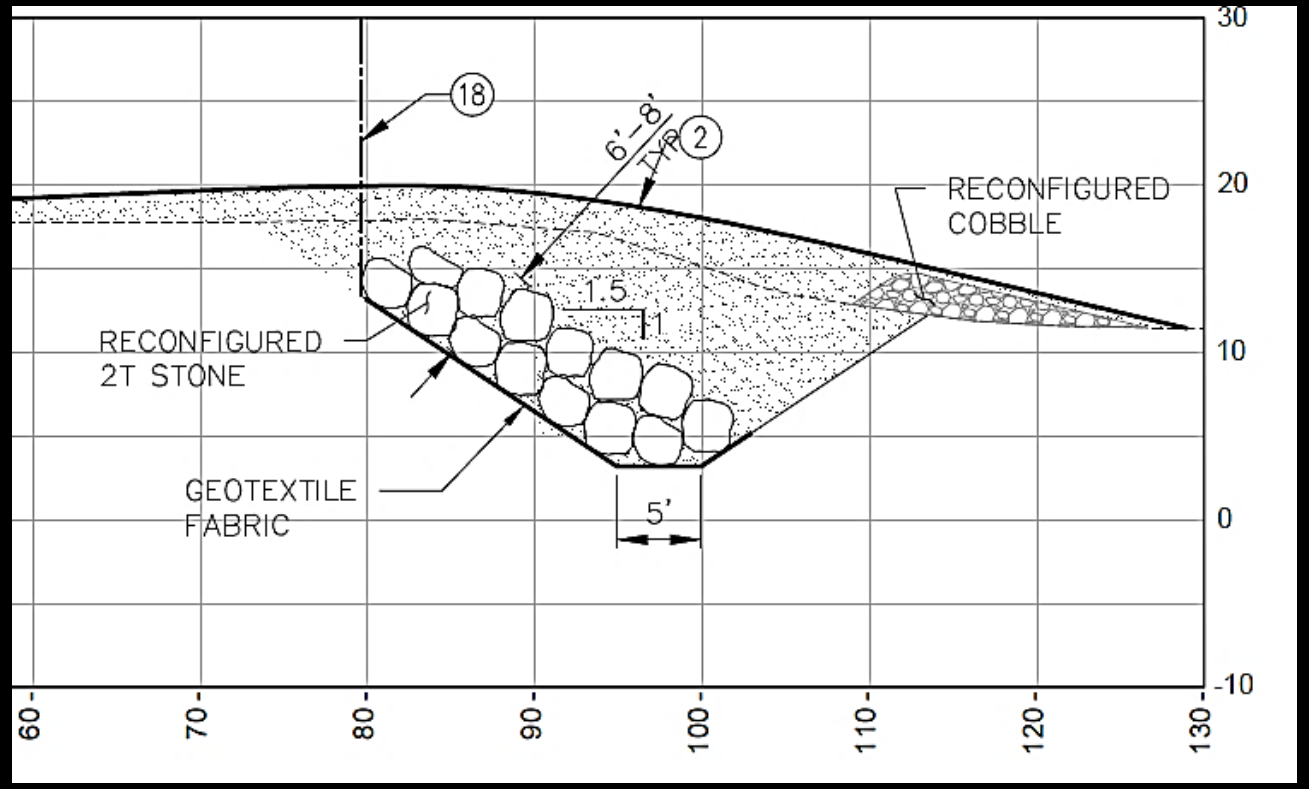
- Open Coast
- Tides & Currents
- Storm Surge
- Swell
- Sea Level Rise
- Pacific Coast Highway (PCH)
- Beach Access

Flooding & Erosion

Shoreline Protection: Protect the Highway from chronic erosion and flooding

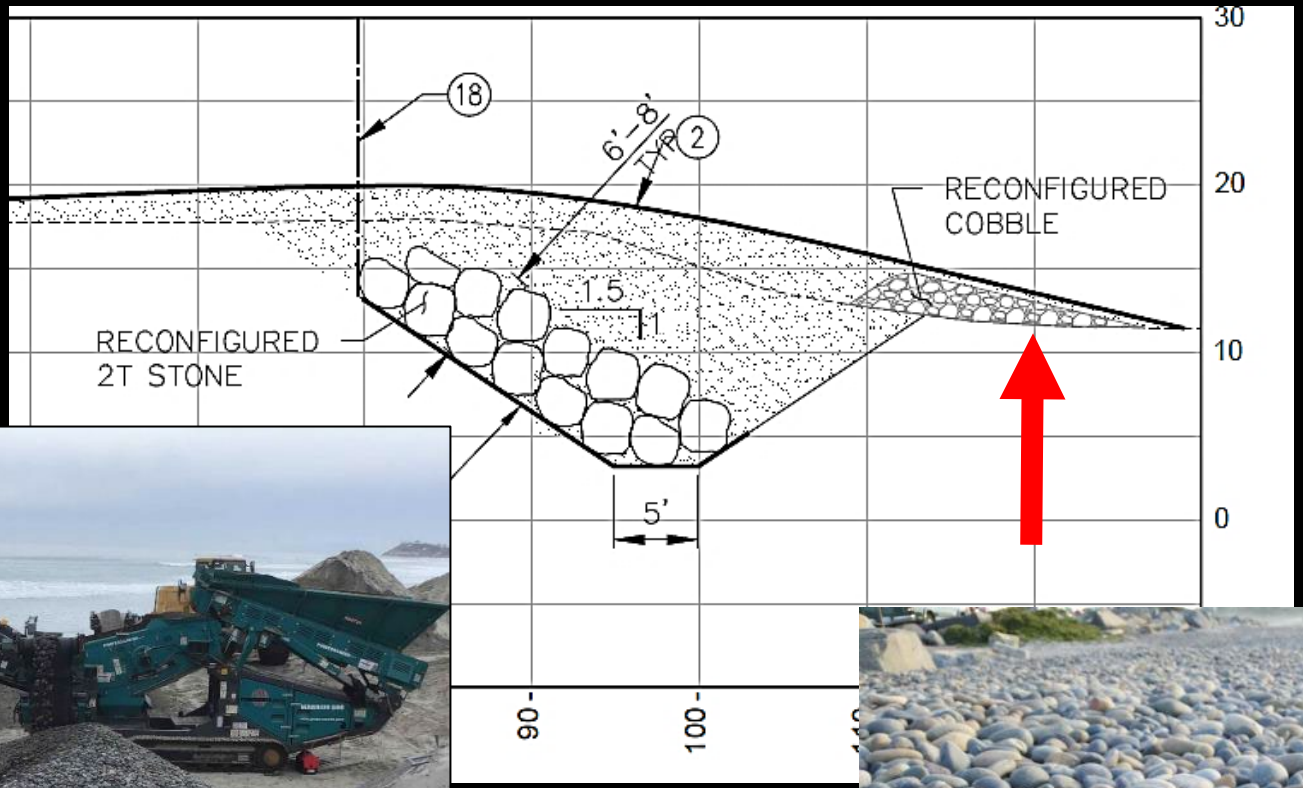
Multi-benefit: public access, erosion and flood protection, ecosystem services

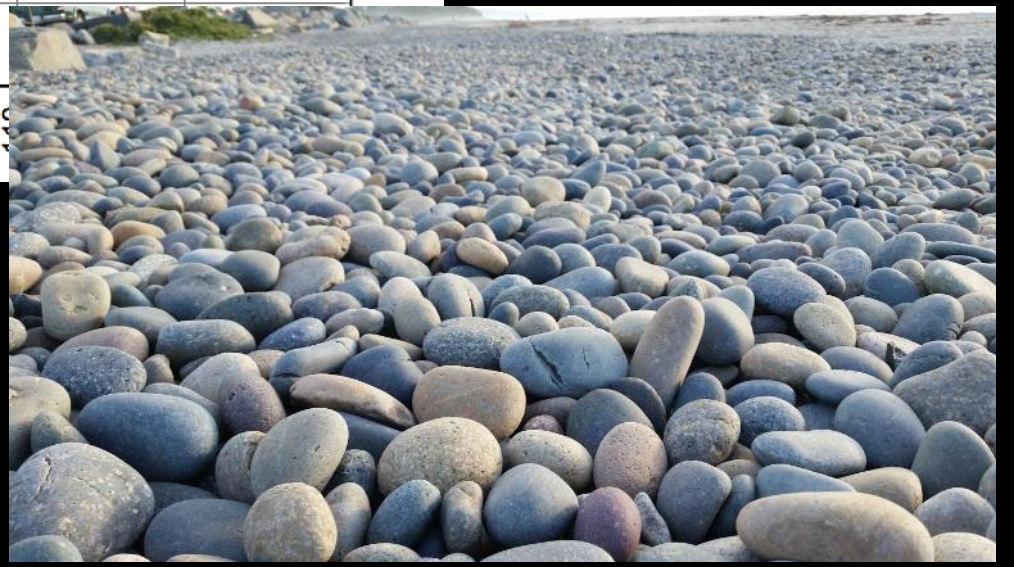
Primary Project Elements



Primary Project Elements – Buried Revetment

Project Element – Cobble Berm





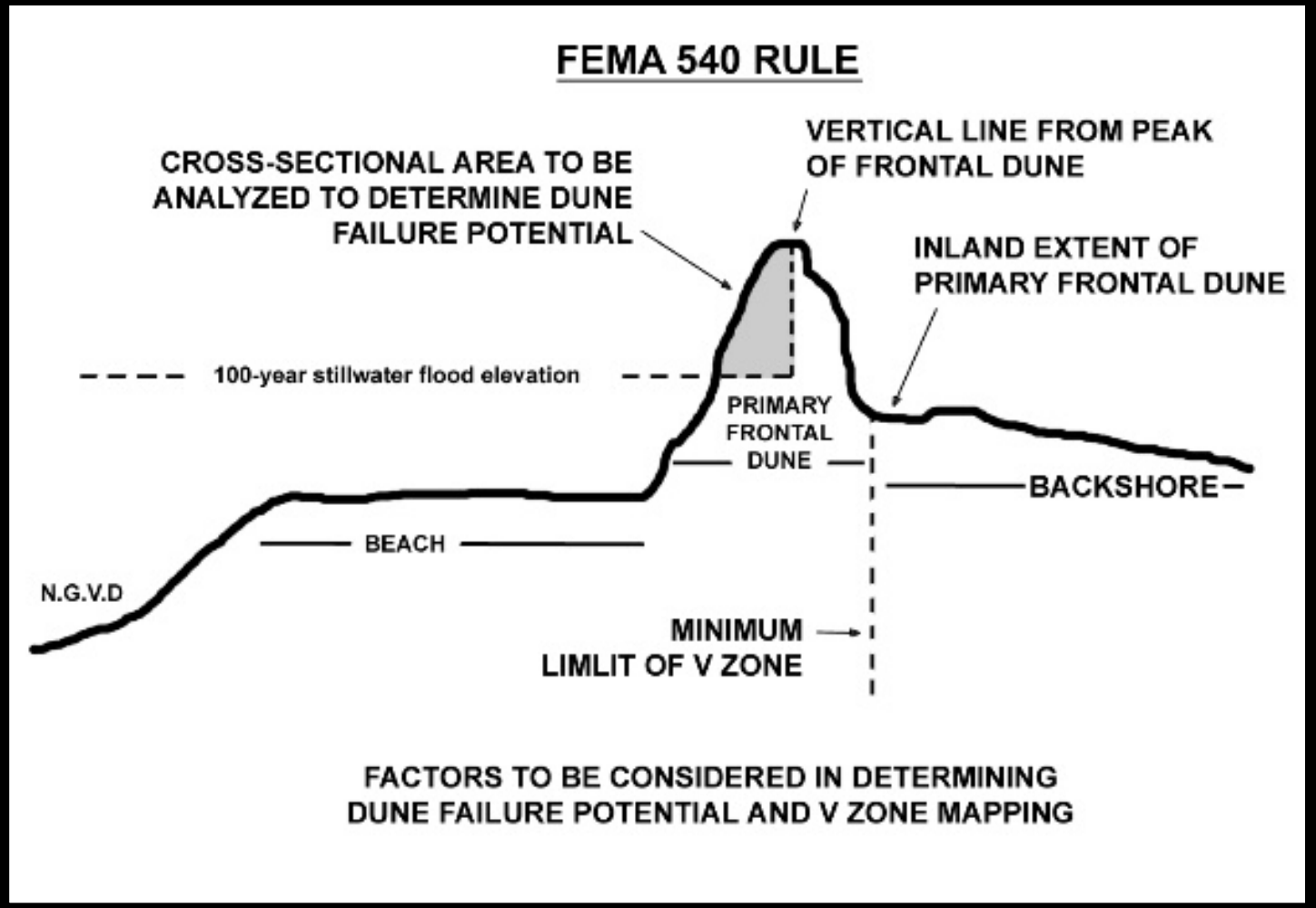
Project Element – Sand Dune

Monitoring

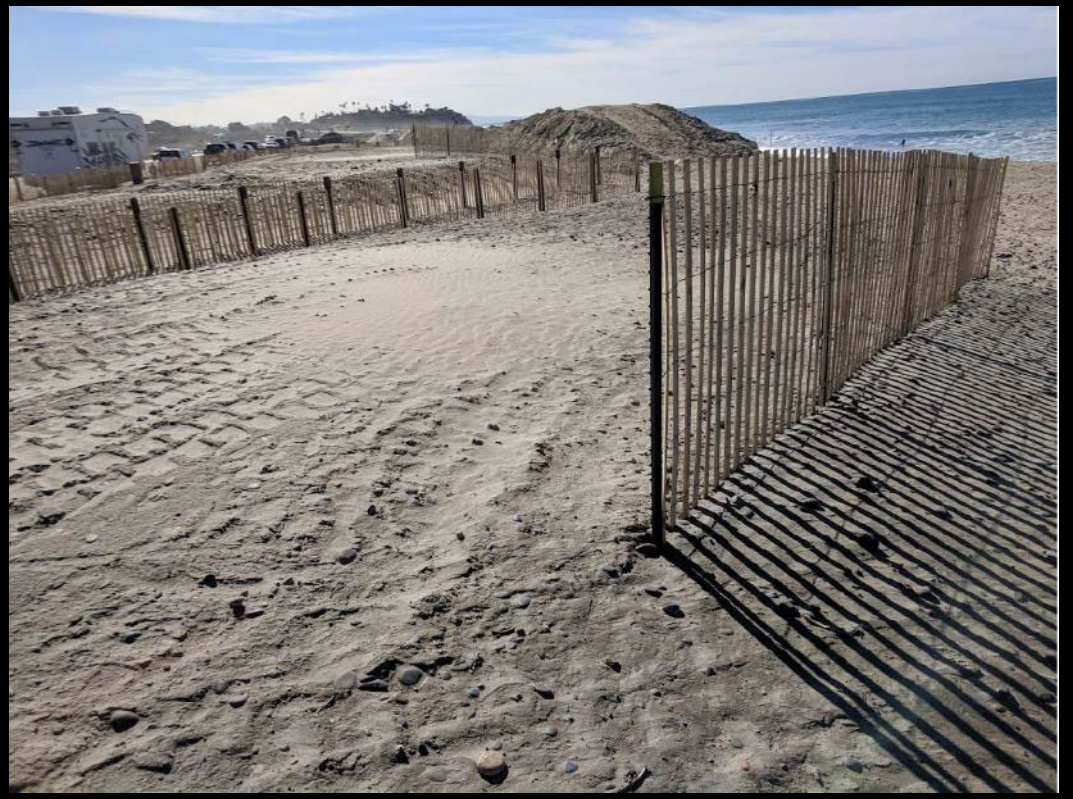
- Quarterly
  - Beach & Dune Topo
  - Beach Bathy Photos
- Annual Vegetation
- Surveys Extreme Event
- Documentation

What level of shoreline protection is provided by cobble berms?

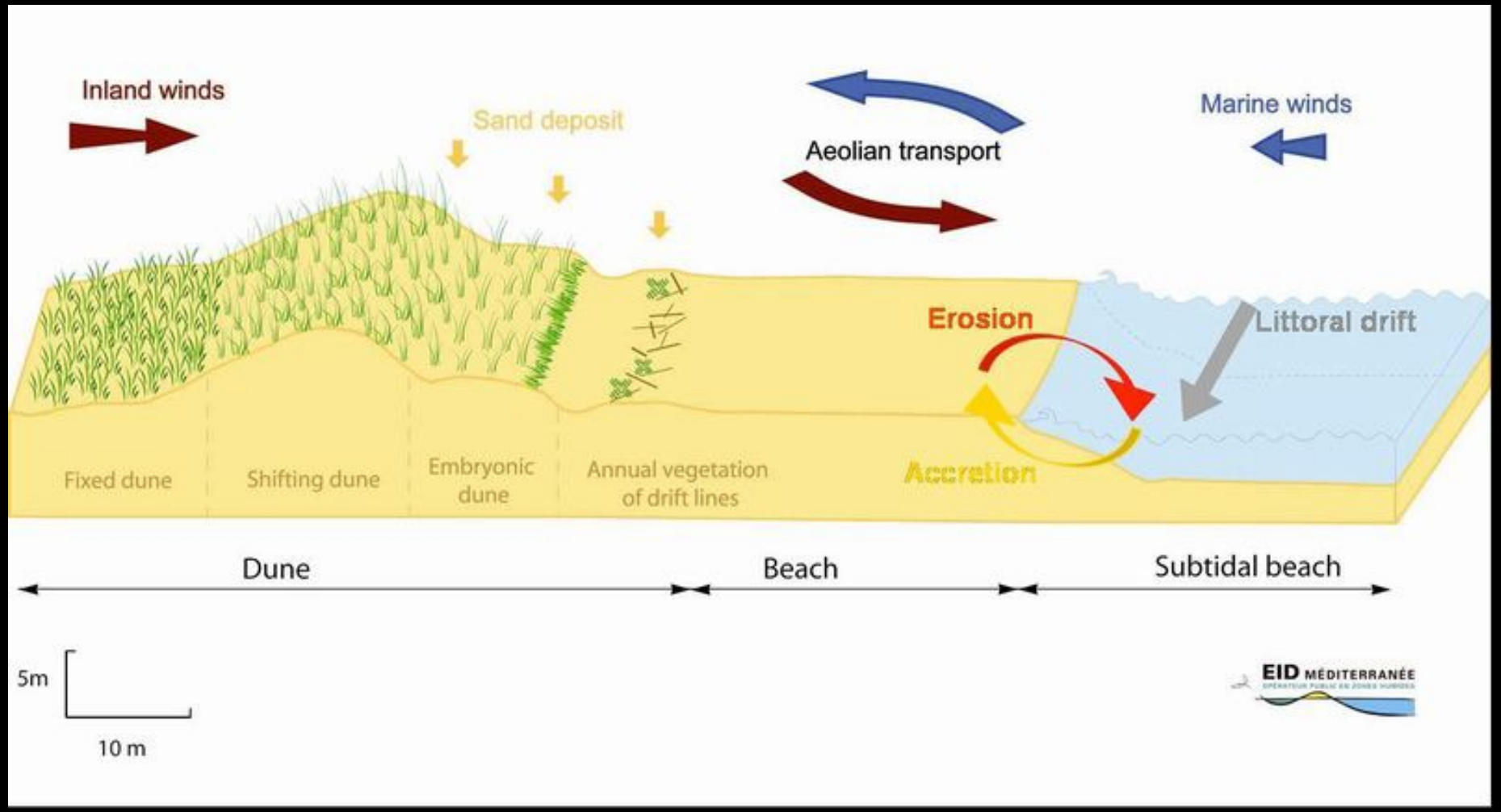
Is dune adequately sized to provide shoreline protection?



How does dune vegetation impact sand loss / Aeolian deposition?



Could the created dunes rebuild naturally on a seasonal basis?

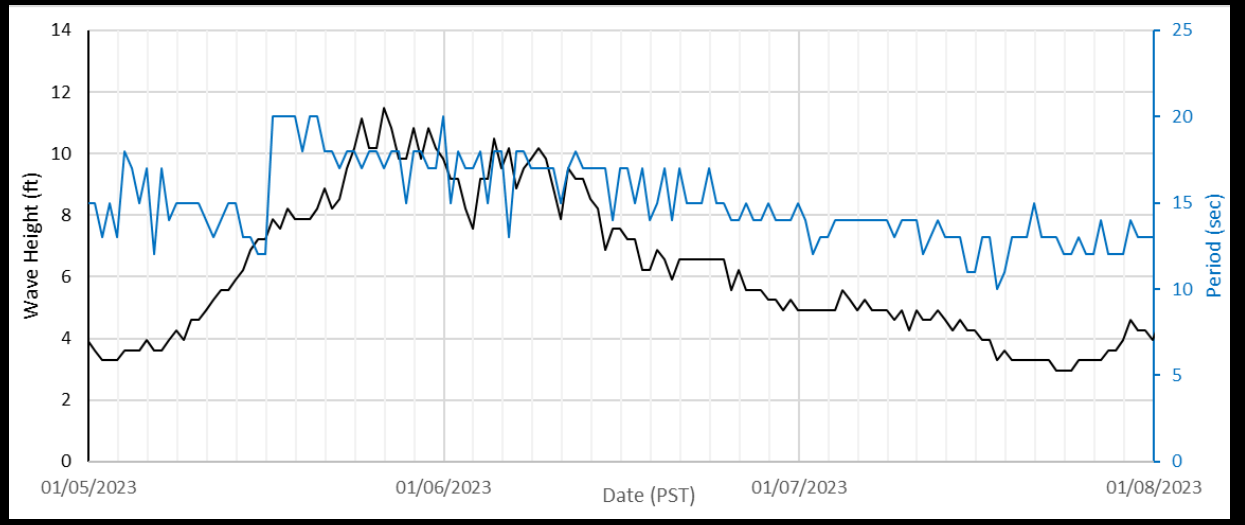


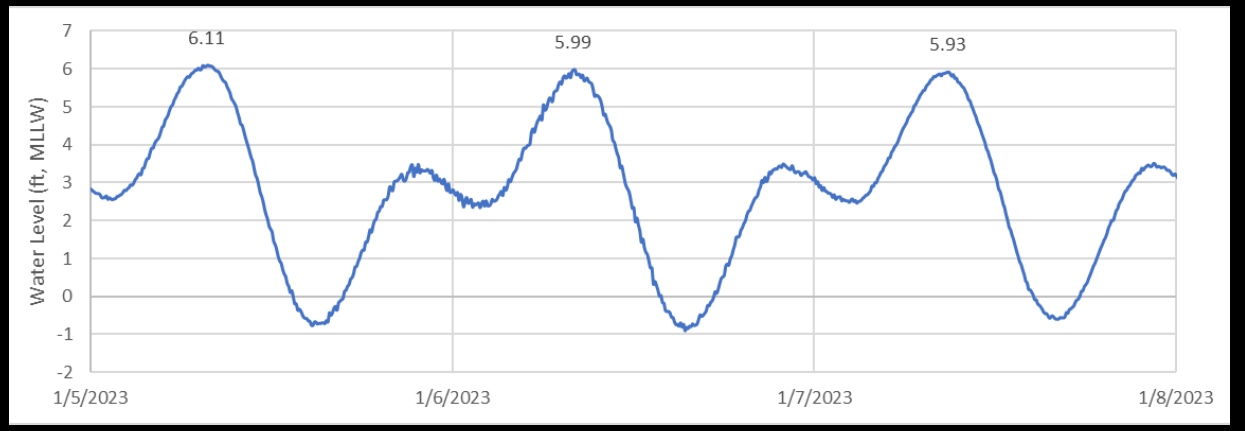
Historical Storm Context

- Wave height: 3-4’
- 11-15 sec period
- 5.5’ high tide

Jan 6th, 2023 15-20yr return period wave event

- Wave height: 11.5 ft
- 17 sec period
- ~6’ high tide





Jan 6th Observations – North End

Jan 6th Observations – Central

Jan 6th Observations – South

Jan 6th Observations – South

Post-Storm Recovery

Jan 6th, 2023

Feb 4th, 2023

Post-Storm Recovery

Jan 6th, 2023

Feb 4th, 2023

Maintenance

- Dune toe maintenance
- Sinkholes
- Opportunistic beach nourishment

What Can We Learn?

Wave Attenuation:

Natural features can help reduce the energy of wind and swell waves, decreasing the impact of storm surges and coastal flooding

What Can We Learn?

Erosion Control:

Natural coastal systems can buffer erosion rates

What Can We Learn?

Adaptive Capacity:

Natural coastal systems can provide a dynamic shoreline to buffer against a changing environment

What Can We Learn?

Multiple Benefits:

Natural coastal systems can provide flooding, erosion, ecosystem and recreation services

Thank You

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