

LEVERAGING HYDROLOGIC MODELS TO COMPARE ECOSYSTEM RESTORATION MEASURES IN A BAR-BUILT ESTUARY

Elizabeth O. Murray¹, Tiffany K. Cheng¹, Dane Behrens², Joél R. Flannery¹, and Jeneya A Fertel¹

¹US Army Corps of Engineers, San Francisco District, San Francisco, CA, USA

²Environmental Science Associates, San Francisco, CA, USA

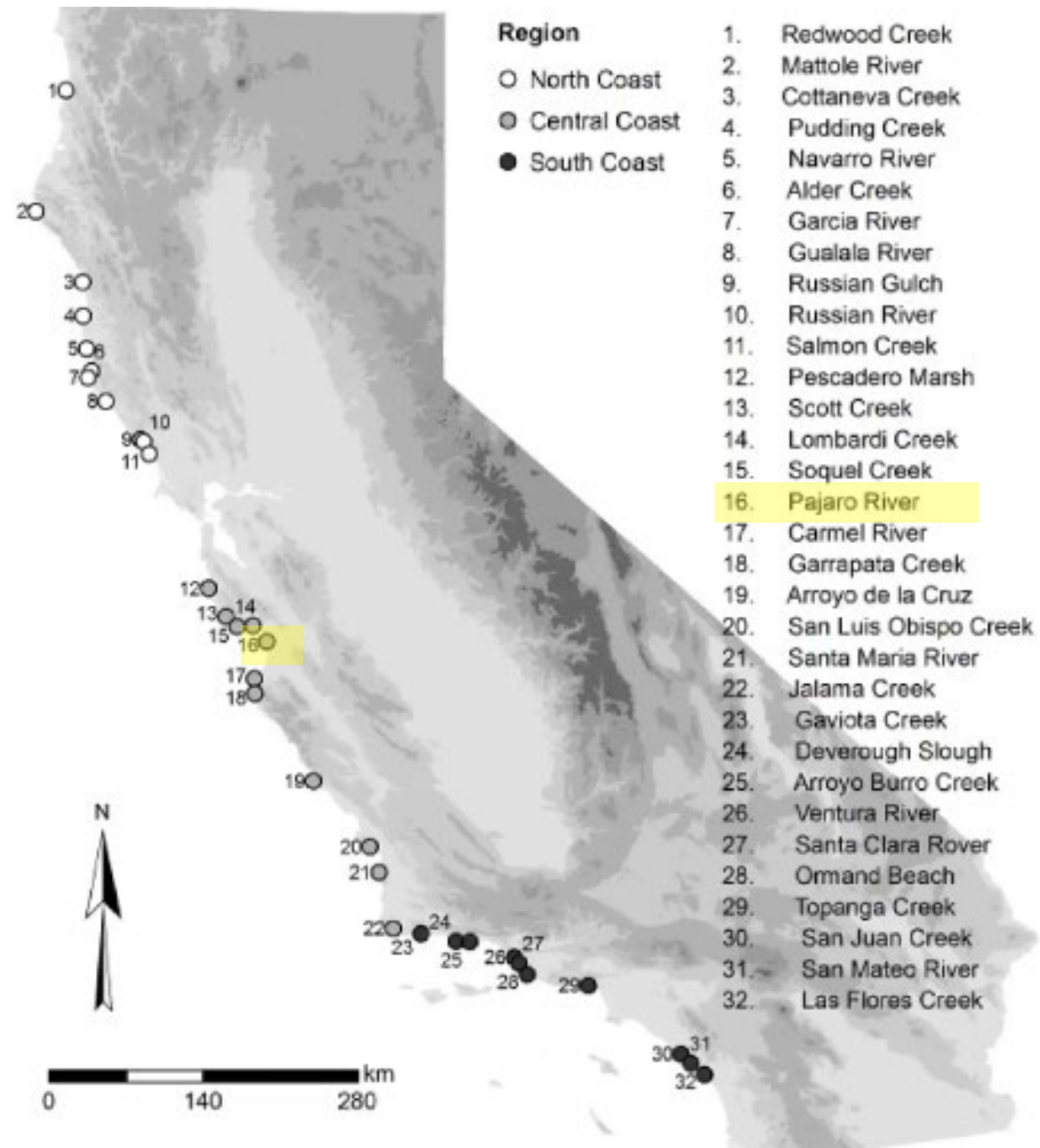
April 18, 2024

National Conference on Ecosystem Restoration
Albuquerque, New Mexico



BAR-BUILT ESTUARIES OF CALIFORNIA

- Roughly half of California's Coastal confluences are BBEs/lagoons
- Natural variations in seasonal wave energy and fluvial flows lead to closures when waves build up beach and block river mouth
- These closures naturally extend days to weeks
- Watsonville Slough is a tributary of the Pajaro River BBE

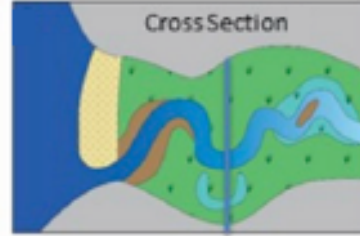


Adapted from Clark and O'Connor 2019

LAGOON MOUTH STATES AFFECT MARSH INUNDATION

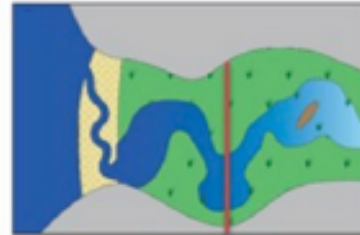
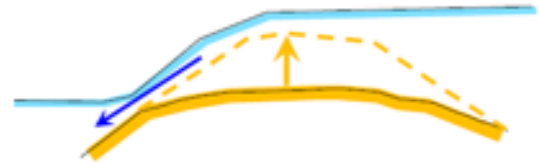
Three natural lagoon mouth states contribute to hydrology

Open
(tidal)



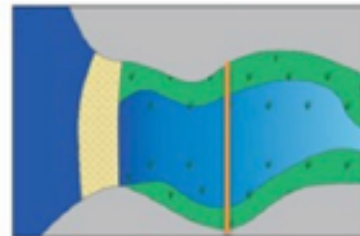
When lagoon is open/tidal, water stays in channels and very low marsh. Inundation dependent on microtopographic relief and side channel connectivity.

Partially Open
(muted tidal)



Muted tidal conditions allow some water to back up onto marsh plain. Microtopographic relief and side channels allow this water to expand onto the marsh plain.

Closed
(nontidal)



Inundation of upper marsh plain only occurs at high water levels (when lagoon mouth is closed) and is part of the natural hydrology of the system.

Ocean Sandbar/beach cross-section Lagoon

Marsh Planview

Closed
Partially Open
Open

Marsh Cross Sections

STUDY

- Army Corps' CAP Section 1135 (Ecosystem Restoration, <\$10 M fed)

OVERVIEW

- *Small (for USACE) Simple (for USACE)*
- Non-Federal Sponsor: Pajaro Storm Drain Maintenance District (PSDMD), within Santa Cruz County

PROJECT TRIBES, STAKEHOLDERS, AGENCIES

- California Coastal Commission
- California State Lands Commission
- California State Office of Historic Preservation
- California State Parks
- City of Watsonville
- Environmental Science Associates
- Land Trust of Santa Cruz County
- Moss Landing Marine Laboratories
- Central Coast Wetlands Group
- NOAA Fisheries
- Pajaro Dunes Association
- Pajaro Valley Water Management Agency
- Resource Conservation District of Santa Cruz
- Santa Cruz County, Code Compliance
- Santa Cruz County Fisheries, represented by Kittleson Environmental Consulting
- Santa Cruz County Mosquito Abatement & Vector Control Division
- State Water Resource Control Board (CA Water Boards)
- U.S. Environmental Protection Agency, Region 9
- U.S. Fish and Wildlife Service
- Watsonville Wetlands Watch

Tribal:

- Amah Mutsun Tribal Band
- Amah Mutsun Tribal Band of Mission San Juan Bautista
- Costanoan Ohlone Rumsen-Mutsun Tribe
- Indian Canyon Mutsun Band of Costanoan
- Muwekma Ohlone Indian Tribe of the SF Bay Area



Photo Credit: Watsonville Wetlands Watch

STUDY AREA



- Watsonville Slough is a tributary of the Pajaro River, and part of its lagoon.
- Lagoon constrained by Federal levees, farm levees, and development.

Source: Adapted from Whipple and Grossinger 2008

EXISTING CONDITION: VEGETATION ON REMNANT MARSH PLAIN

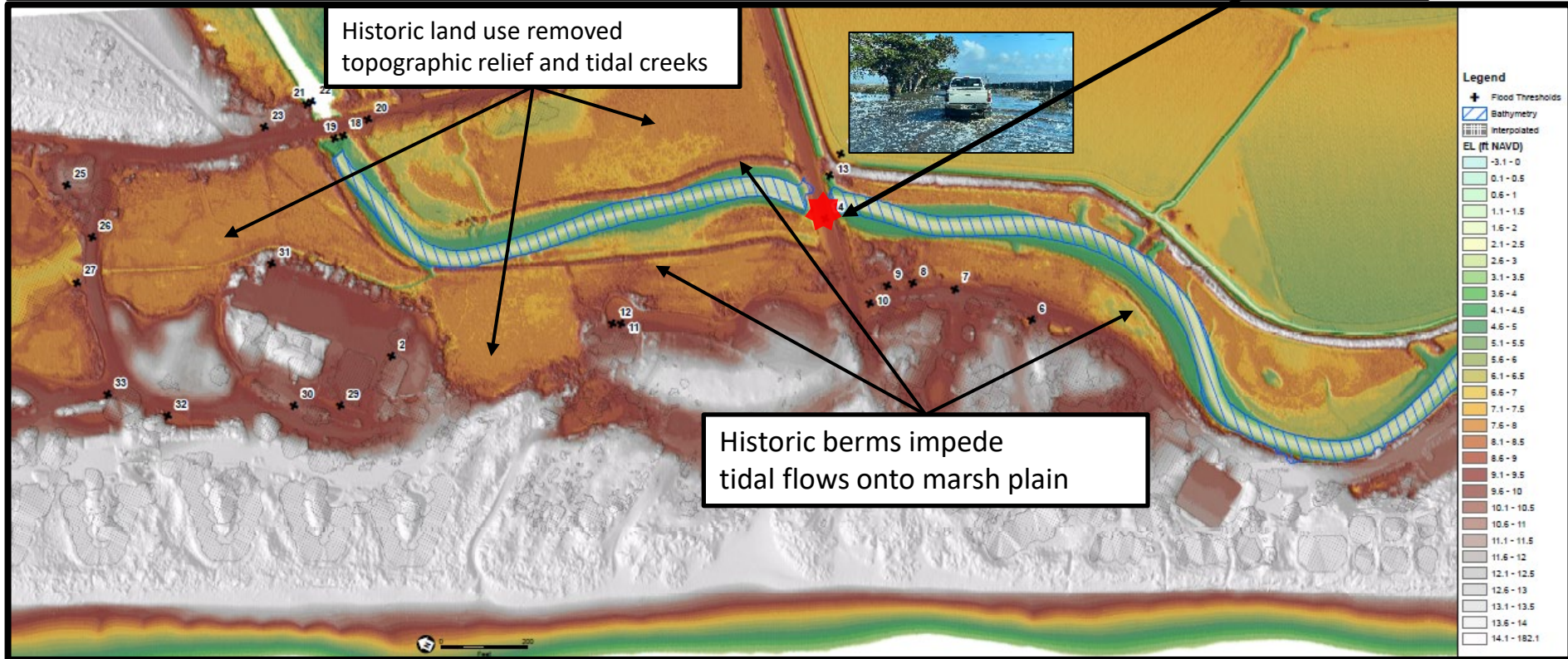
- Watsonville Wetlands Watch mapping of existing vegetation on the marsh plain indicate many areas are **stressed**, supporting stunted marsh species or **co-dominated by xeric non-native invasive plants** (e.g., A and C)
- Other areas support healthy marsh (e.g., B), especially in lower areas where existing side channels exist
- This suggests **truncated hydrology** of the marsh plain, which reduce **inundation periods**
- There's a desire to restore adjacent ag lands, so improving hydrology on existing marsh is first step to sets up future restoration.



EXISTING CONDITIONS THAT MAY TRUNCATE HYDROLOGY OF MARSH PLAIN



Low/undersized infrastructure requires manual breaching of lagoon

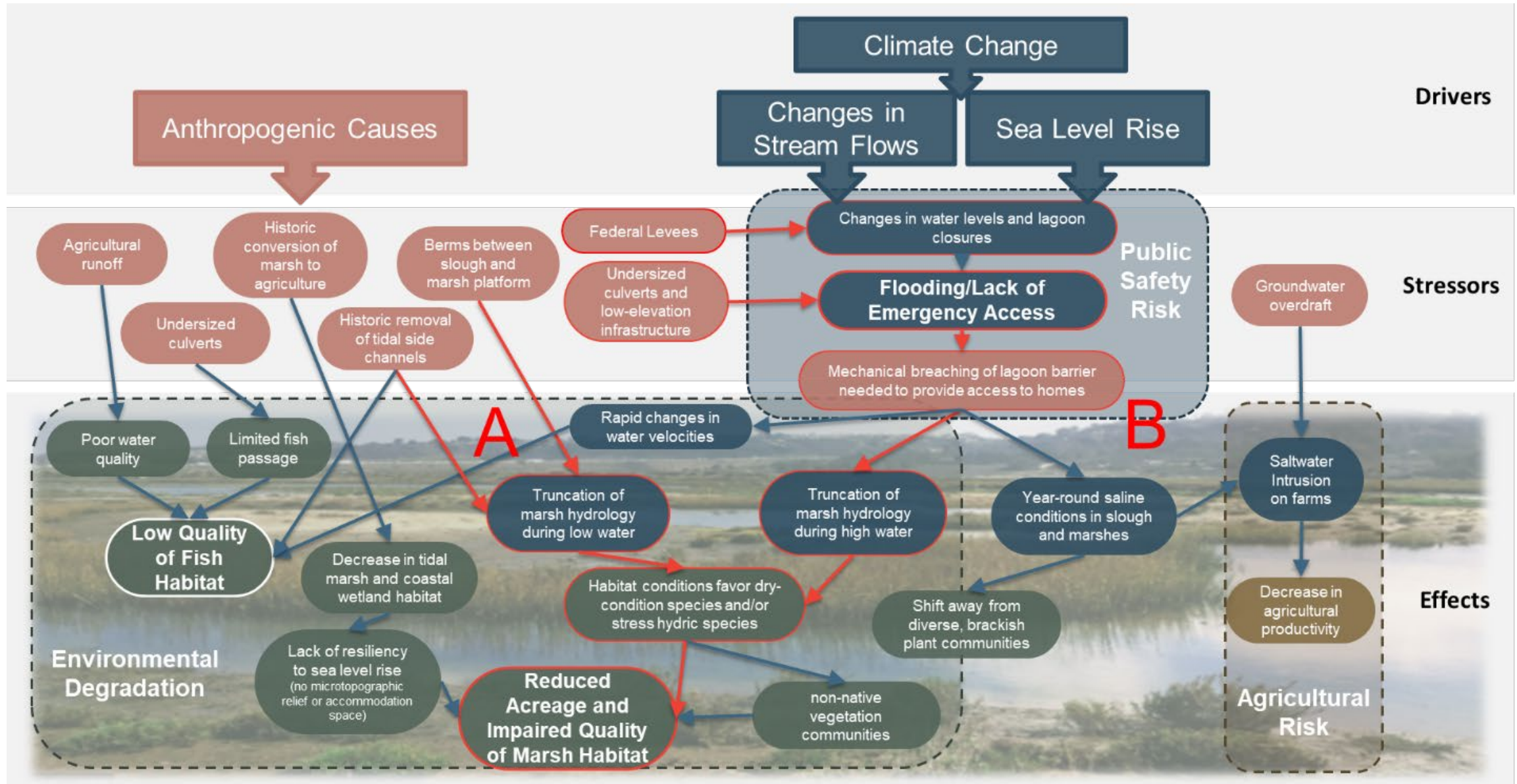


- Having established that truncated hydrology is a potential cause limiting marsh health and vegetation quality, the team worked to identify factors that may contribute to the problem.

Pajaro Dunes and Lagoon Flood Vulnerability - D780065.00

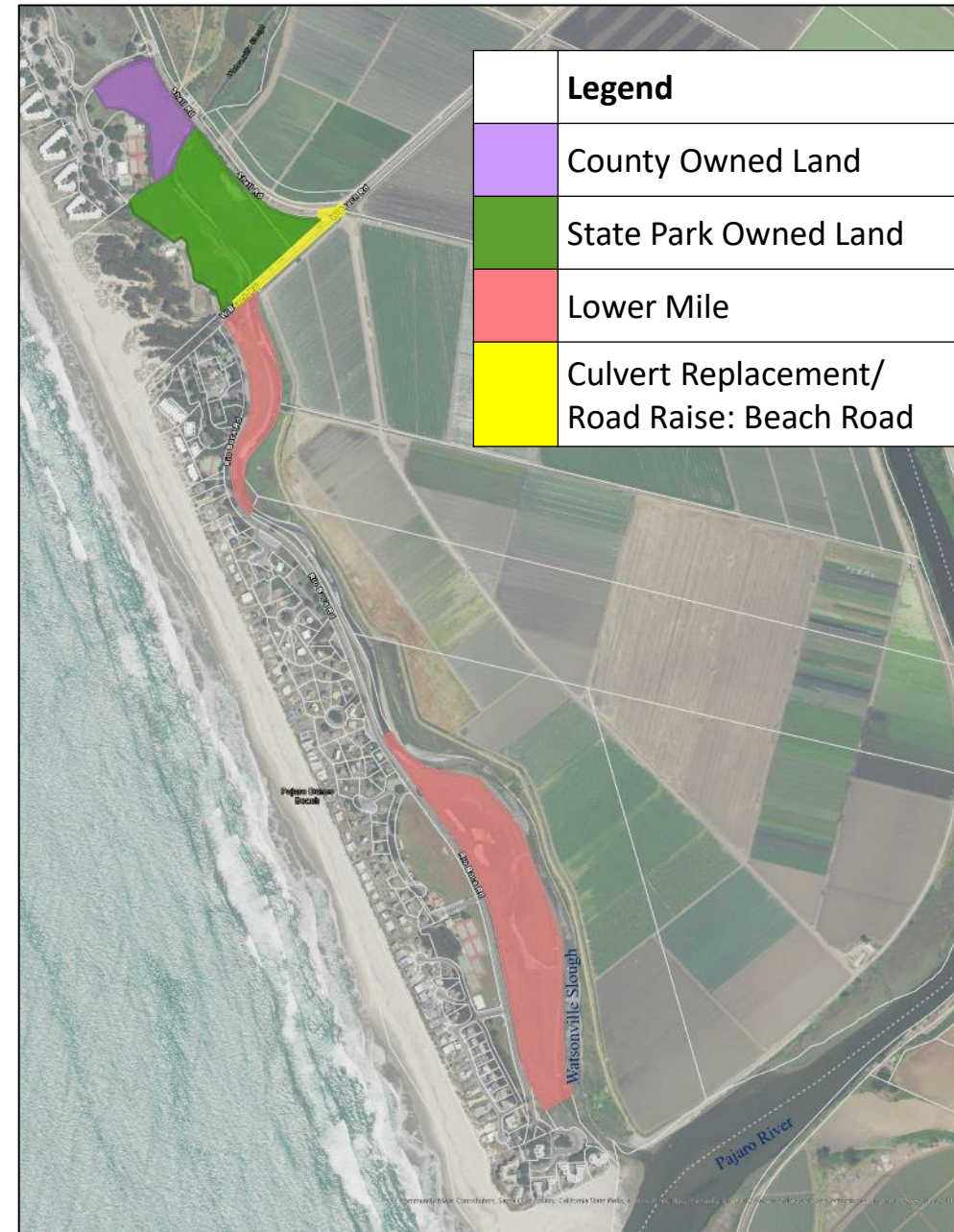
Pajaro Dunes and Lagoon Flood Vulnerability - D780065.00

ECOLOGICAL CONCEPTUAL MODEL



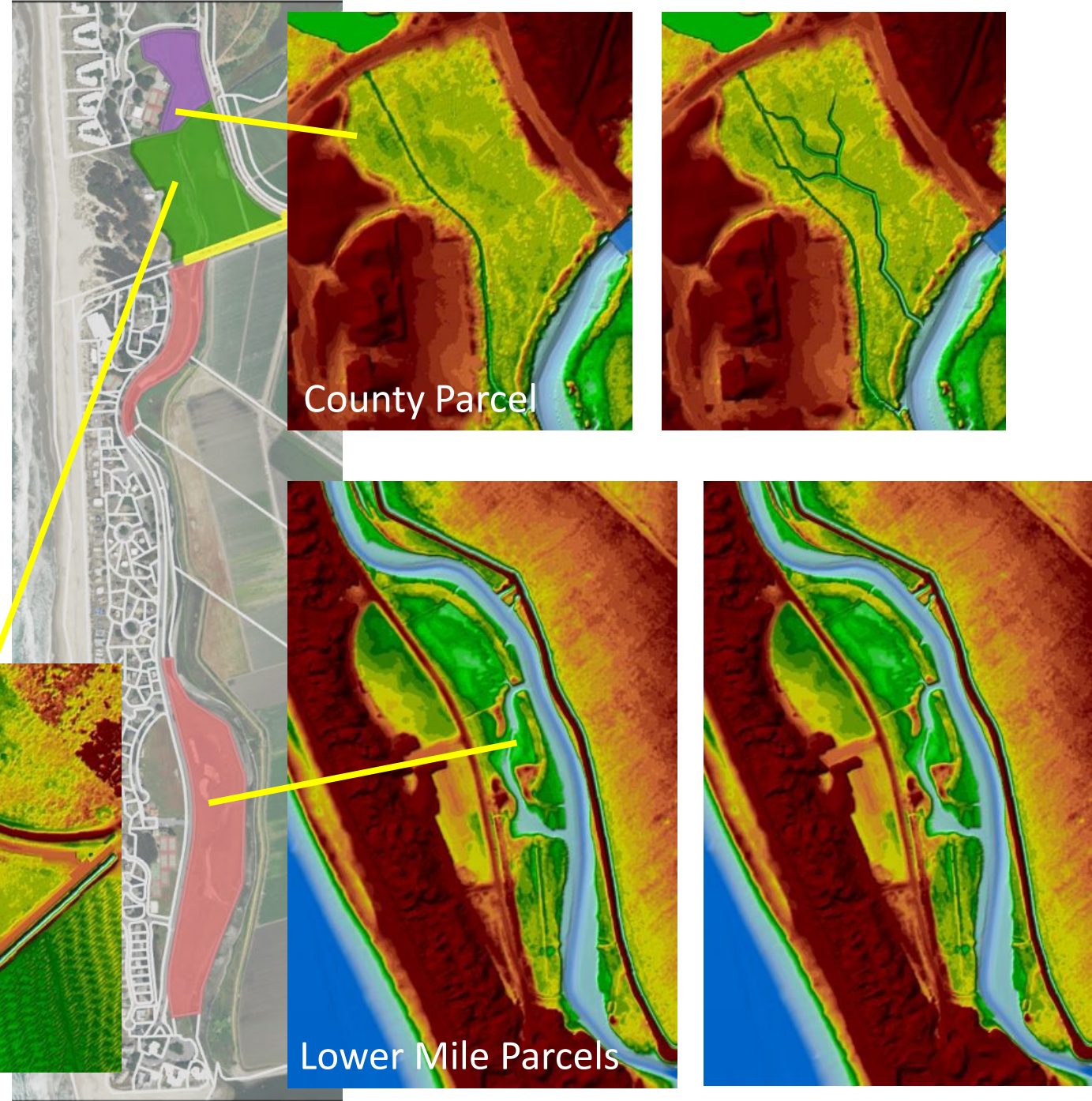
MEASURE FORMULATION / ECOSYSTEM RESTORATION BENEFIT ANALYSIS

- At each of the retained parcels, three different ways of affecting the marsh hydrology were evaluated in HEC-RAS, testing the efficiency of the two major pathways identified for the hydrology truncation.
 - No Action/FWOP – just considers SLR
 - Earthwork Scenario – hydrology changed by notching of berms and excavation of side channels
 - Road Raise Scenario – hydrology changed by replacing undersized culverts and raising road / changing the lagoon breach threshold
 - Earthwork + Road Raise Scenario – hydrology changed by both raising road and changing the lagoon breach threshold
- Point is to restore more natural wetland hydrology so new plantings will thrive.



DETAILS OF TIDAL CREEKS AND BERM BREACH MEASURES FOR EARTHWORK SCENARIOS

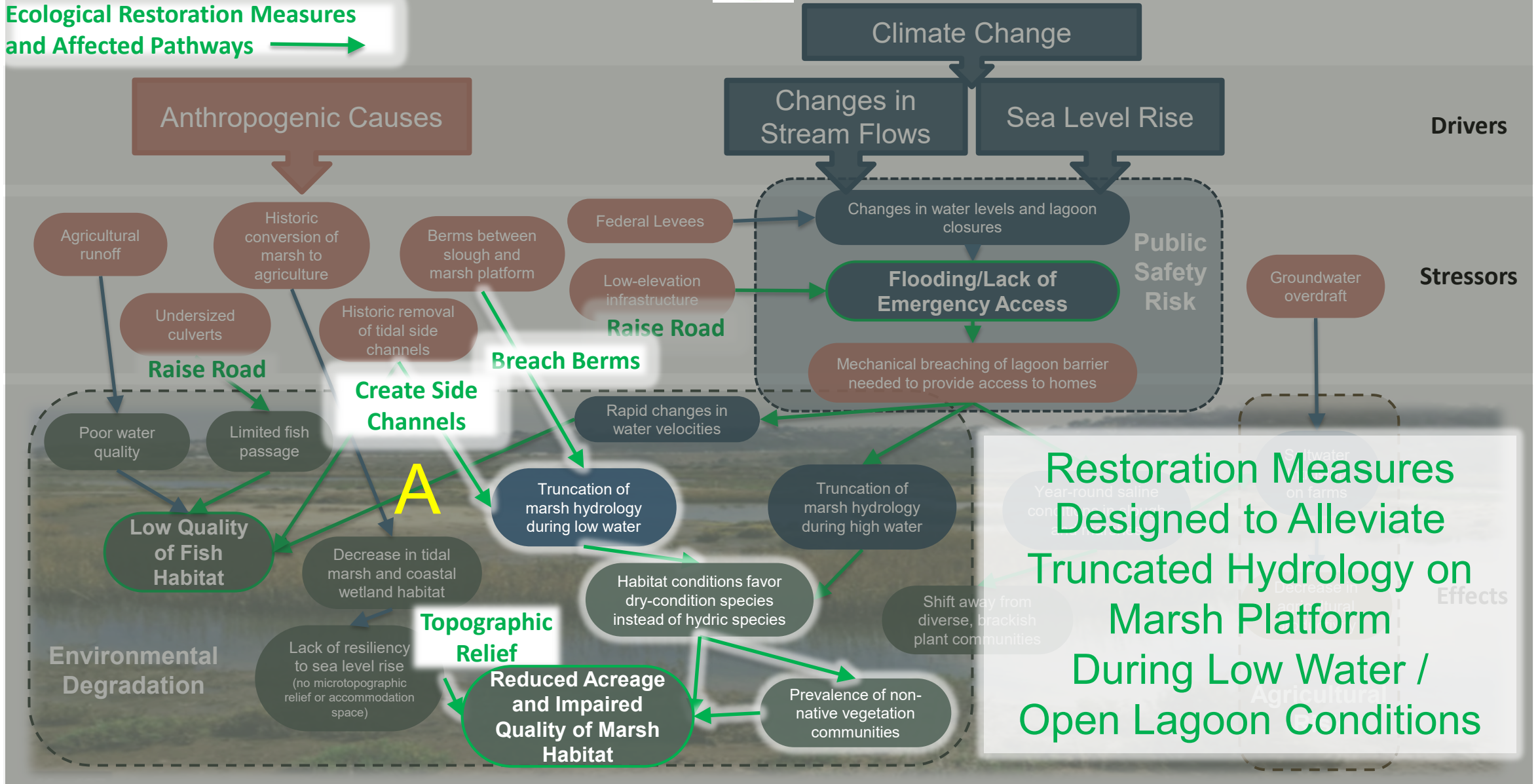
- At each parcel, a restoration design including tidal channels and berm breaches was incorporated into the HEC-RAS terrain for the “Earthwork” scenarios.
- Expected to allow tidal flows to access more of marsh plain



ECOLOGICAL CONCEPTUAL MODEL

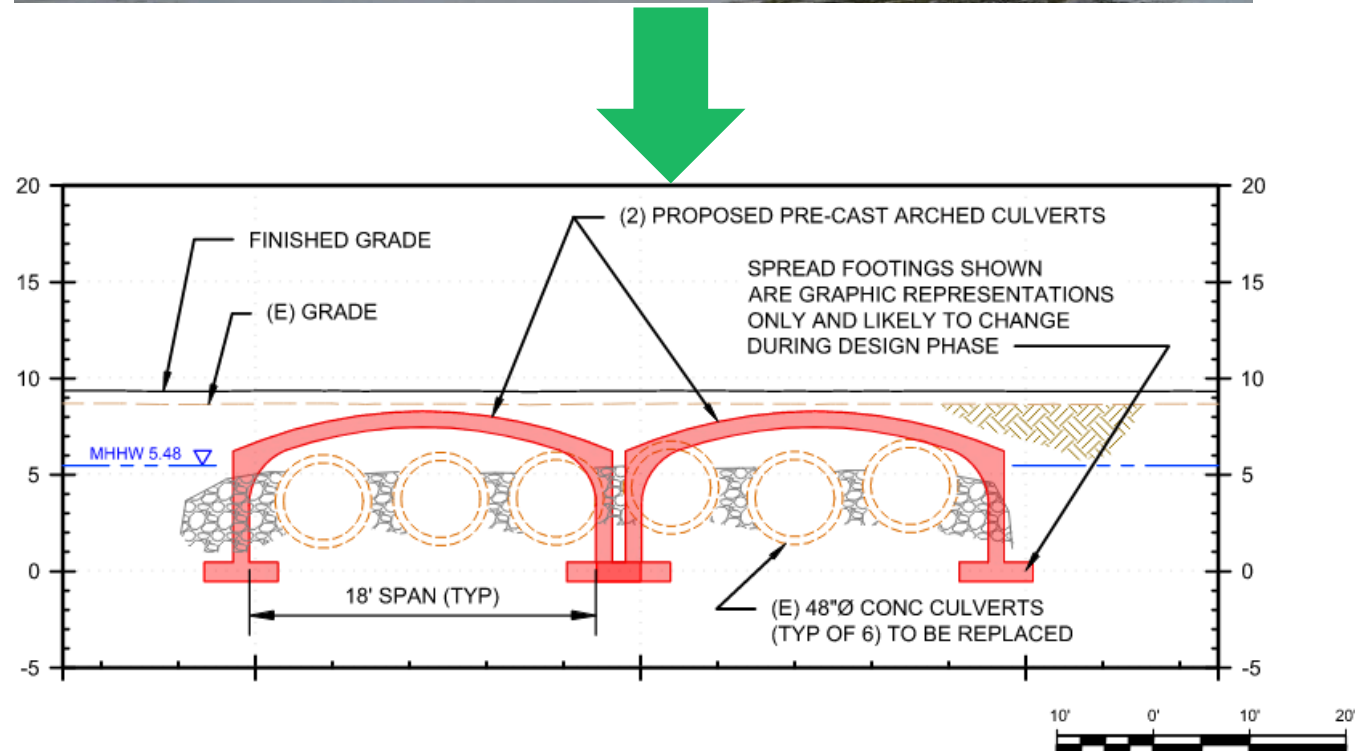


Ecological Restoration Measures and Affected Pathways →



“RAISE BEACH ROAD” MEASURE

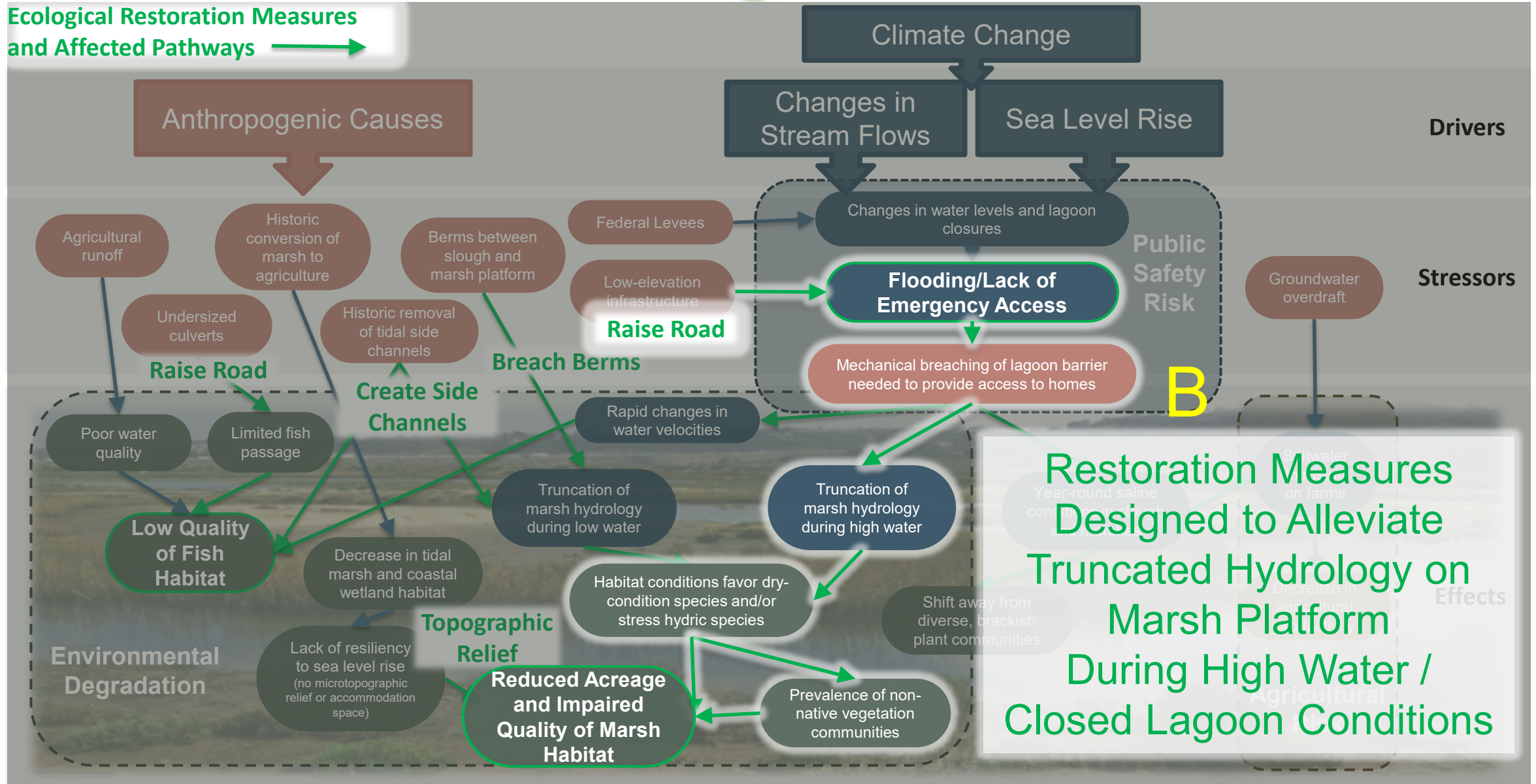
- Beach Road is currently the trigger for mechanical breaching and draining of the lagoon at 8ft NAVD88. The culvert replacement and road raise will change the breach threshold to 9.2 ft NAVD88. Raising it more than that would add cost but no benefit to marsh hydrology, since other infrastructure would trigger the breach at that point.
- 9.2 ft NAVD88 based on review of prior asset vulnerability study and coordination with Local Sponsor
- Modification is expected to allow longer and broader natural inundation of marsh plain, which will be tested by the modeling.



ECOLOGICAL CONCEPTUAL MODEL



Ecological Restoration Measures and Affected Pathways →



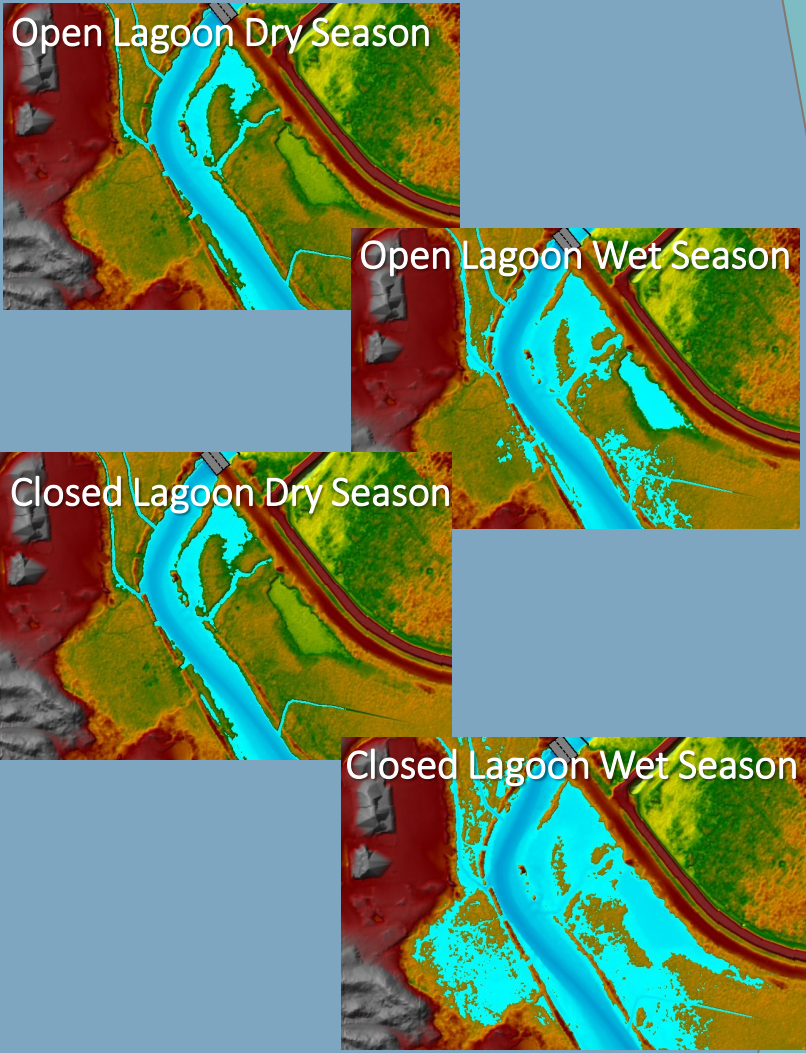
HYDROLOGIC AND MARSH ECOLOGICAL BENEFIT : TECHNICAL APPROACH

- HEC-RAS 6.2 used to evaluate no-project and with-project conditions within Watsonville Slough for different lagoon regimes
 - Full model includes upper watershed
 - Generate percent time inundated for each scenario
- Assumptions around lagoon mouth behavior patterns informed by Lagoon QCM (Behrens et al. 2015)
- Modeling built upon previous studies around the area by USACE, Local Sponsor and ESA



ECOLOGICAL BENEFIT MODELING: HYDRAULIC MODELING TECHNICAL APPROACH

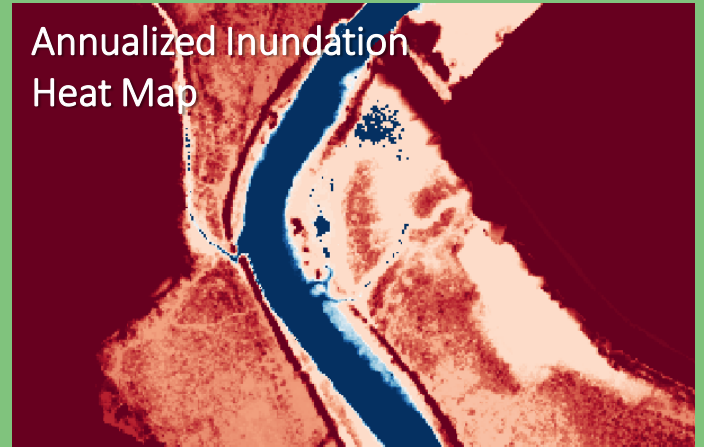
HEC-RAS Short 2-month Model Runs for Specific Lagoon states



HEC-RASMapper generates inundation “heat maps” for each run



ArcGIS-Pro used to combine individual heat maps via a weighted average calculation into an annualized heat map of inundation ranges. This was compared to locations of healthy middle marsh.

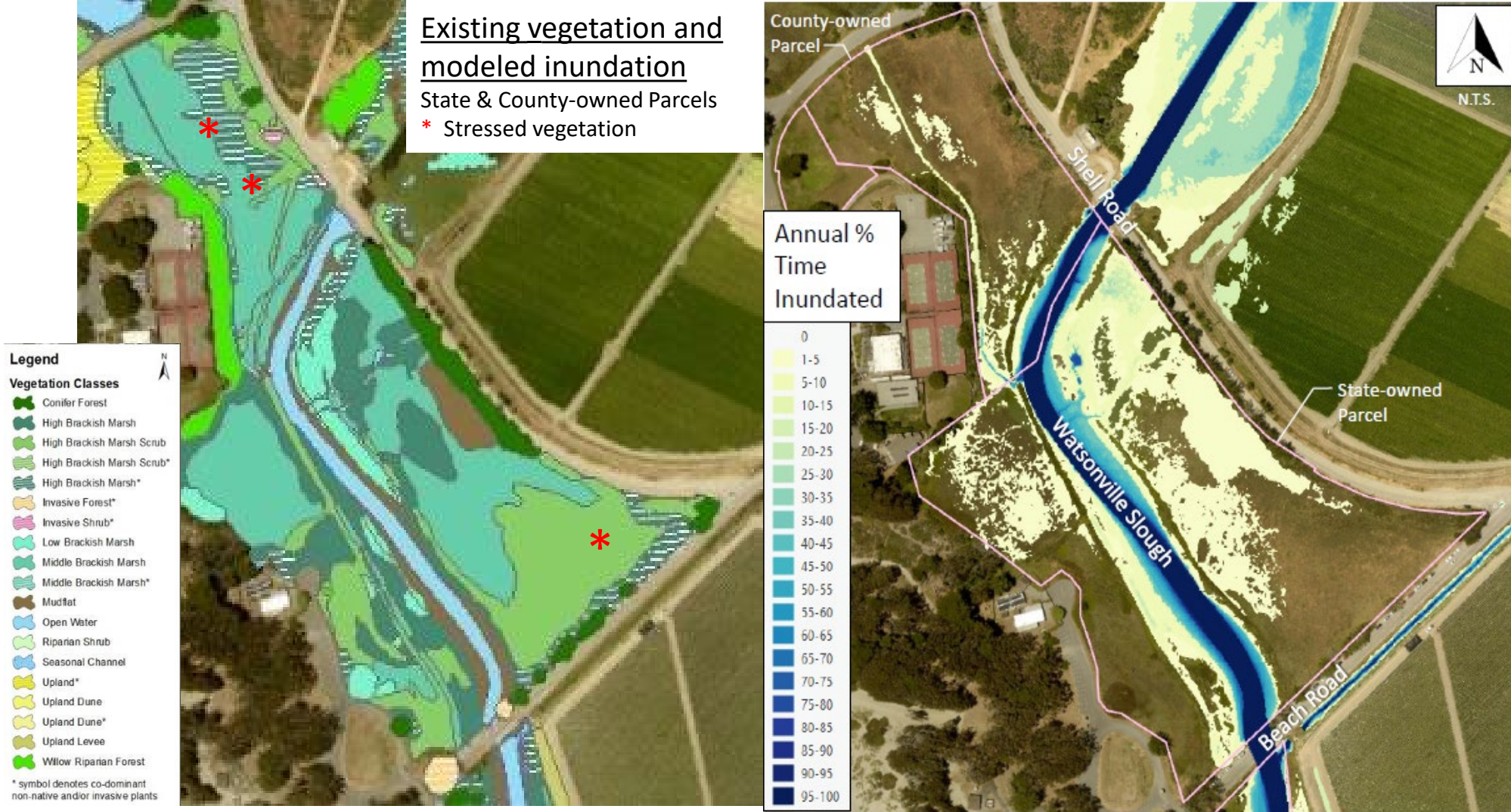


Weights are based on 10 yrs empirical data for existing conditions, and calibrated **Lagoon QCM** for forecasting

* Example only for illustrative purposes

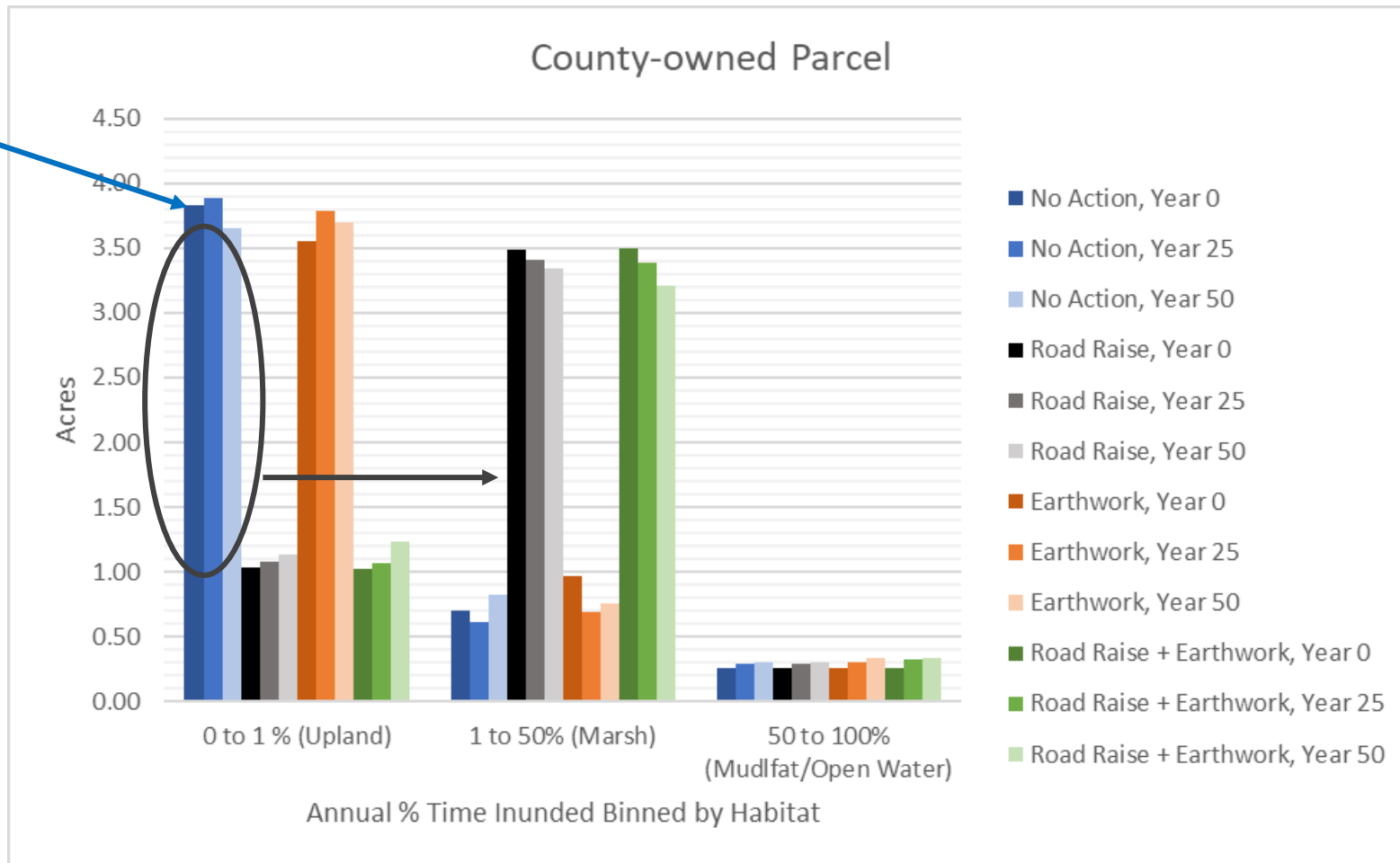
DEFINING “MARSH HYDROLOGY” BY COMPARING EXISTING VEGETATION WITH MODELED INUNDATION EXISTING CONDITIONS

- “Marsh Hydrology” determined to be 1-50% annual inundation, which includes mapped healthy low, middle, and high marsh
- 0-1% annual inundation excluded because mapped as stressed marsh and marsh codominant with xeric non-native species
- 50-100% annual inundation correlates with mudflat and open water



DETERMINING BENEFITS PER PARCEL PER MEASURE

- No Action (blue bars) has a lot acreage with “upland” hydrology. Earthwork Only (orange bars) is almost the same.
- The Road Raise (grey bars) scenario has MUCH MORE marsh hydrology. Road raise and earthwork (green bars) is almost the same
- No change in amount of open water across all scenarios



MAJOR OUTCOMES FROM MODELING

- Under No Action, as SLR increases, the lagoon will need to be breached more frequently, until the lagoon system becomes permanently (with constant breaching) open and tidal.
- Non-trivial amount of modeling:
 - 4 Scenarios (No Action, Earthwork, Road Raise, Earthwork and Road Raise) each requiring
 - 4 Lagoon States (Open Dry Season, Open Wet Season, Closed Dry Season, Closed Wet Season) at
 - 3 Time Steps (Years 0, 25, and 50)
 - Equals 48 HEC-RAS model runs, plus post processing with Lagoon QCM weights to synthesize 12 Annualized Inundation Maps
 - BUT it clearly shows that the replacement of culverts and raising of the road/breaching threshold is most effective restoration measure.
- Was this too much for CAP? If we'd done an ecosystem index model based on side channels and veg, we would have gotten the wrong answer... THAT would have been expensive.
- **CAP studies aren't always "simple"**
- **Sometimes the best thing you can do for the ecosystem is get out of its way.**
- New breaching threshold will better support expansion of the marsh as agricultural land becomes available for restoration. Important first step in larger watershed restoration.

THANKS TO THE WATSONVILLE SLOUGH CAP 1135 FEASIBILITY STUDY TEAM MEMBERS

USACE Project Deliver Team (San Francisco District & Regional CAP Production Center)

- **Joél Flannery, Project Manager/Planner (Author)**
- **Tiffany Cheng, Coastal Engineer/Technical Lead (Author)**
- **Elizabeth Murray, Lead Planner/Wetland Biologist (Author/Presenter)**
- **Jeneya Fertel, Biologist and GIS Heat Map Analyst (Author)**
- Joel Achenbach, Hydrology & Hydraulics
- David Demko, Civil Design Engineering
- Anna Kirsch, Civil Design Engineering
- Luke Zimmerman, Geotechnical Engineer
- Warren Tan, Cost Engineering
- Josh Miller, Geospatial Analyst
- Jamie You, Environmental Planner
- Stephanie Bergman, Cultural Resources
- Robert Grimes, Economics
- Kate Stowe, Real Estate
- Gerry Prado, Construction

Non-Federal Sponsor: Pajaro Storm Drain Maintenance District (PSDMD)

- Mark Strudley, PSDMD Program Manager
- Antonella Gentile, PSDMD Resource Planner (CEQA Lead)
- Rusty Barker, PSDMD Civil Engineer
- **Dane Behrens, ESA, Consultant (Author)**

**Discussion/
Questions**

