Designing Tidal Restoration Projects for Physical Processes

Brian Wardman, P.E.

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northwest hydraulic consultants

water resource specialists

Restoration Body of Knowledge

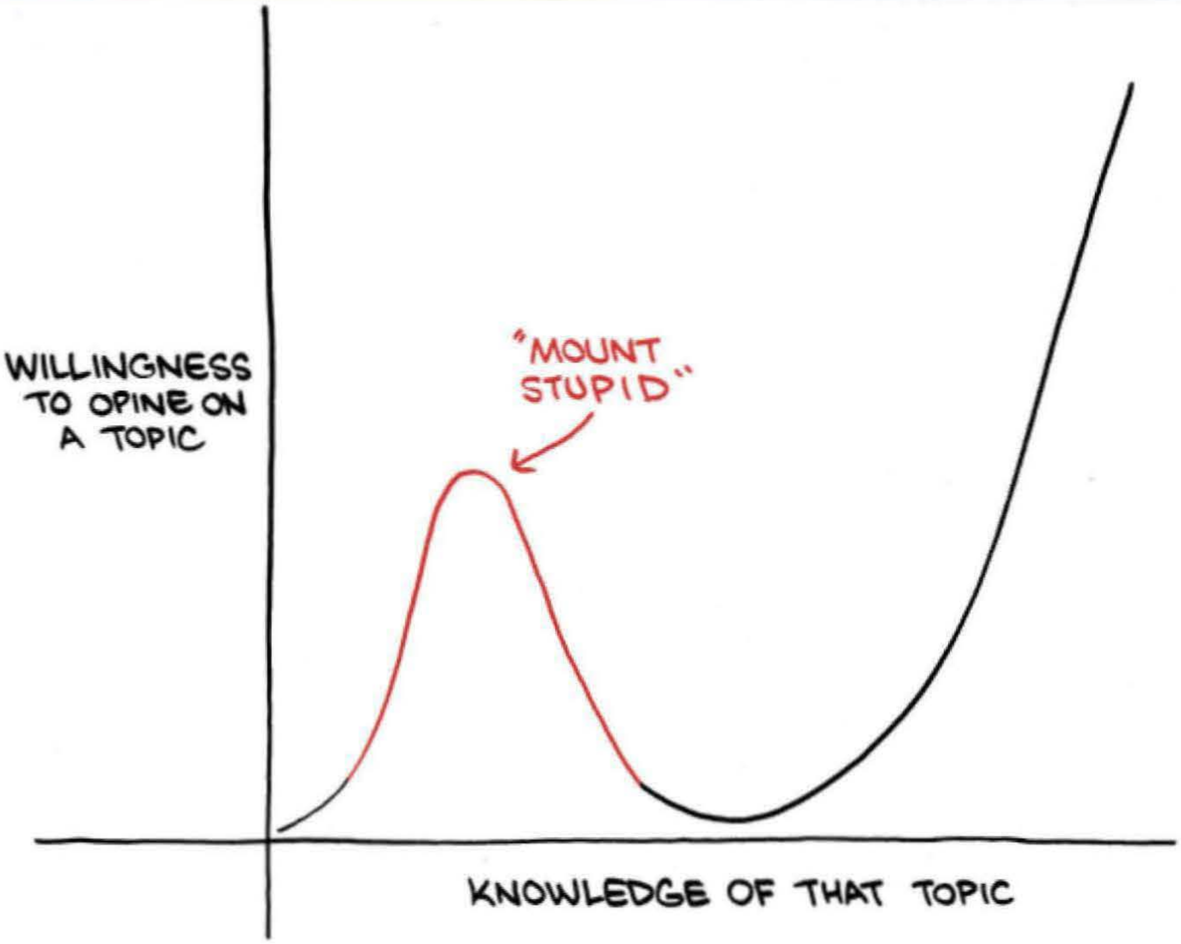
Foundational Outcomes

- Hydrology
- Hydraulics
- Fluvial Geomorphology
- Sediment Transport
- Stream Ecology
- Habitat Structure and Function
- Fish Biology
- Plant Ecology and Riparian Dynamics
- Surveying/Hydrometry
- Watershed Analysis
- Geomorphic and Habitat Assessment
- Biomonitoring/bioassessment
- Alternatives Analysis
- Analytical Techniques
- Restoration Design
- Uncertainty and Risk
- Project Development
- Restoration Policy (codes and regulations)
- Communication and information management
- Construction Inspection
- Professional and Ethical Responsibility

Level of Learning

- L1 Knowledge
- L2 Comprehension
- **L3 Application**
- L4 Analysis
- L5 Synthesis
- **L6 Evaluation**

Niezgoda et al (2004). "Defining a Stream Restoration Body of Knowledge as a Basis for National Certification." *J. Hydraulic Eng.* Vol. 140, I2.



http://www.smbc-comics.com/comic/2011-12-28

Overview

- Case Study: Tule Red Tidal Mitigation Site
- Project Site
- Objectives
- Channel Sizing and Layout
- Conceptual Design
- Sustainability

Tule Red Tidal Mitigation Site

- SFCWA project to meet goals outlined in BDCP and OCAP.
- Westervelt Ecological Services led design team
- Started Construction in September 2016, bulk of construction in 2017, final breach in 2018 or 2019

Project Site

- 400 ac site
- 8,000 ft of Shoreline
- Currently Managed Marsh
- Natural Marsh Berm Currently Protects Site from Inundation

Project Site-Historically

Warner et al (2004). “Floodtide pulses after low tides in shallow subembayments adjacent to deep channels.” *Esuarine, Coastal and Shelf Science* 60. p213-228

Objectives

- **Overall Objective** is to **sustainably** restore natural tidal marsh processes while meeting objectives of Suisun Marsh Plan.
  - Restore 5,000+ ac. Tidal Marsh
  - Protect and Enhance Existing Managed Wetland
  - Improve Ecological Processes and Reduce Stressors
  - Maintain Waterfowl Heritage and Improve Sporting Opportunities
  - Maintain and Improve Marsh Levee System

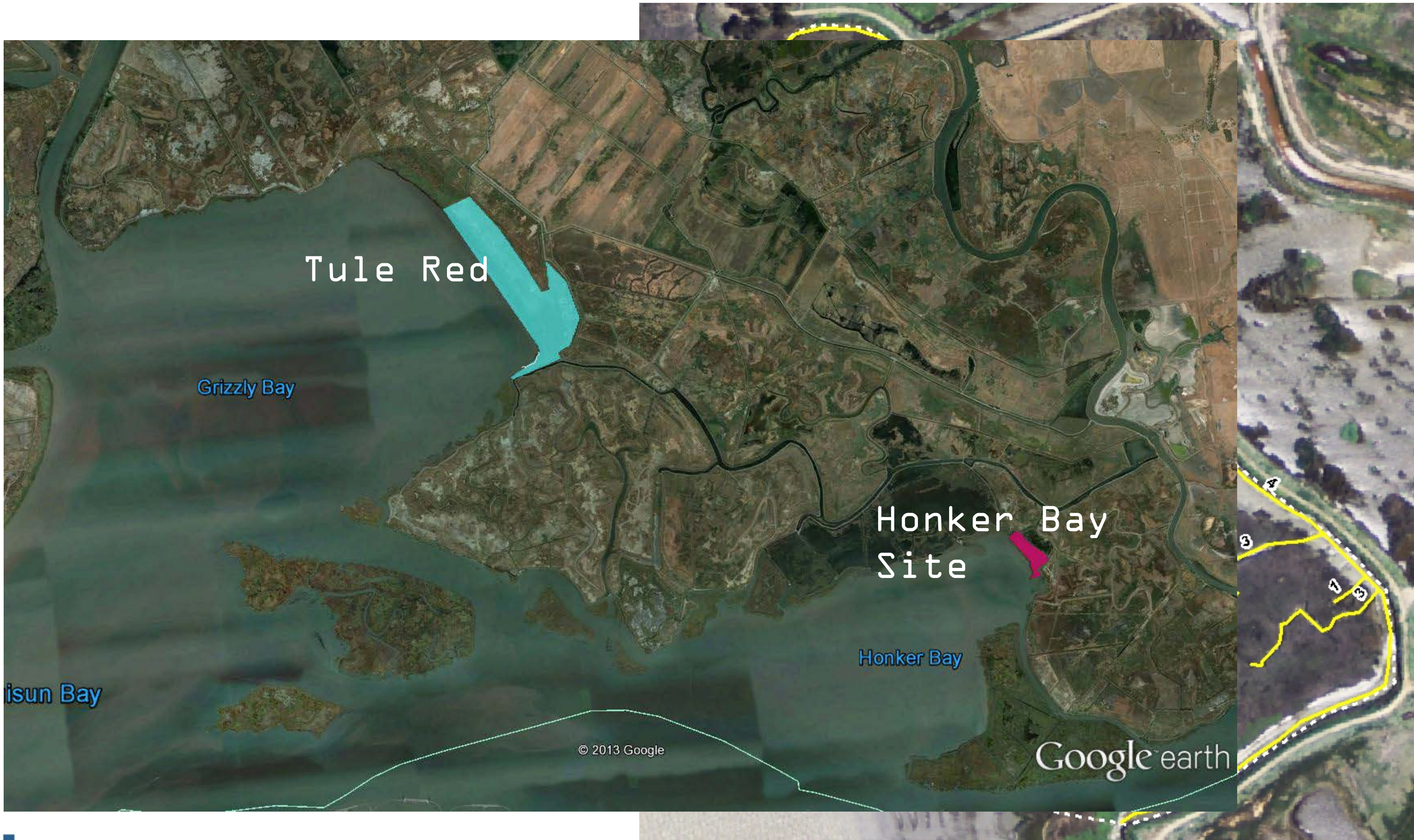
Design Objectives

- Full tidal exchange
  - Sediment Delivery
  - Nutrient Export
- No impact to neighbors
- Strengthen existing levee
- 14-day mean residence time
- Balanced cut/fill
- Minimize footprint
- Constructability

Empirical Channel Sizing and Layout

- Tide Marsh Morphology
  - *f(*tidal regime, freshwater inputs, vegetative and sediment characteristics)
- Values Published in Literature (Odell et al., 2008)
  - Channel order v. drainage basin area
  - Channel bifurcation ratio v. channel order
  - Sinuous channel length v. channel order
  - Channel top width vs. drainage basin area
  - Channel geometry v. channel top width
- Analog Sites
  - Odell et al. based on mature salt marshes in San Pablo and South San Francisco Bay
  - Honker Bay compared to Odell et al. values

Honker Bay Analog



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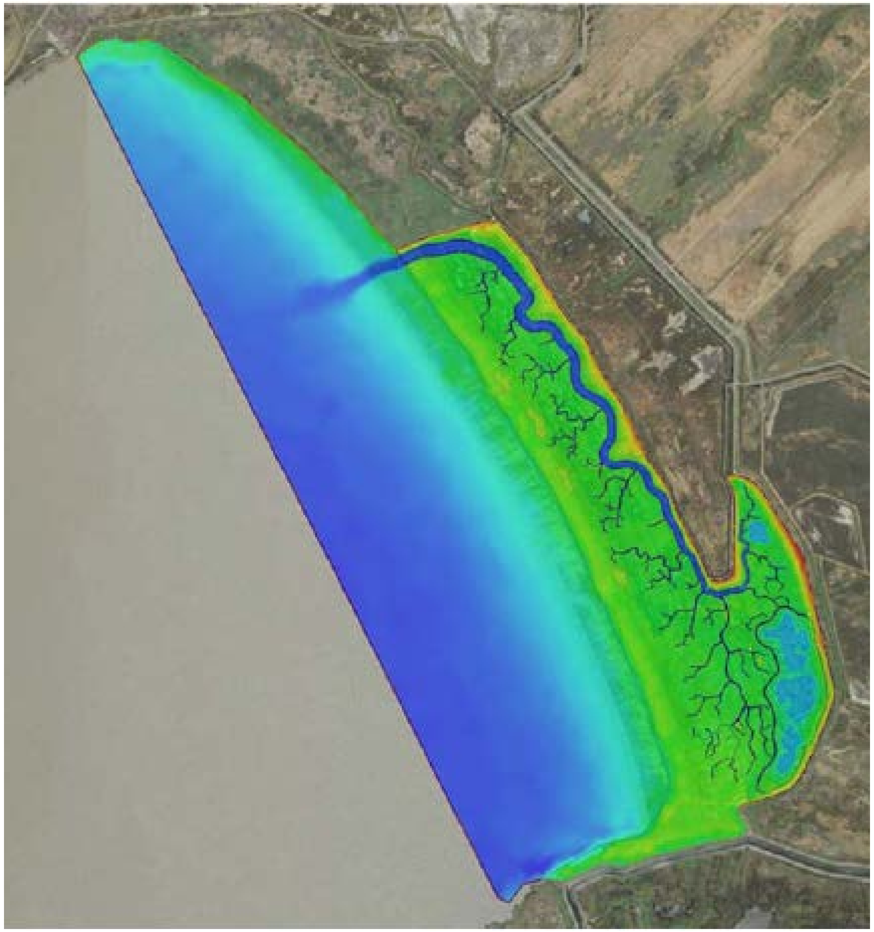
Odell vs Honker Bay

Parameter	Odell et al (2008)	Honker Bay Analog
Channel Order	4	4
Bifurcation Ratio	1st order – 3 - 5 2nd order – 3 - 6 3rd order – 2 - 10 4th order – 2 - 4	1st order – 1 - 3 2nd order – 2 - 3 3rd order – 2 - 4 4th order – 10
Channel Length	1st order – 0.9m – 60m 2nd order – 20m – 110 m 3rd order – 40m – 300 m 4th order – 100 m – 600 m	1st – 8.9 m – 36.5 m 2nd – 14.9 m – 116.9 m 3rd – 77 m – 131.3 m 4th order – 683.3 m
Main Channel Top width	15 m	12 m-15 m
Sinuosity	1 to 2	1.04
Channel Pattern	All	All

Numerical Verification

- 2D AdH Model
- Resolved major features (low-order channels, berms)
- Applied tidal boundary condition
- Evaluate tidal muting and channel stability



Numerical Model Channel Stability

- Determine if channel hydraulics will result in channel deposition, erosion, or if channel will be stable.
  - Erosion occurs if applied shear stress, τ, exceeds shear strength of soil
  - Deposition will occur if shear velocity, u_*, is less than sediment fall velocity
- Depth, *H*, and Velocity, *U*, computed in ADH used to determine shear stress and velocity
- USGS published values of Grizzly Bay sediment used for sediment values

$$c_f = \frac{gn}{\phi H^{1/3}} \qquad u_* = \sqrt{c_f}U \qquad \tau = \rho u_*^2$$

Variable	Value	Unit	Description
τ_cr	0.05	Pa	Critical Shear Stress (Warner et al 2004)
ρ	1000	kg/m^3	Fluid Density
g	9.81	m/s^2	Acceleration due to gravity
γ	9810	N/m^3	Specific Gravity
Φ	0.9	-	Porosity (Warner et al 2004)
E_0	0.000 1	kg/(m2-s)	Bed erodibility constant (Warner et al 2004)
w_s	0.000 5	m/s	Settling velocity (Warner et al 2004)

Concepts

- Pull Tide Gates-No Grading
  - Tidal muting, insufficient flow to naturally create channels, affected neighbors
- South Entrance
  - Constructability concerns
- Central Entrance
  - Maintenance concerns
- North Entrance
  - Increased residence time, allowed for maintenance berm

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Secondary/Distributary Channels

- Important to sediment delivery and nutrient export
- Layout based on Odell et al (2008) and scaled channels from nearby marshes
- Evaluated letting channels naturally form, short “starter” channels, and full excavation

Secondary Channels

- Followed methodology of D'Alpaos (2007) for channel development
- Coupled 2D model results with sediment information- neglected vegetation.

Increase in Channel Length (ft/yr)			
As-Built Geometry	Final Geometry	Wallace et al. (2005)	D'Alpaos et al. (2007)
3	10	4-20	10-54

- Final design includes full channel dimensions due to concerns of growth rate, vegetation

D'Alpaos, et al. (2007) "Spontaneous tidal network formation within a construction salt marsh: Observations and morphodynamic modeling." *Geomorphology* 91. pp 187-197

Residence Time

- Tidal Ponds and Pannes intended to increase residence time.
- Excavated material placed as marsh ridge at MHW surrounding ponds
- Reactor based model following Lionberger et al (2004) used to evaluated residence time, evaporation, and salinity.

Residence Time	Including Evaporation and Infiltration	No Infiltration	No Evaporation or Infiltration
Minimum	38 hours	45 hours	45 hours
5 Percentile	63 hours	91 hours	93 hours
Median	105 hours	202 hours	211 hours
95 Percentile	210 hours	430 hours	466 hours
Max	297 hours	677 hours	717 hours

$$T_i = \frac{(V_{i-1} - E\Delta t - I\Delta t)(T_{i-1} + \Delta t) + \Delta V\left(\frac{\Delta t}{2}\right)}{V_i}$$

$$V_i = V_{i-1} - E\Delta t - I\Delta t + \Delta V$$

Lionberger et al. (2004). *Salt-Pond Box Model (SPOOM) and its application to the Napa-Sonoma Salt Ponds, San Francisco Bay, Ca.* USGS Water Resources Investigation Report

Marsh Accretion

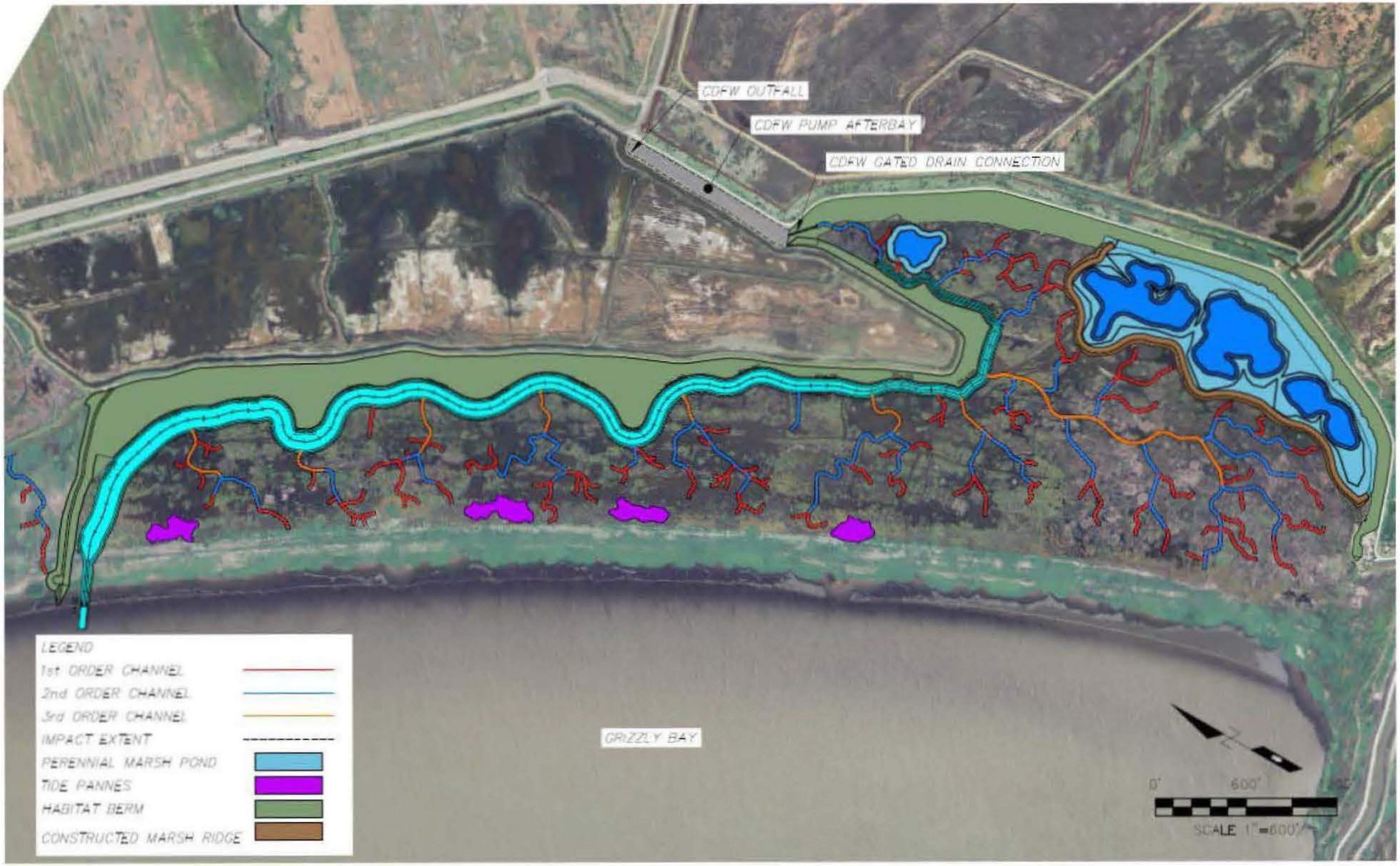
- Krone (1971) model used to evaluate mineral accretion utilizing Warner (2004) measured sediment values in Grizzly Bay.
- Mineral accretion is expected to exceed projected sea level rise over the next 50 years.

	Average Accretion Rate (in/yr)					
Marsh Elevation (feet above MSL)	C*=50	C*=75	C*=100	C*=125	C*=200	C*=400
0	0.54	0.81	1.08	1.35	2.16	4.31
0.5	0.42	0.63	0.84	1.05	1.68	3.35
1	0.29	0.44	0.59	0.73	1.17	2.34
1.5	0.17	0.26	0.34	0.43	0.69	1.37
(MWH) 2	0.08	0.12	0.16	0.20	0.33	0.65
(MHHW) 2.5	0.03	0.04	0.05	0.06	0.10	0.21
3	0.00	0.01	0.01	0.01	0.02	0.04

NRC (2012) predicted SLR in San Francisco relative to 2000

- 2030 – 5.7 in +/- 2 in (0.19 in/yr)
- 2050 – 11.1 in +/- 3.6 in (0.27 in/yr from 2030-2050)
- 2100 – 36.3 in +/- 10 in (0.5 in/yr from 2050-2100)

The Design!



CDFW OUTFALL
CDFW PUMP AFTERBAY
CDFW GATED DRAIN CONNECTION
GRIZZLY BAY
LEGEND
1st ORDER CHANNEL
2nd ORDER CHANNEL
3rd ORDER CHANNEL
IMPACT EXTENT
PERENNIAL MARSH POND
TIDE PANNES
HABITAT BERM
CONSTRUCTED MARSH RIDGE
0'
600'
SCALE 1"=600'

Questions?