MODELING OF WAVE INTERACTION WITH NATURAL AND NATURE-BASED FEATURES

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Natural and Natured-Based Features

Coastal Engineering and Ecosystem Benefits of Natural and Nature-Based Features

Corps has ongoing research with agency and academic partners to:

- Summarize **state of knowledge** for Natural and Nature-Based Features (NNBF)
- Quantify capacity to provide **coastal engineering** and **ecosystem** services
- Advance **open-source models** for coastal engineering & ecosystem benefits
- Develop **guidance** for design, maintenance, and adaptation of NNBF

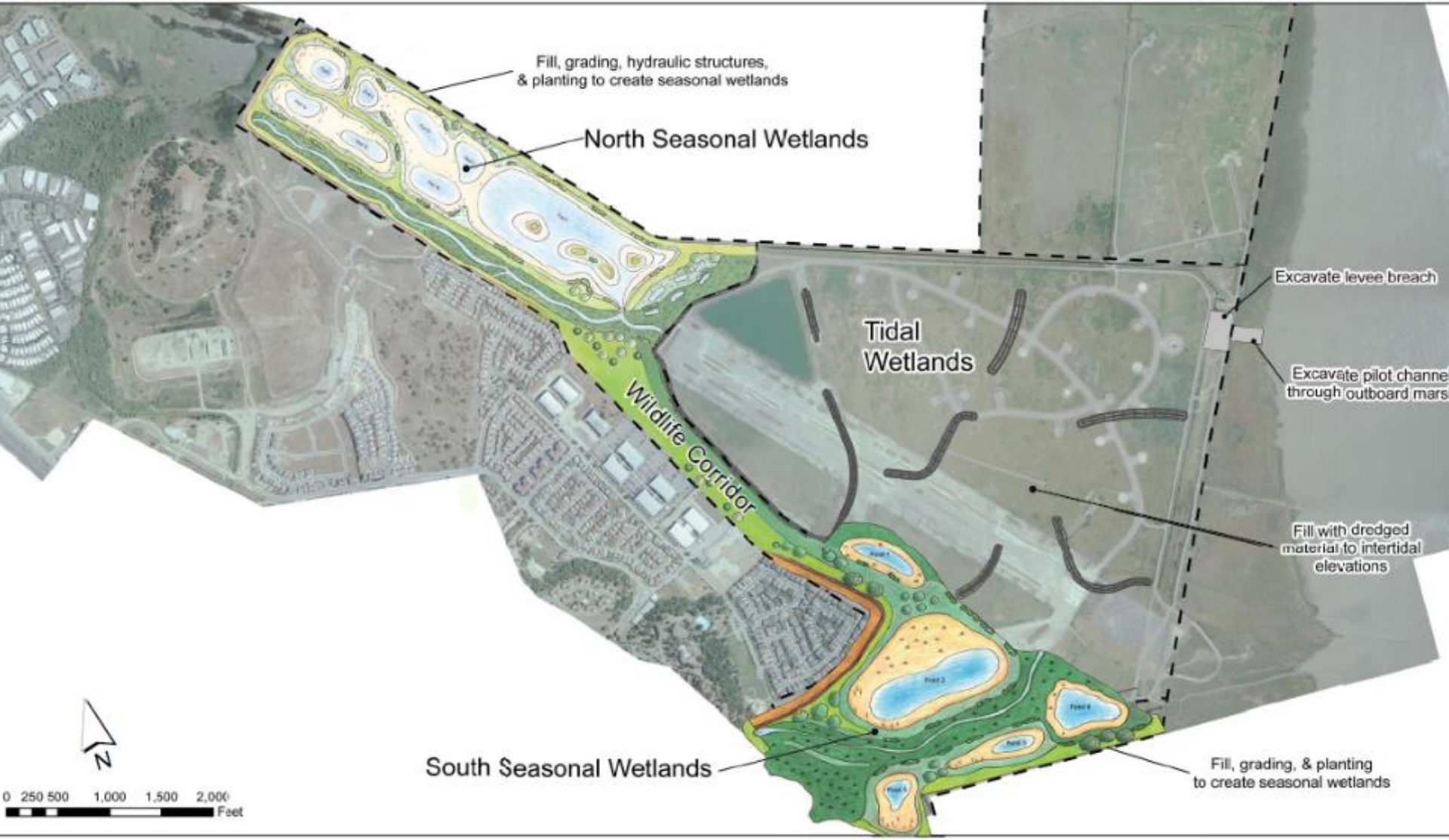
San Francisco Bay

- 90% of tidal wetlands filled
- Reduced habitat
- Endangered plant & animal species
- Removed buffer for rising sea level

Hamilton Bay Restoration

- Site diked ~100 yr ago, Hamilton Army Airfield
- Significant subsidence
- 260-hectare wetland restoration, 20 yrs
- Beneficial use of 19 mill m^3 of dredged material
- Wetland design w/ berms
- U.S. Army Corps of Engineers and the California Coastal Conservancy

Hamilton Bay Restoration



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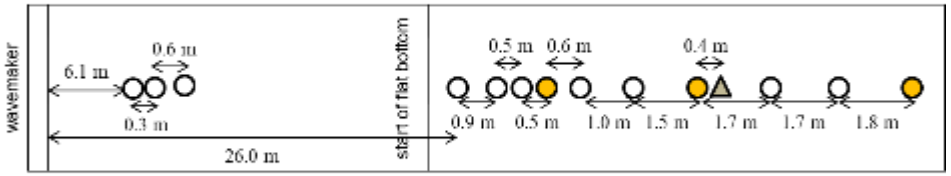
WaveWatch III

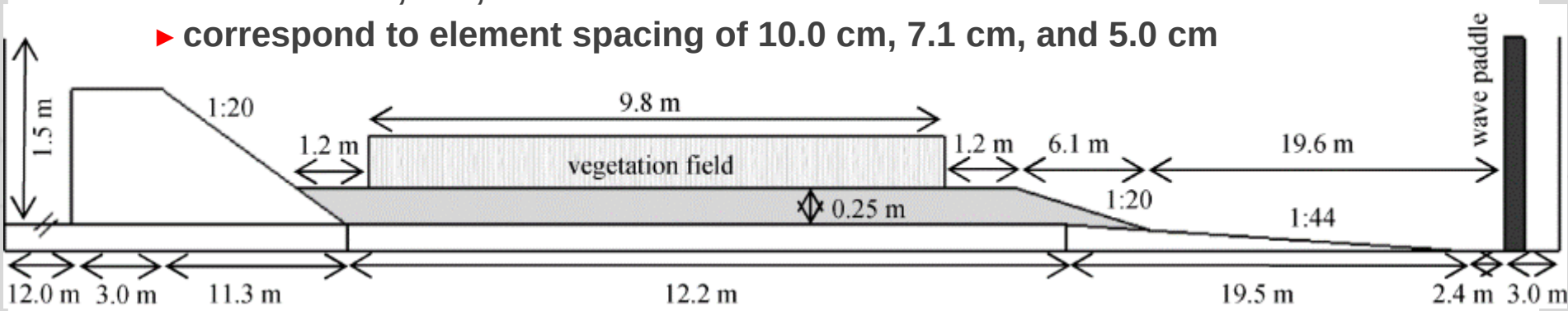
- Phase-averaged, spectra wave model
  - Unstructured grid
  - Implicit solver
  - Domain decomposition
- Wave-vegetation interaction based on Mendez and Losada (2004)
  - $\epsilon_v = \sqrt{\frac{2}{\pi}} \frac{g^2 C_d b_v N}{h} \left(\frac{\bar{k}}{2\pi\bar{f}}\right)^3 \frac{sinh^3(\bar{k}\alpha h)+3\sinh(\bar{k}\alpha h)}{3\bar{k}cosh^3(\bar{k}h)} \sqrt{\bar{E}}$
  - C_d= drag coefficient, b_v= stem diameter, α= relative stem length, N=vegetation density
- Implementation called with VEG1 switch
- Operates in serial or parallel, implicit or explicit, structured or unstructured grids
- Called after depth limited breaking but before bottom interactions
- Spatially and temporally variable vegetation coefficients read with ww3_prnc, or homogeneous variables in ww3_shel

Laboratory Test

- 1.5 m-wide wave flume
  - 64.1 m long, 1.5 m deep
- Wave and Water Levels
  - Depths: 30.5 cm, 45.7 cm, 53.3 cm
  - l_s/h ratios of 1.0 (emergent), 0.91, 0.78
  - Irregular waves
    - T_p ~ 1.25 s to 2.25 s
    - H_{m0} ~ ranging from 5.0 cm to 19.2 cm
- Polyolefin tubing
  - 6.4 mm diameter
  - 41.5 cm stem length
  - densities of 100, 200, and 400 stems/m^2
    - correspond to element spacing of 10.0 cm, 7.1 cm, and 5.0 cm



Anderson & Smith 2014



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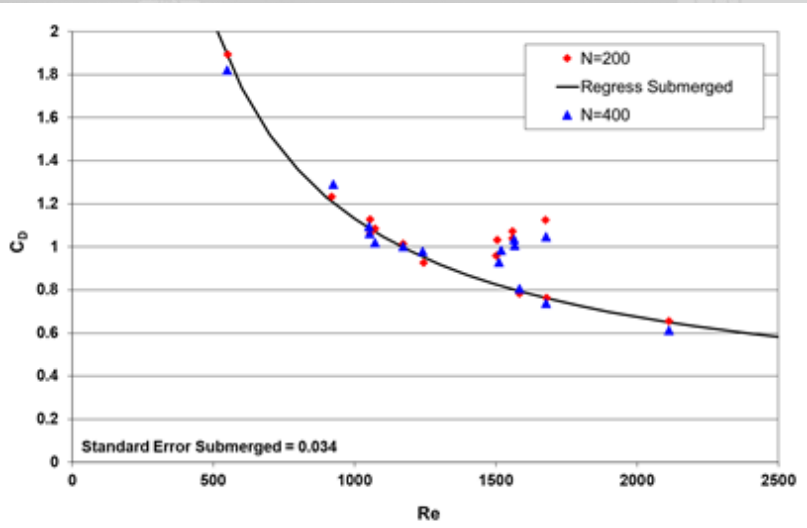
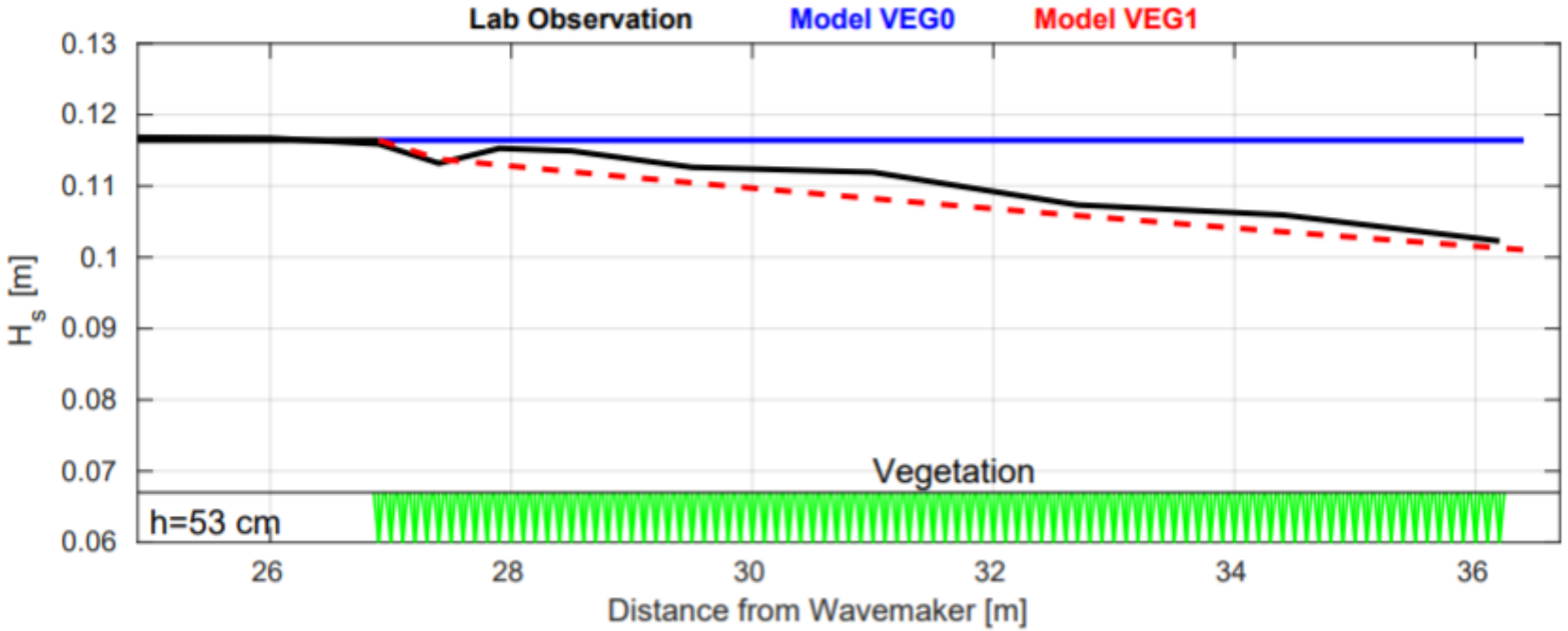
Laboratory Test

- **Validation example**
  - **Depth 53.3 cm**
  - **$\alpha = l_s/h = 0.78$**
  - **$T_p = 1.25$ s**
  - **$H_{m0} = 11.8$ cm**
  - **$C_D = 1.0$**





Hamilton Field Data Collection

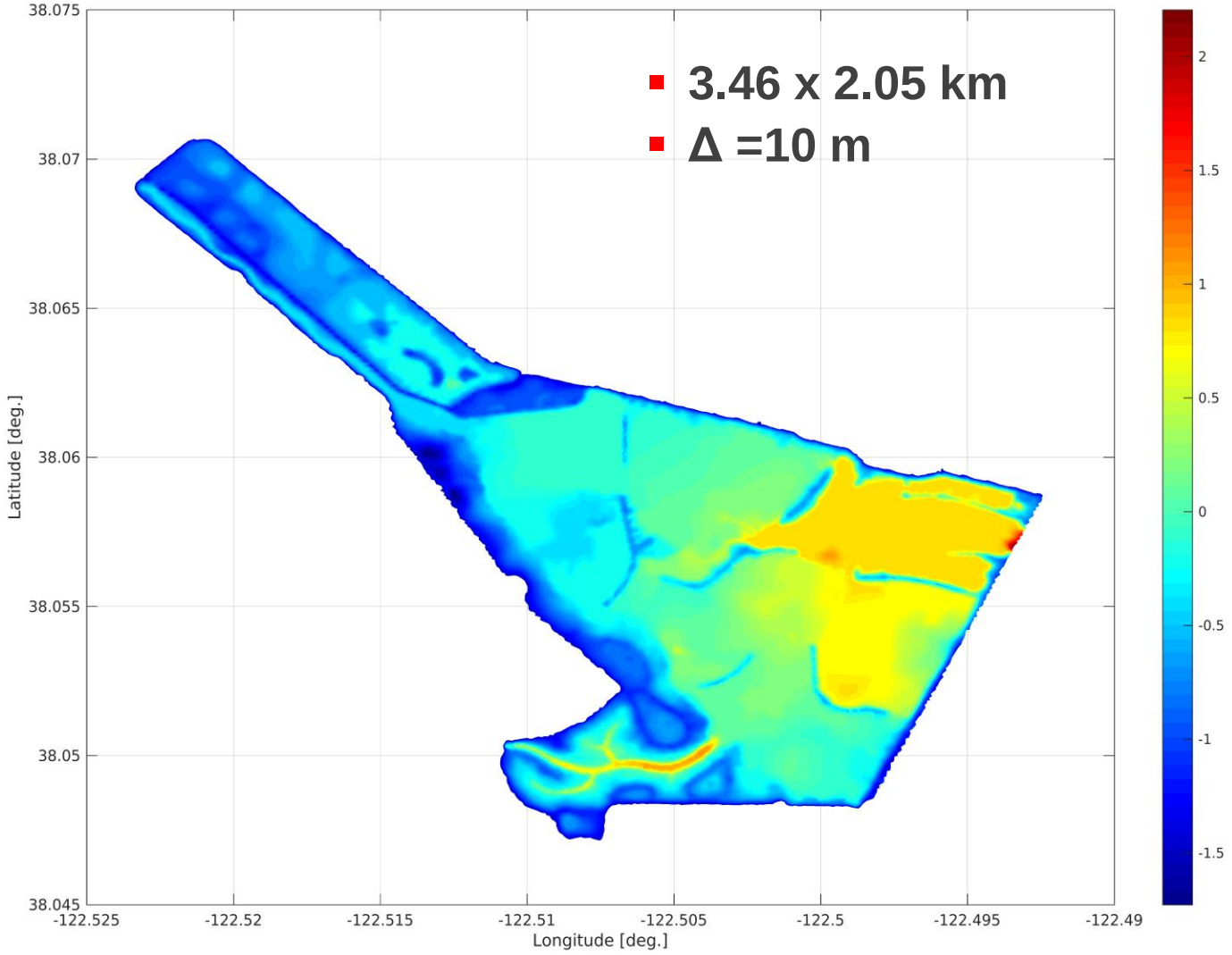
- Waves (wave staffs)
- Water Levels
- Currents
- Salinity
- Conductivity
- Temperature
- Wind Speed and Direction
- Sedimentation

Field Data Collection

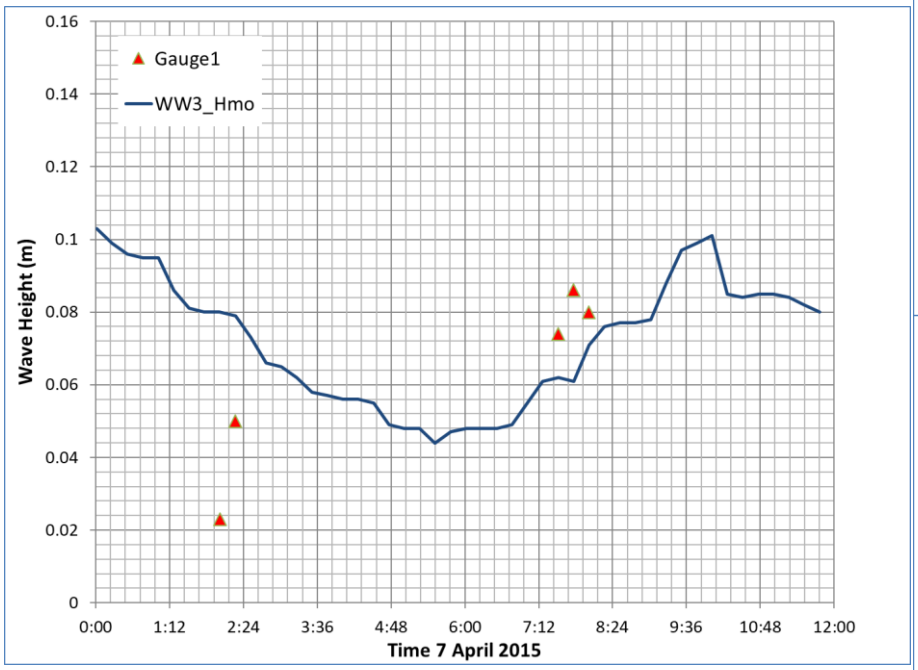
Validation

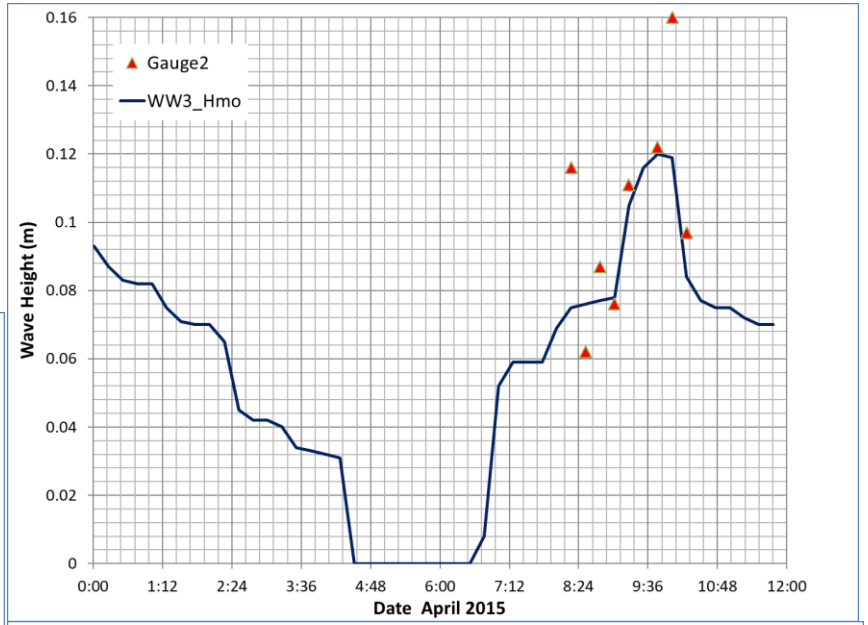
- **Two Storms**
  - **Feb 2015**
    - **9 m/s NW**
  - **April 2015**
    - **10 m/s SW**

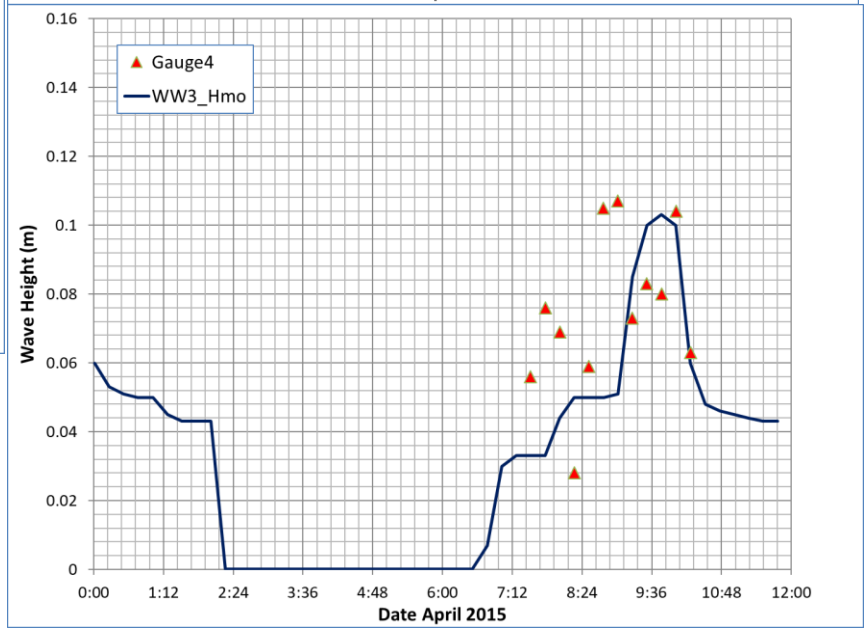
Hamilton As-Built



Validation







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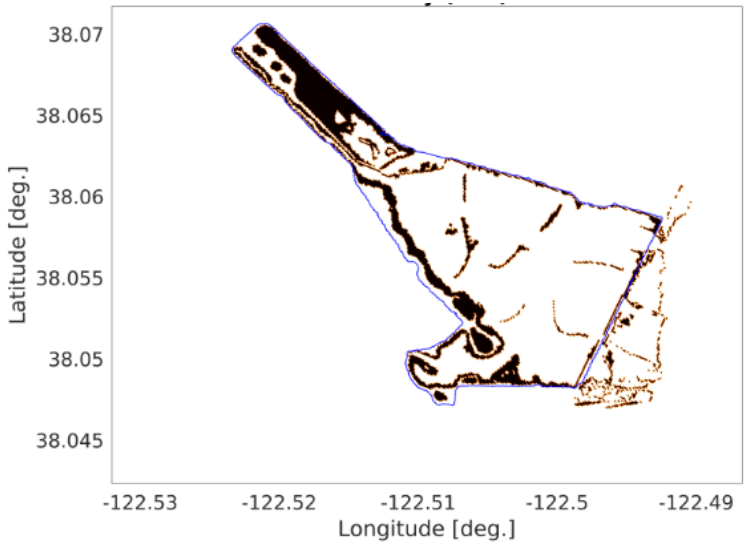
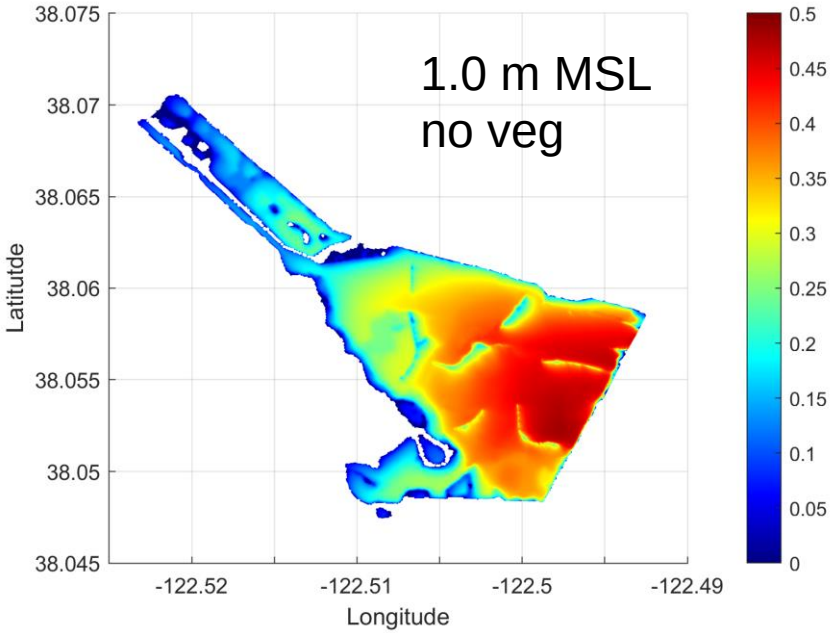
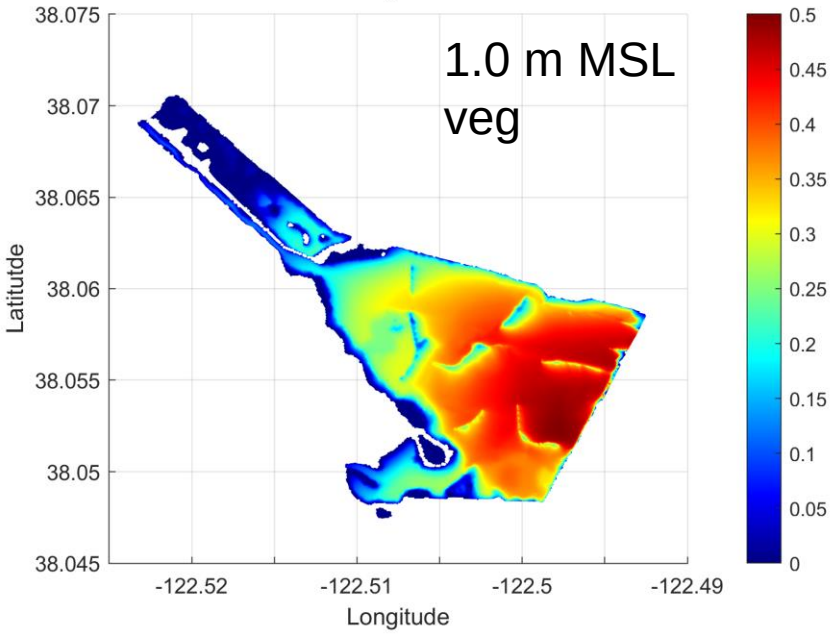
Idealized Simulations

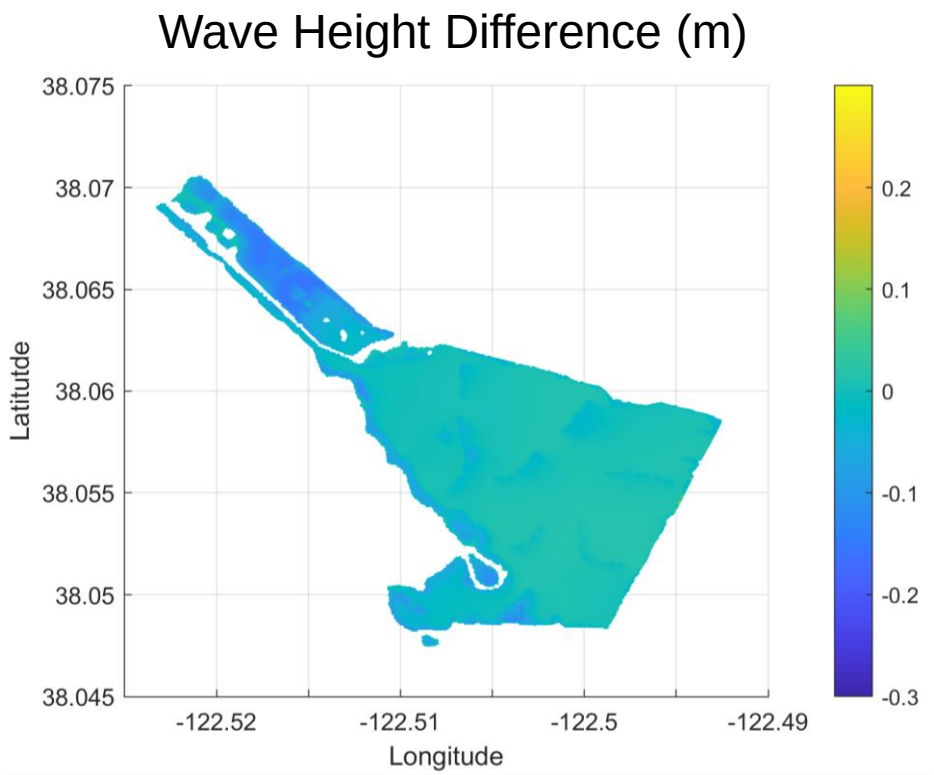
- Winds of 15 and 20 m/s (14-yr wind record at Richmond, CA)
- Water levels of + 0.5 and +1.0 MSL
- 8 wind directions (N, NE, E, SE, S, SW, W, NW)
- With and without vegetation
  - Pickleweed
  - Within depth range of +0.4-0.95 m MSL
  - C_D = 0.1, stem height=0.6 m, density = 300/m^2 diameter = 0.01 m (Northwest Hydraulic Consultants 2011)



Example Results (20 m/s wind, NW)







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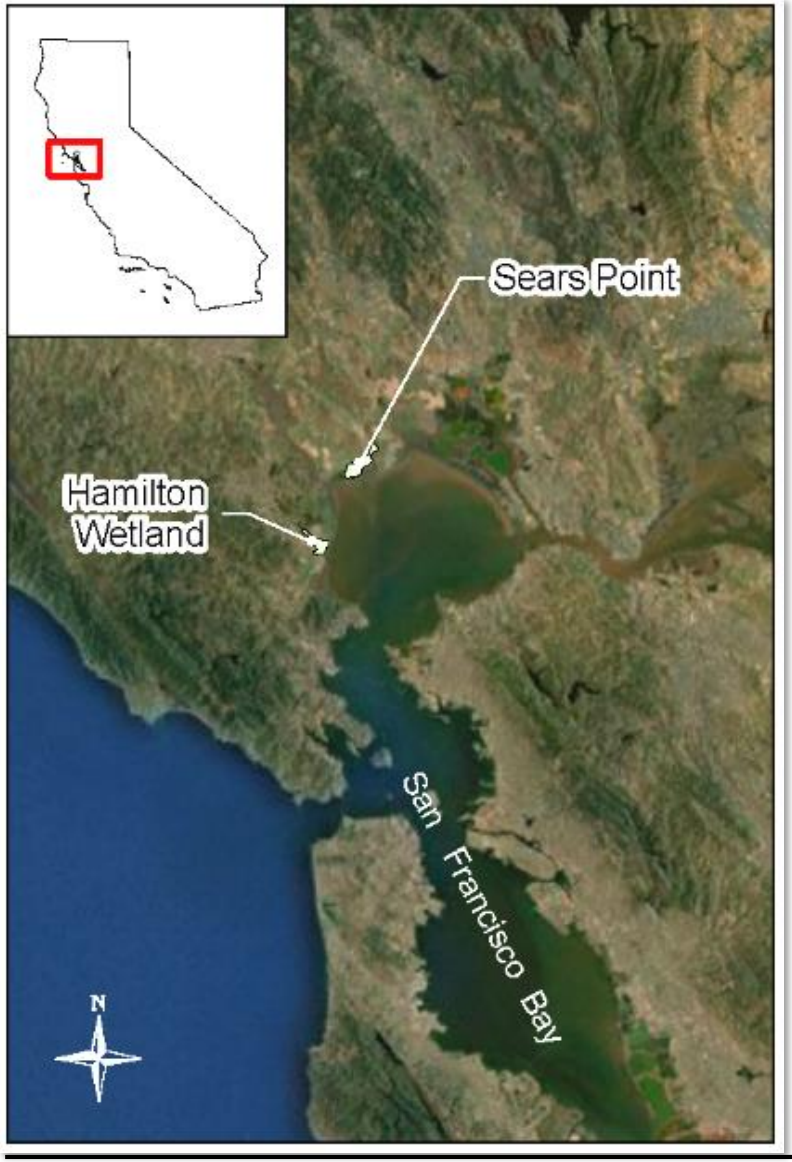
Sears Point Restoration



- Similar environment to Hamilton
- 390 hectare tidal wetland restoration
- Wetland design w/ mounds
- Sonoma Land Trust and Ducks Unlimited

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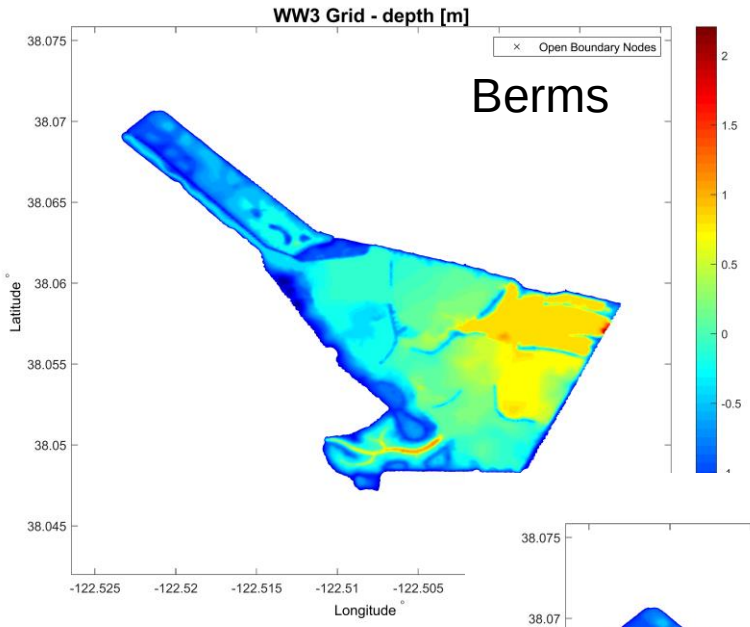
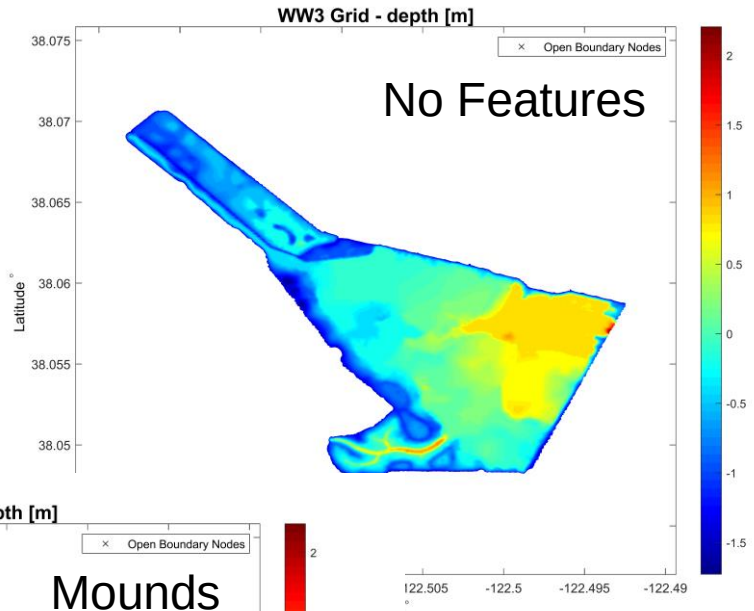
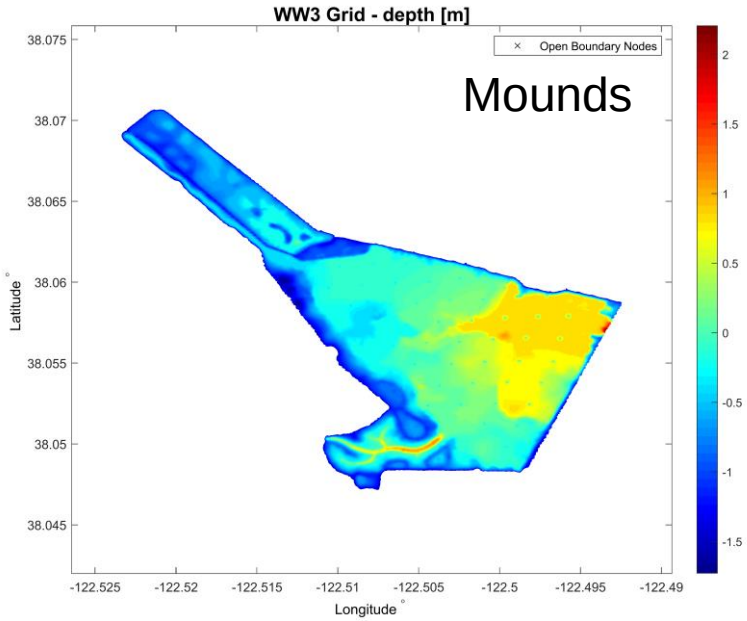
Bathymetry: Berms, Mounds, No Features







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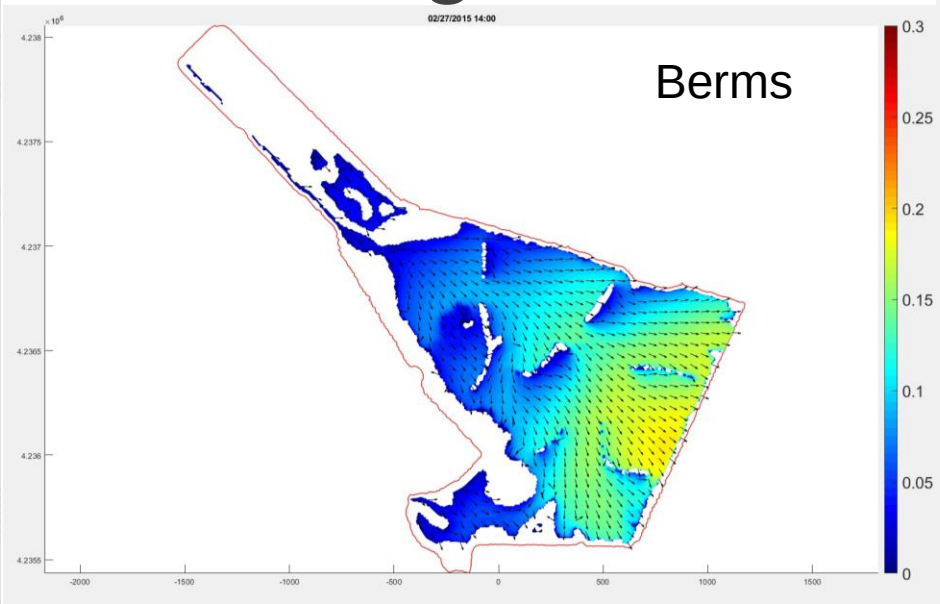
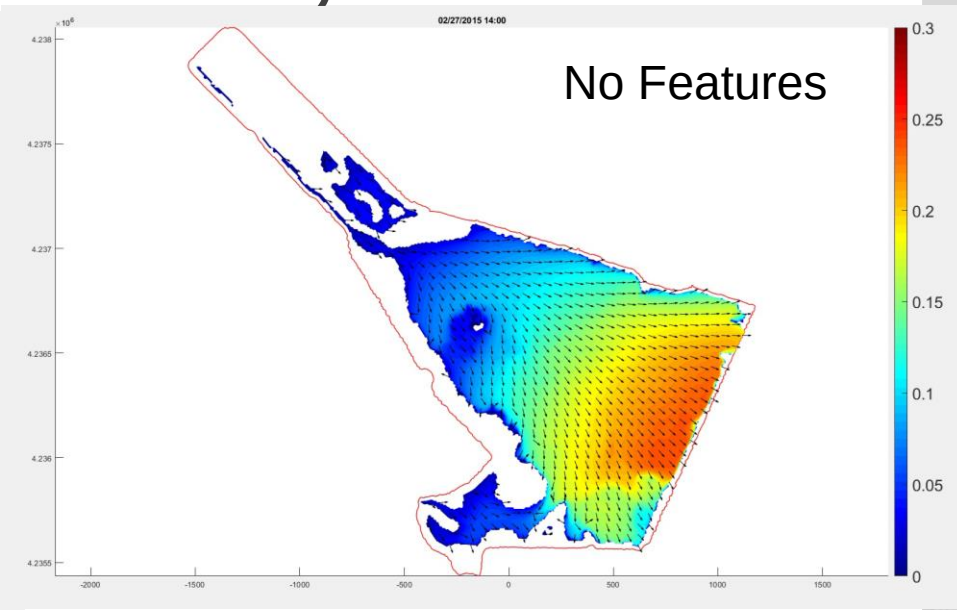
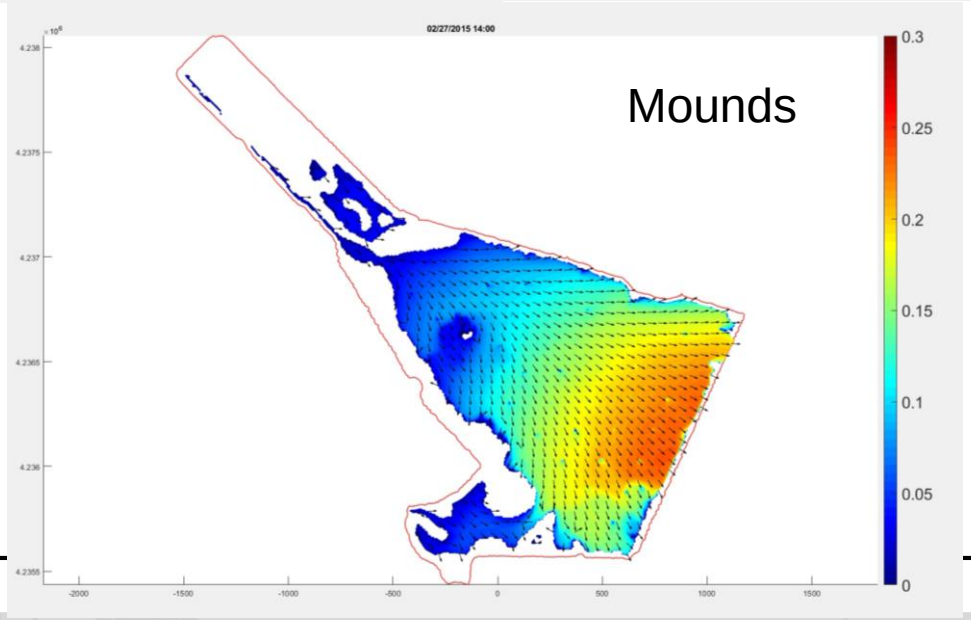
Wave Height: Berms, Mounds, No Features







Wind: NW
0.5 m MSL

Summary

- Spatially/temporally variable vegetation source term implemented in WW3 branch (C_D, stem thickness, stem length, stem density)
  - Documentation and additional validation underway
- Nature-based island features:
  - Significant reduction in wave height in the wetland
  - Long, linear berms were ~ twice as effective as mounds to reduce wave energy (depends of water level)
  - Vegetation increases wave height reductions (dependent on submergence)
- Unstructured WW3 is effective for complex wetland configurations to evaluate NNBF features
  - Requires vegetation parameters
  - Requires C_D specification