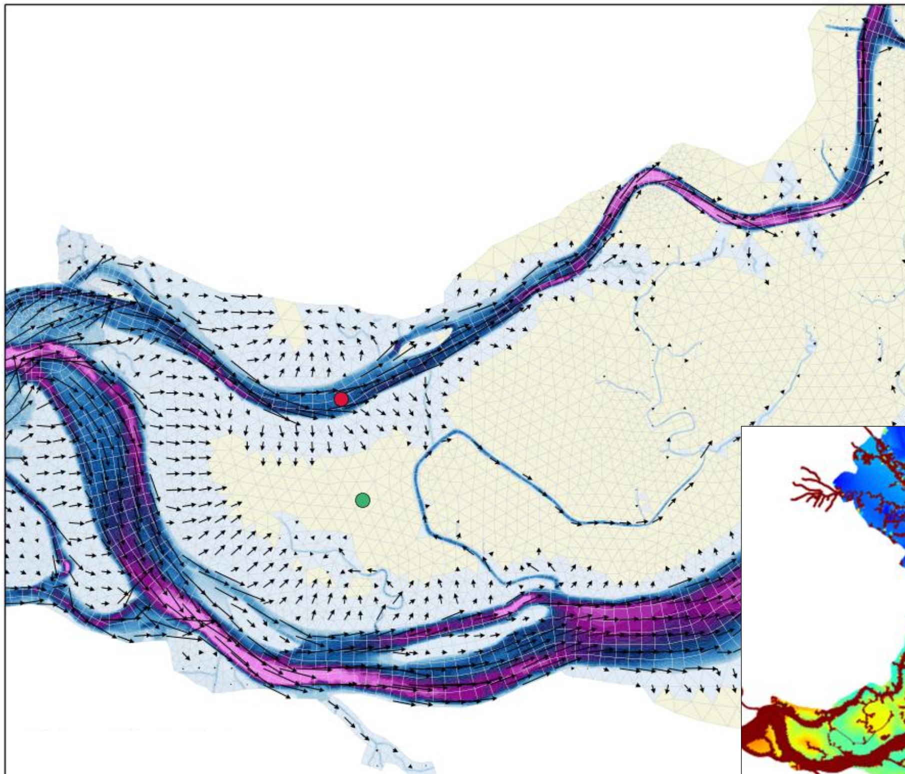
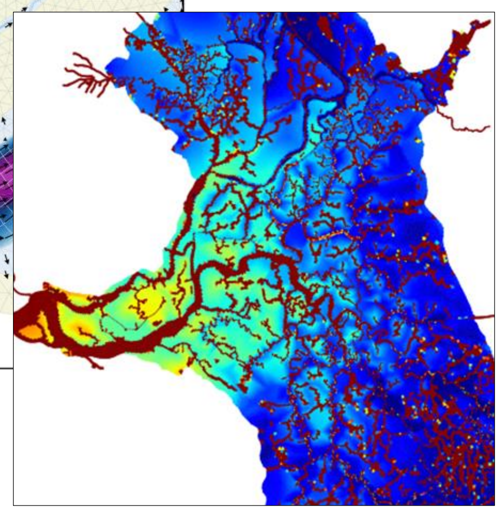
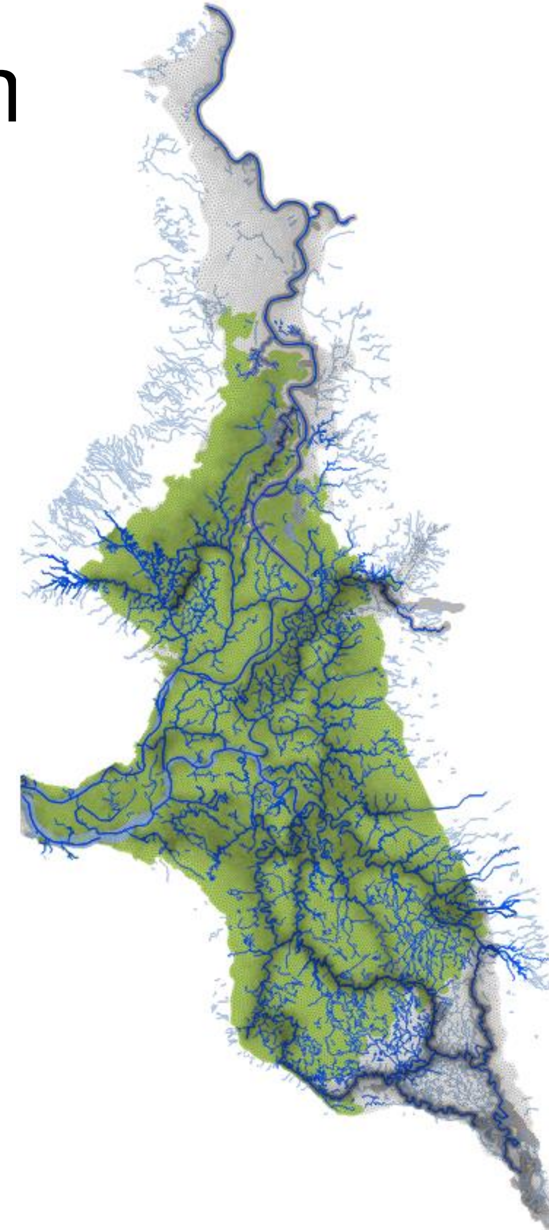
# Development and Calibration of the Historical Delta Model







John DeGeorge, Ph.D., P.E.

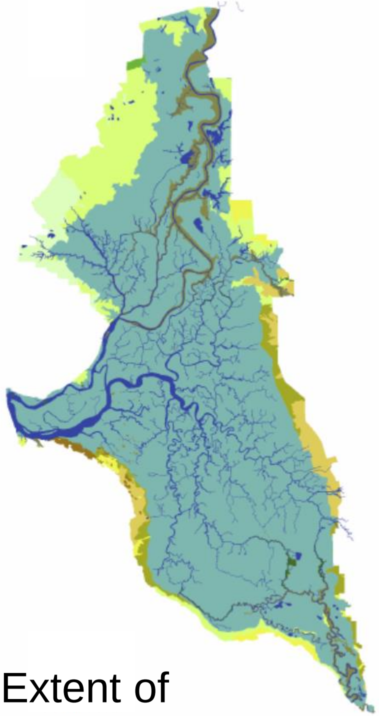
Stephen Andrews, Ph.D.

RESOURCE MANAGEMENT ASSOCIATES

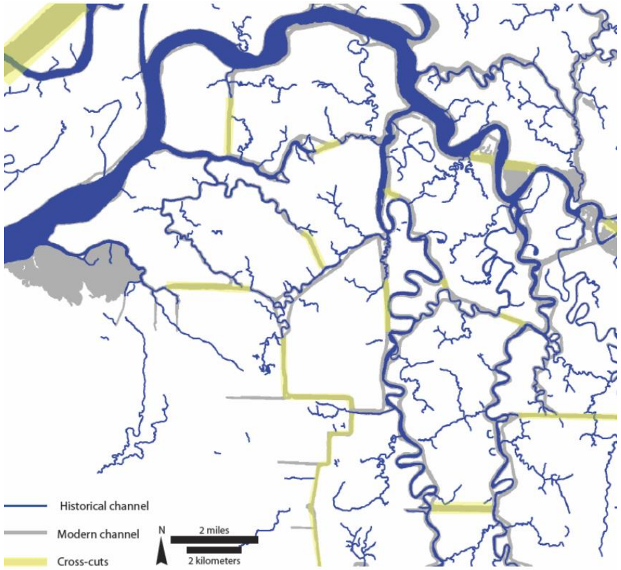
WATER RESOURCES ENGINEERING

# Project Goals

- This study motivated by the publication of the historical ecology report by the San Francisco Estuary Institute (Whipple et al., 2012)
- Characterize hydrodynamic and salinity regime of Delta prior to geomorphic and hydrologic modifications that began in the 1850s
    - Levee construction
    - Channel modifications
    - Upstream dams
    - Bathymetric changes (hydraulic mining sed.)
    - Others…
- Comparison to Current Delta
    - Tidal prism
    - Flood vs. ebb dominance
    - Advective and dispersive flux
    - X-2 relationship to Net Delta Outflow



Extent of historical tidal marsh




Changes in channel geometry

From Whipple et al. (2012)

# Project Team

- **Metropolitan Water District of Southern California**
  [Funding agency]
  - Paul Hutton,  Project Manager

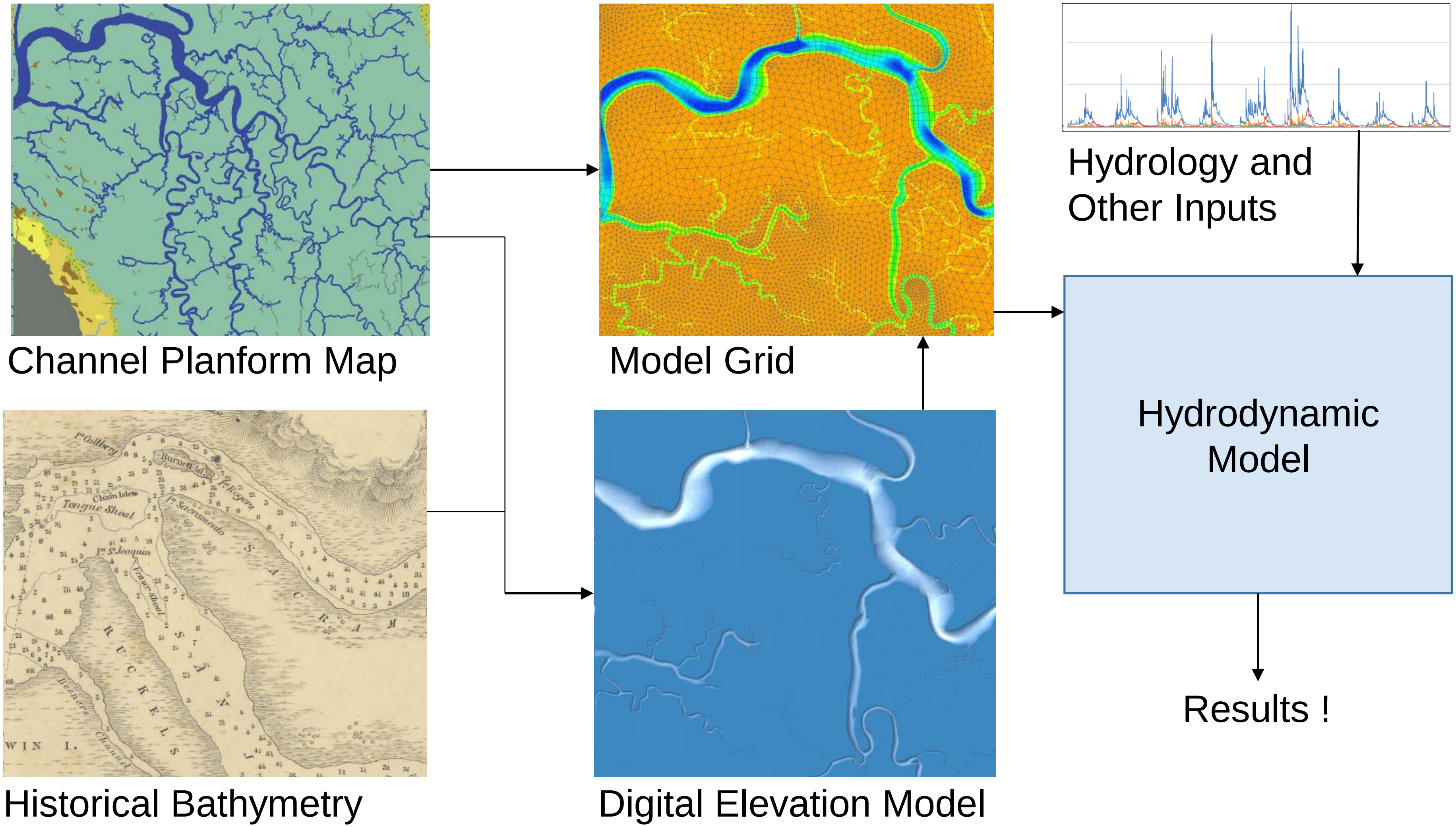
- **San Francisco Estuary Institute**
  [Historical Delta Configuration, Bathymetry]
  - Robin Grossinger
  - Sam Safran
  - Julie Beagle

- **Hydrology Team**
  - Andy Draper (MWH)
  - J. Phyllis Fox
  - Dan Howes (CSU, San Luis Obispo)
  - Tariq Kadir (DWR)
  - Guobiao Huang (DWR)

- **Resource Management Associates**
  [Hydrodynamics]
  - Steve Andrews
  - John DeGeorge
  - Ed Gross
  - Stacie Grinbergs

- **University of California, Davis Center for Watershed Studies**
  [DEM creation, Hydrodynamics]
  - Bill Fleenor
  - Fabian Bombardelli
  - Andy Bell
  - Alison Whipple
  - Steve Micko
  - Mui Lay
  - Amber Manfree

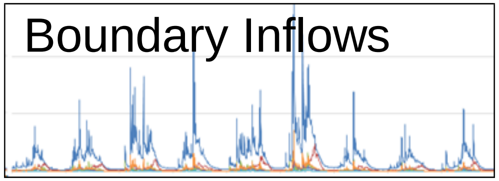
# How to Convert a Historical Delta Map and Observations into a Historical Delta Model?

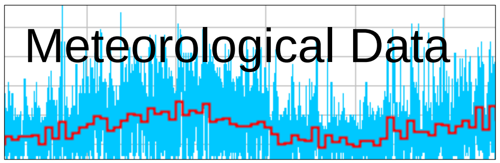


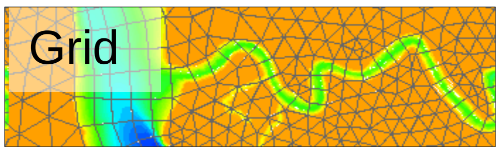
# 3D Hydrodynamic Modeling Framework

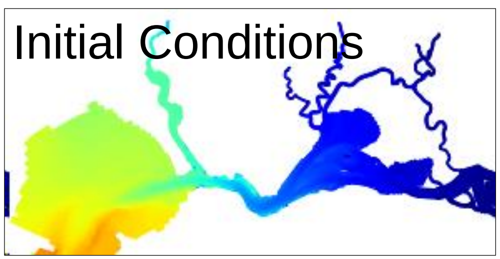
## New Application of the UnTRIM Engine by RMA with UCD

### Inputs




Gate Operations
Flow Diversions
Model Parameters

### Compute

Interface Code

- Read Inputs
- Write Outputs

Computational Submodels

- Turbulence
- Bed Friction
- Wind
- Hydraulic Structures

Set Forcing

Get Results

UnTRIM Engine
(Vincenzo Casulli, Univ. of Trento, Italy)

### Outputs

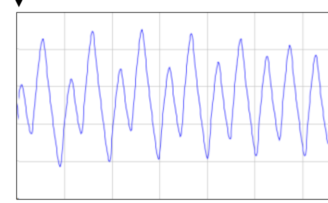
Text Files

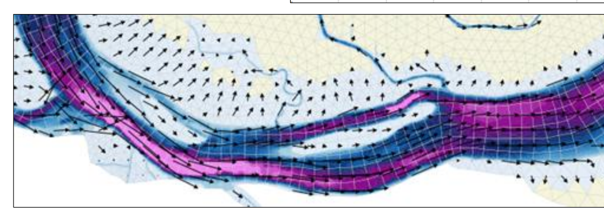
netCDF Files

Flows, velocities, water surface elevations, salinity

Python Post-Processing, Visualization Routines

Time Series
Maps
Animations

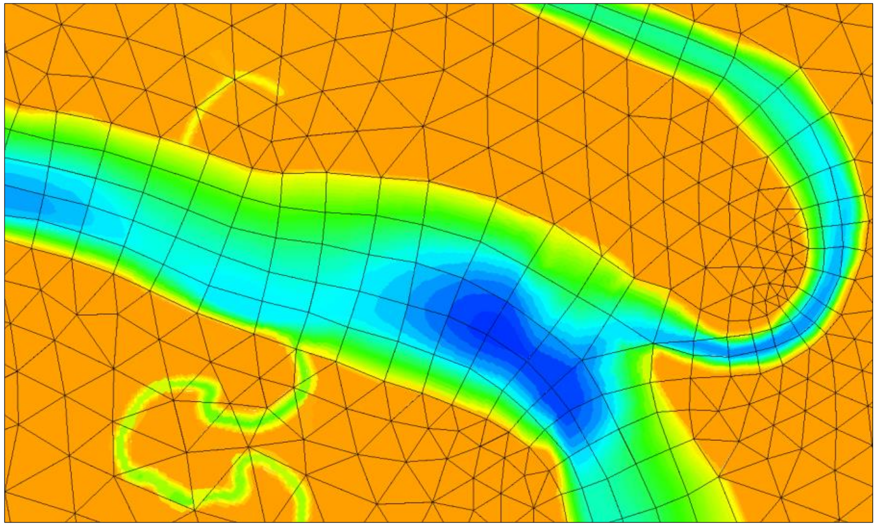




RMA RESOURCE MANAGEMENT ASSOCIATES
WATER RESOURCES ENGINEERING

# Hydrodynamic Model Information

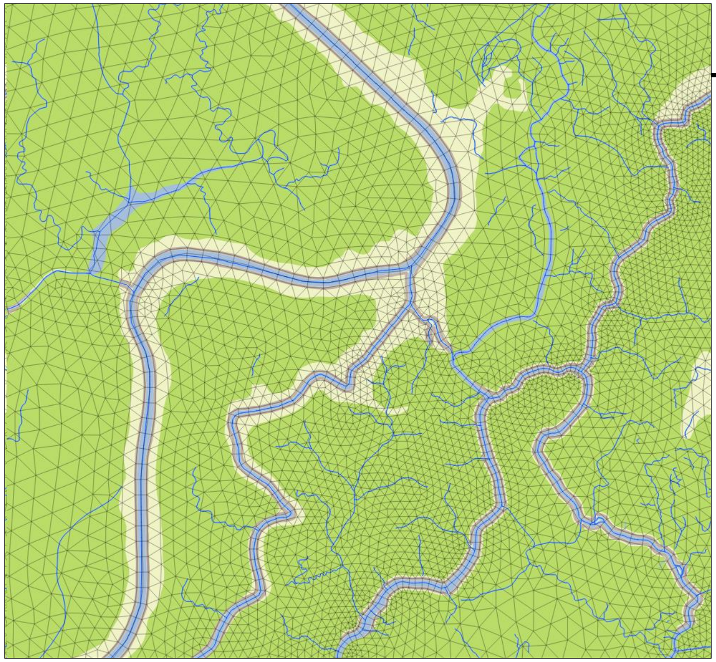
- UnTRIM Computational Engine
  - 3D hydrodynamic and scalar transport model
  - Utilizes unstructured orthogonal grid
  - Computationally efficient and stable
  - Developed and maintained by V. Casulli (Univ. of Trento, Italy)
  - Casulli and Cheng (1992), Casulli and Walters (2000), Casulli and Stelling (2010)
- z0 bed friction parameterization
- Generalized length scale vertical turbulence closure scheme (Warner, 2005)
  - Implemented by Bundesanstalt für Wasserbau (BAW)
- Constant wind stress, evaporation, and precipitation by region
- Target moderate grid resolution with subgrid
  - Produces improved estimates of cell volume and channel conveyance

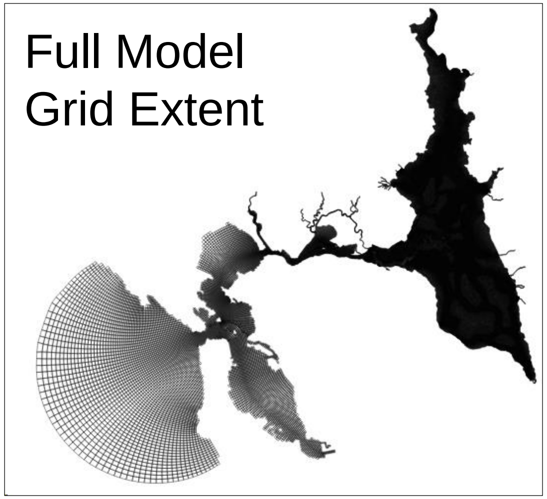


Model geometry with contoured subgrid bathymetry

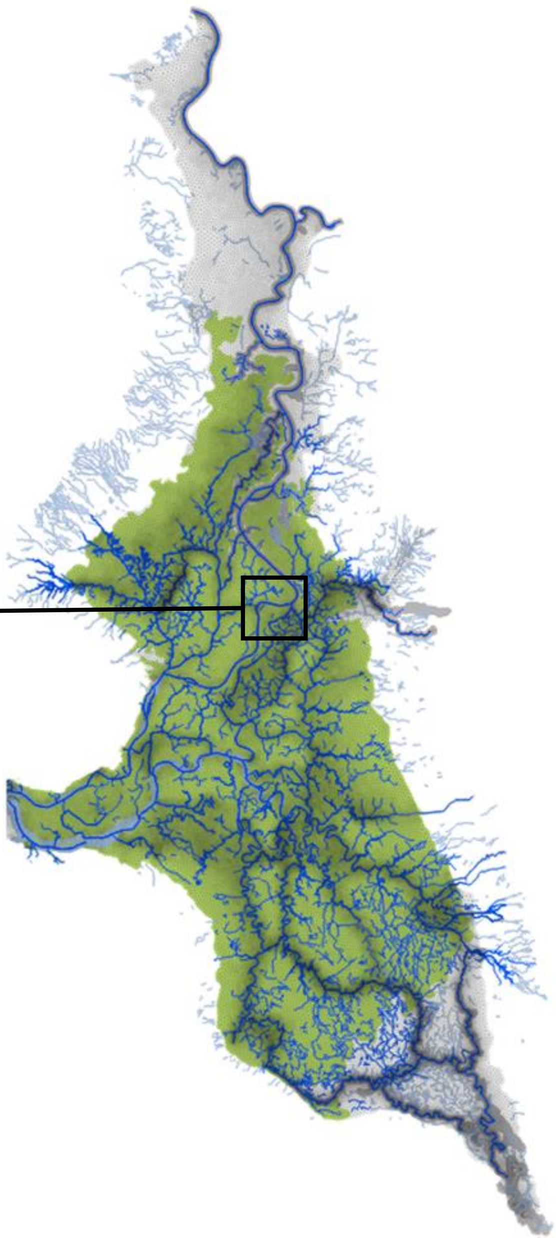
# Mesh Topology

- Flow-aligned quadrilateral elements follow levee crests in main channels
- Triangular elements fill tidal plains
- Low-order channels captured implicitly with subgrid
- Janet grid generation software (Lippert and Sellerhoff, 2006)



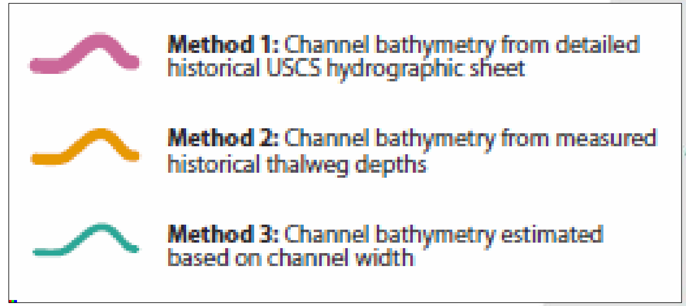


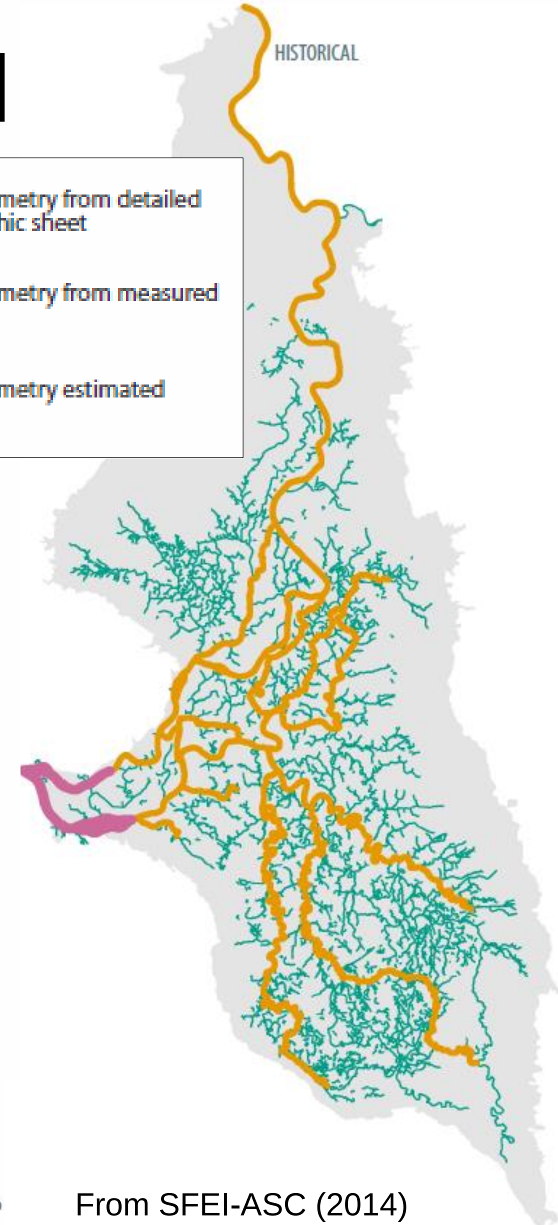

≈175,000 elements

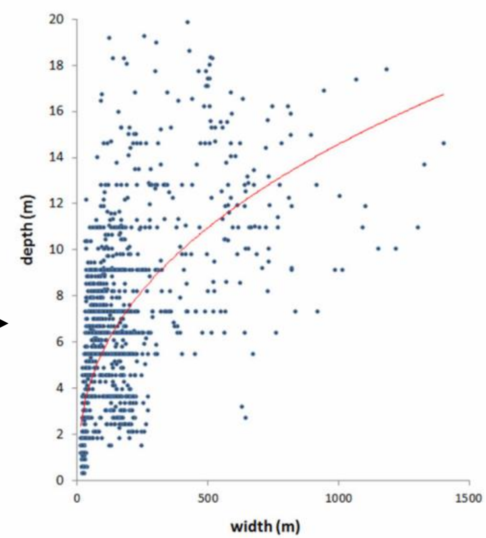


# Historical Bathy. Data → DEM

- Channel limits mapped in detail (±10 m) as part of Delta Historical Ecology report
- Sources for historical bathymetry
  - US Coast Guard 1867 [Method 1]
  - Gibbes 1850
  - Ringgold 1850
  - Debris Commission 1908 (post hydraulic mining)
- Cubic spline thalweg depth interpolation
- General width-depth relation for smaller channels →



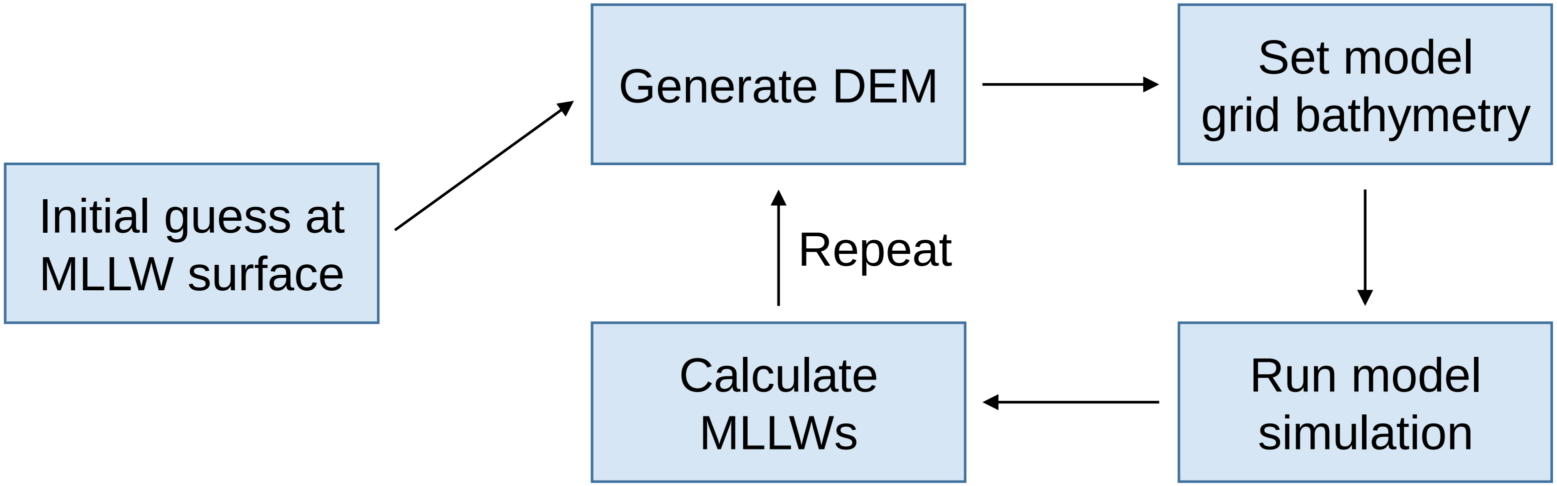




From SFEI-ASC (2014)

# Referencing Historical Depth Data

- Historical bathymetric data is measured relative to a tidal datum (MLLW)
- Model needs bed elevations relative to an absolute datum (NAVD88)
- Need to know absolute elevations of MLLW throughout the historical Delta to convert and set channel depths
  - These vary spatially and cannot be assumed to be similar to present day values because of sea level rise and major Delta modifications
- Iterative method used for calibration

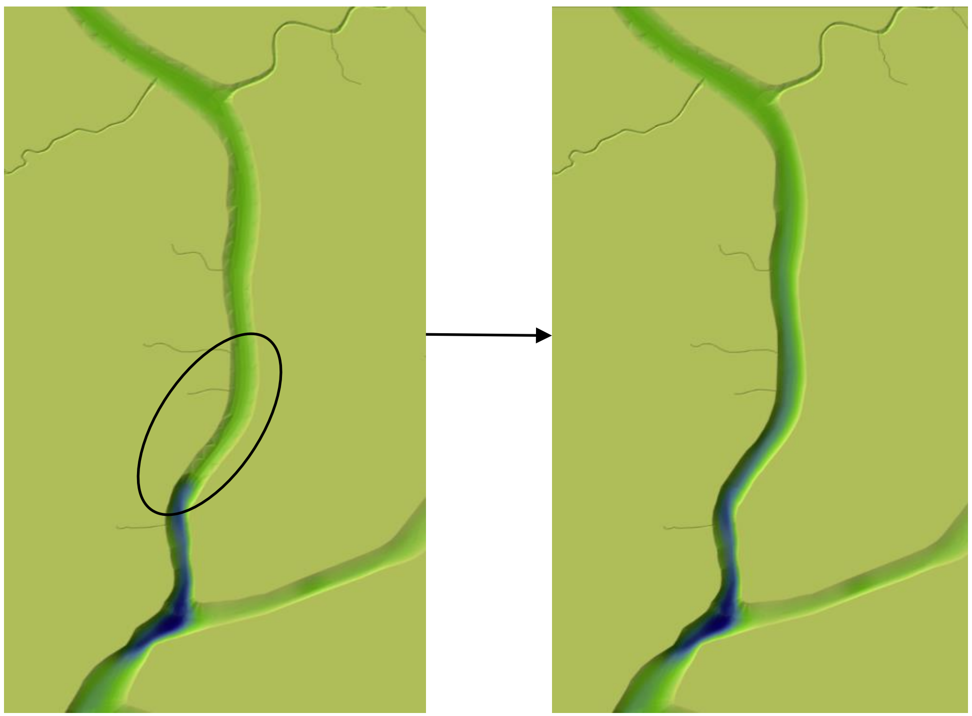


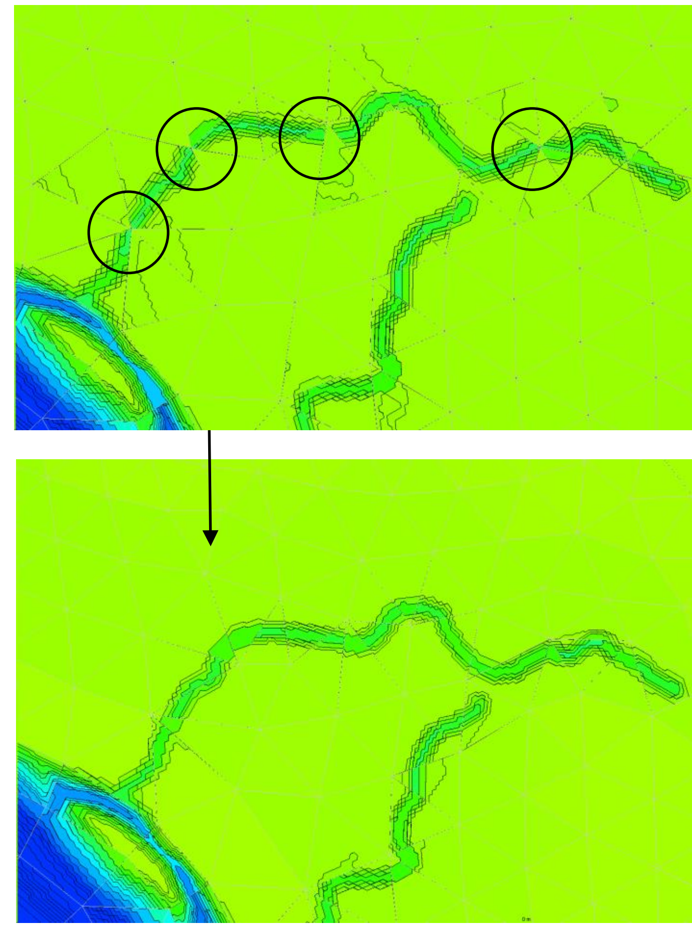
# How To Know Whether the Model is Behaving Correctly?

- Historical Observations at Specific Locations
  - Tidal Range in Channels
    - "[Q] How high do the tides rise in the M[okelumne] five miles below Bensons? [A] About three feet and a half which will bring it about a mile or a mile and a half below the head of the Island as near as I can judge." (J. Van Scoyk, 1859)
  - Marsh Plain Inundation Depths and Frequency
    - "[Q] To what height does the tide rise there? [A] About 6 or 8 inches above the ground, indicated by the water mark left upon the tule." (C.L. Thayer, 1859)
  - Spatial Extents of Tidal Freshwater Marsh
- General Delta Trends
  - Tidal Inundation Dynamics
  - Maximum Channel Velocities (channel stability)
  - Delta Tidal Prism

# What Can We Do To Calibrate?

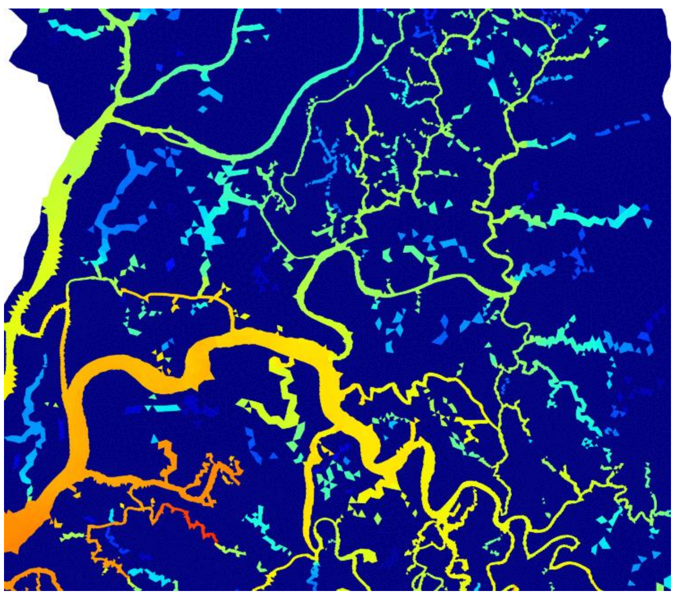
- Adjust marsh plain elevations
  - Influences tidal range in channels, marsh plain inundation and frequency
- Identify and fix artifacts in the DEM and grid

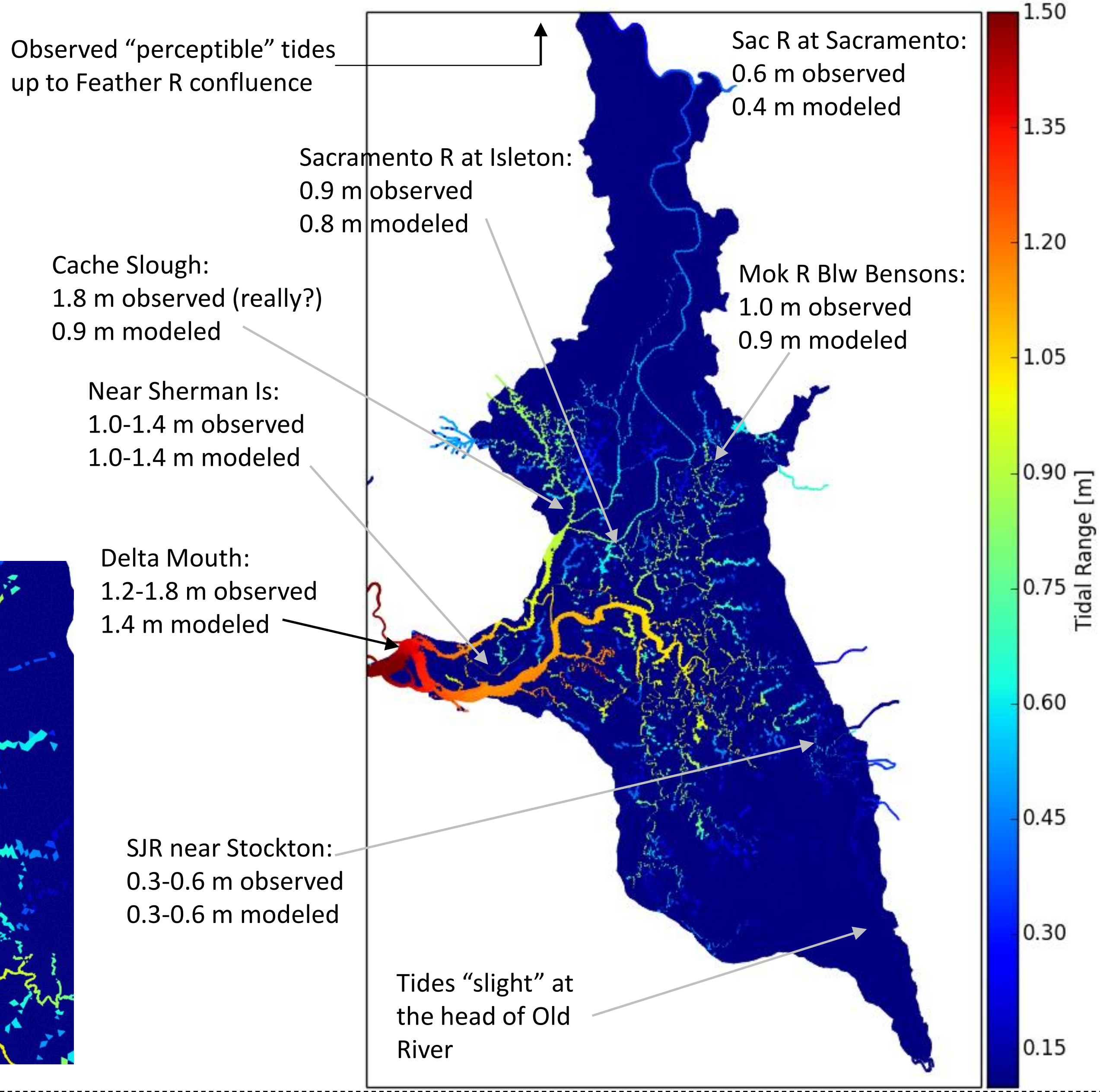




# Tidal Range

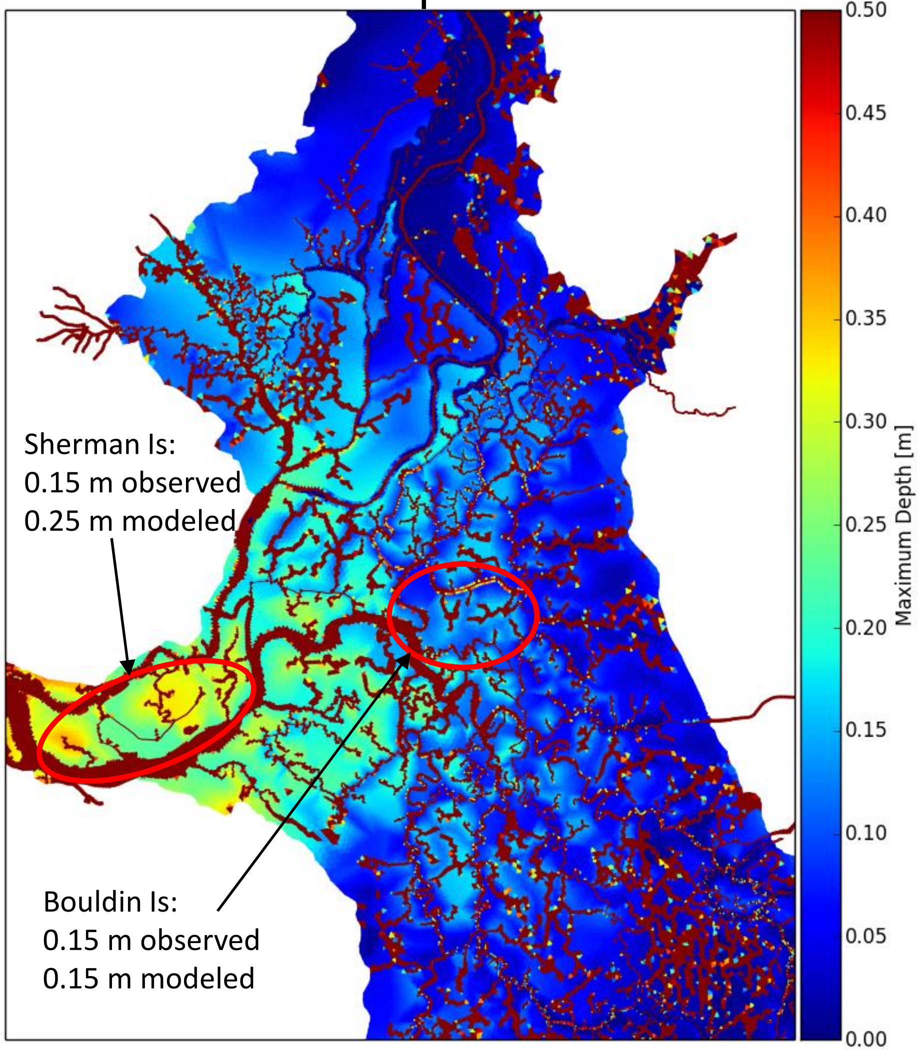
- Try to match point observations
- Try to match general patterns



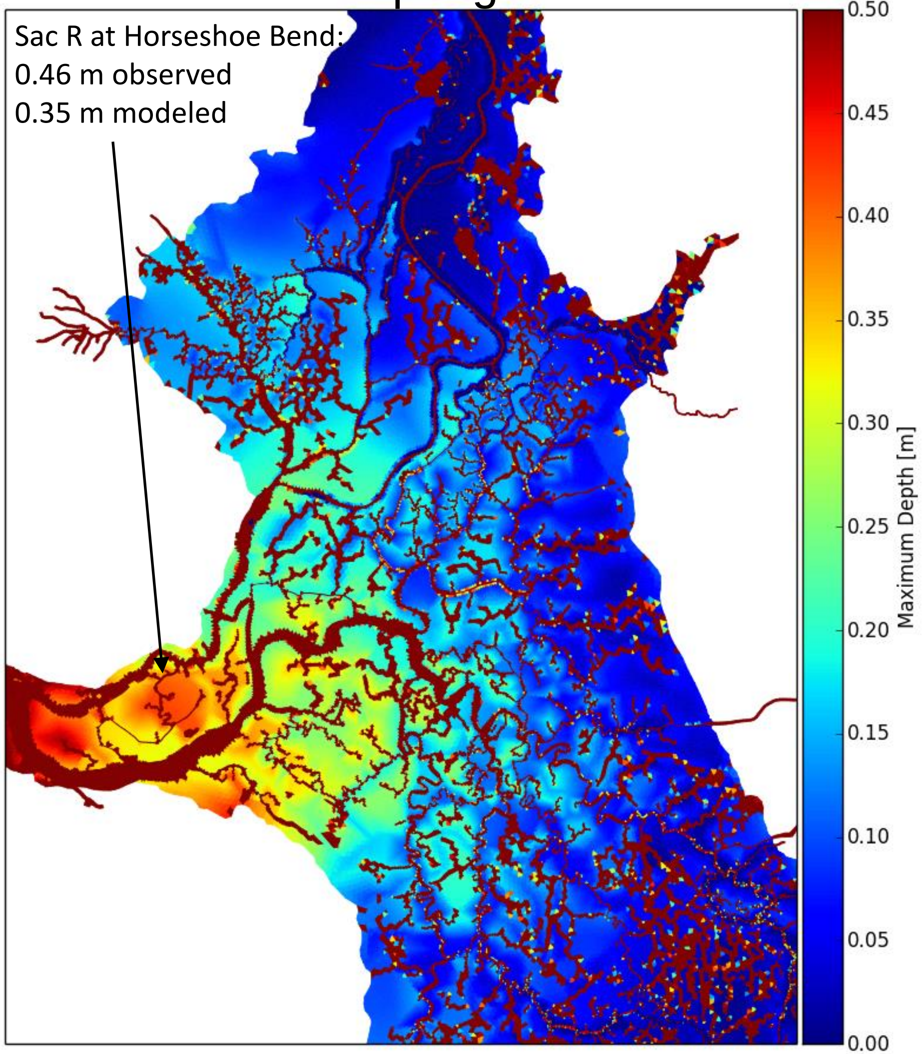


# Maximum Depth of Marsh Plain Inundation

Neap Tide




Spring Tide

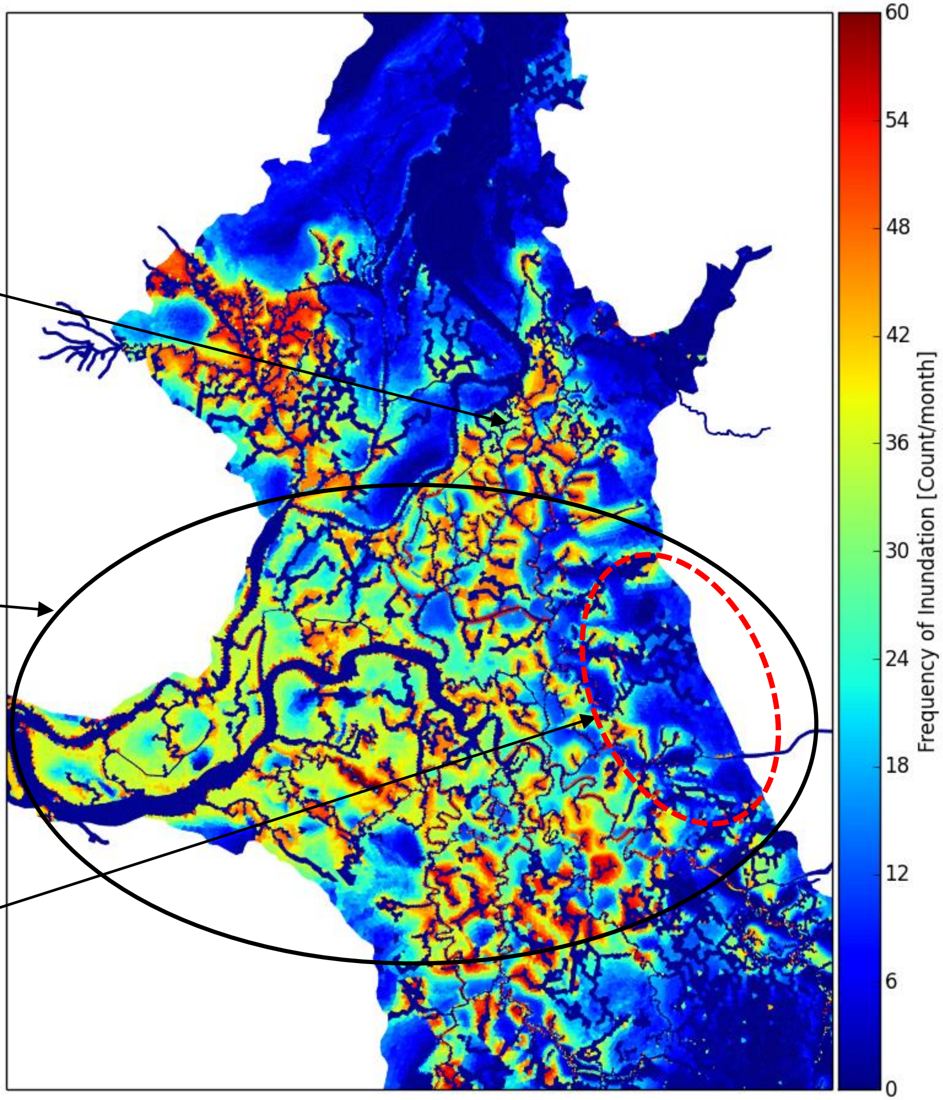


# Marsh Plain Inundation Frequency

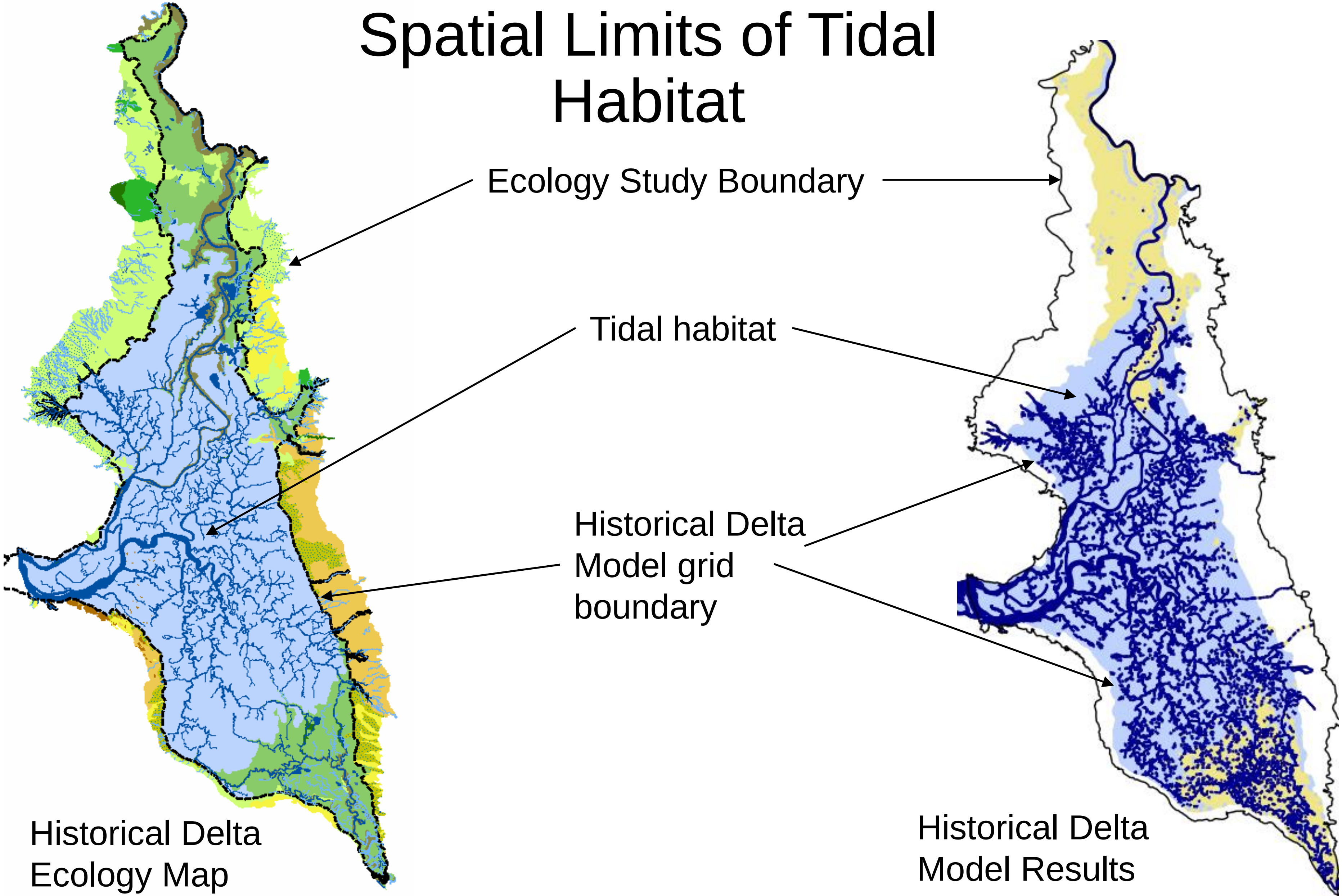
Observed: Tyler and Staten Islands wetted twice daily at south end, only by spring tides at north end
Modeled: no strong north-south gradient in inundation frequency

Observed: Central Delta wetted twice daily, inundated on spring tides
Modeled: similar

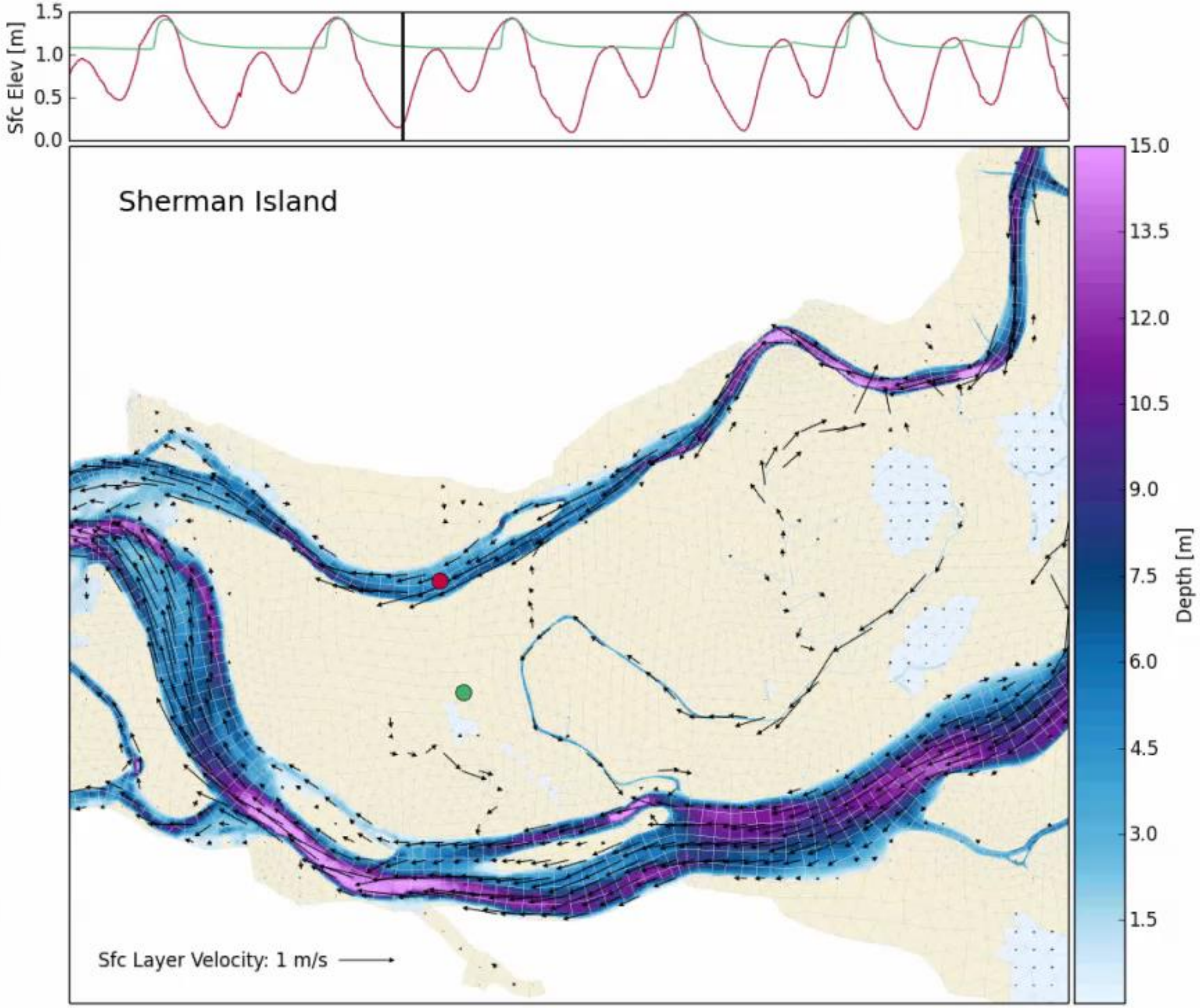
Observed: Eastern margin only wetted by spring tides
Modeled: similar



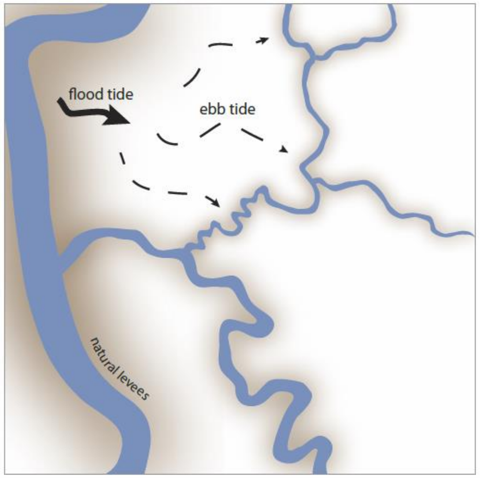
# Spatial Limits of Tidal Habitat



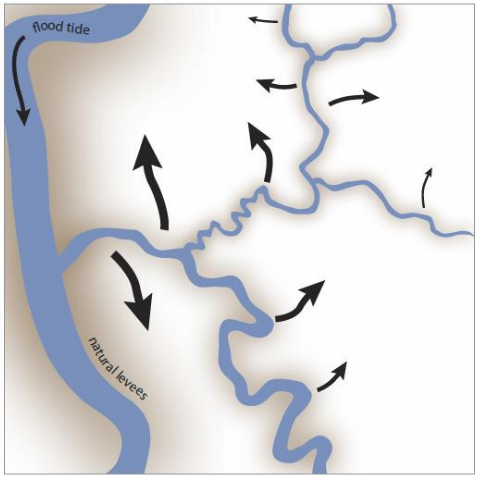
# Marsh Plain Inundation Patterns




High high tides spill over natural levees, drain through sloughs



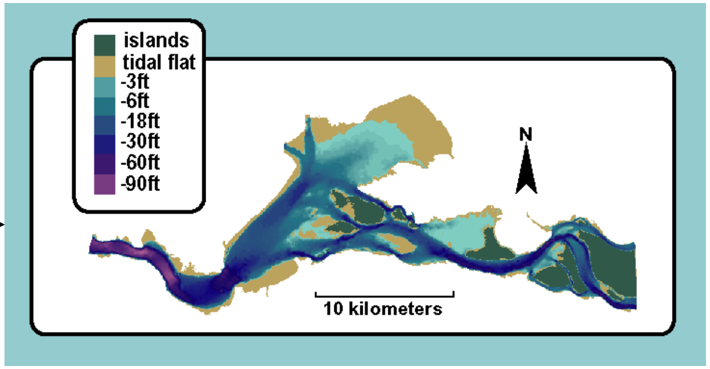

Lower high tides flood marsh from sloughs



# Continuing Work

- Refine calibration
- Higher flow simulations
- Comparison to present-day Delta:
  - X2 relationship to Net Delta Outflow
  - Flood vs. ebb tide dominance
  - Advective and dispersive flux
  - Tidal prism
    - Present-day Delta: 205M $m^3$
    - Historical Delta*: 197M $m^3$

    * at current state of calibration
- Incorporation of 1867 Suisun Bay bathymetry
- Lots more?




From Cappiella et al. (1999)

# Thanks!

- **Metropolitan Water District of Southern California**
  [Funding agency]
  - Paul Hutton, Project Manager

- **San Francisco Estuary Institute**
  [Historical Delta Configuration, Bathymetry]
  - Robin Grossinger
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  - Dan Howes (CSU, San Luis Obispo)
  - Tariq Kadir
  - Guobiao Huang


- Development and calibration of the Historic Delta Model was funded by the Metropolitan Water District of Southern California, under the direction of Paul Hutton


- DWR and UCD are independent collaborators

- **University of California, Davis Center for Watershed Studies**
  [DEM creation, Hydrodynamics]
  - Bill Fleenor
  - Fabian Bombardelli
  - Andy Bell
  - Alison Whipple
  - Steve Micko
  - Mui Lay
  - Amber Manfree

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- Whipple, A.A., Grossinger, R.M., Rankin, D., Stanford, B., and R.A. Askevold. 2012. Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process. Prepared for the California Department of Fish and Game and Ecosystem Restoration Program. A Report of SFEI-ASC's Historical Ecology Program, Publication #672, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA.

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