Human alterations of channel characteristics in the Delta and effects on hydrodynamics and sediment transport

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Presented at:
8th Biennial Bay-Delta Science Conference
on October 30, 2014, Sacramento, CA

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Outline

- Background on human alterations to the Delta channels
- Methods of data collection and measuring changes in hydrodynamics and sediment transport
- Results
  - Effects of flooded islands
  - Effects of changes in channel geometry
  - Sediment deposition in the Delta
- Conclusions

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Background

- **U.S. Bureau of Reclamation is working to develop hydrodynamic and sediment transport models for the purpose of evaluating management effects on endangered species in the Delta.**
- **USGS is currently supporting the development of these models by collecting field data on bed-material as well as investigating changes in sediment dynamics**
- **Why is it important?**
  - Bed-material size and characteristics can affect turbidity, which is particularly important for Delta Smelt
  - Sediment supply to the Bay has been decreasing
  - Channel and shear velocity affect sediment transport and can play an important role in shaping ecosystem characteristics.

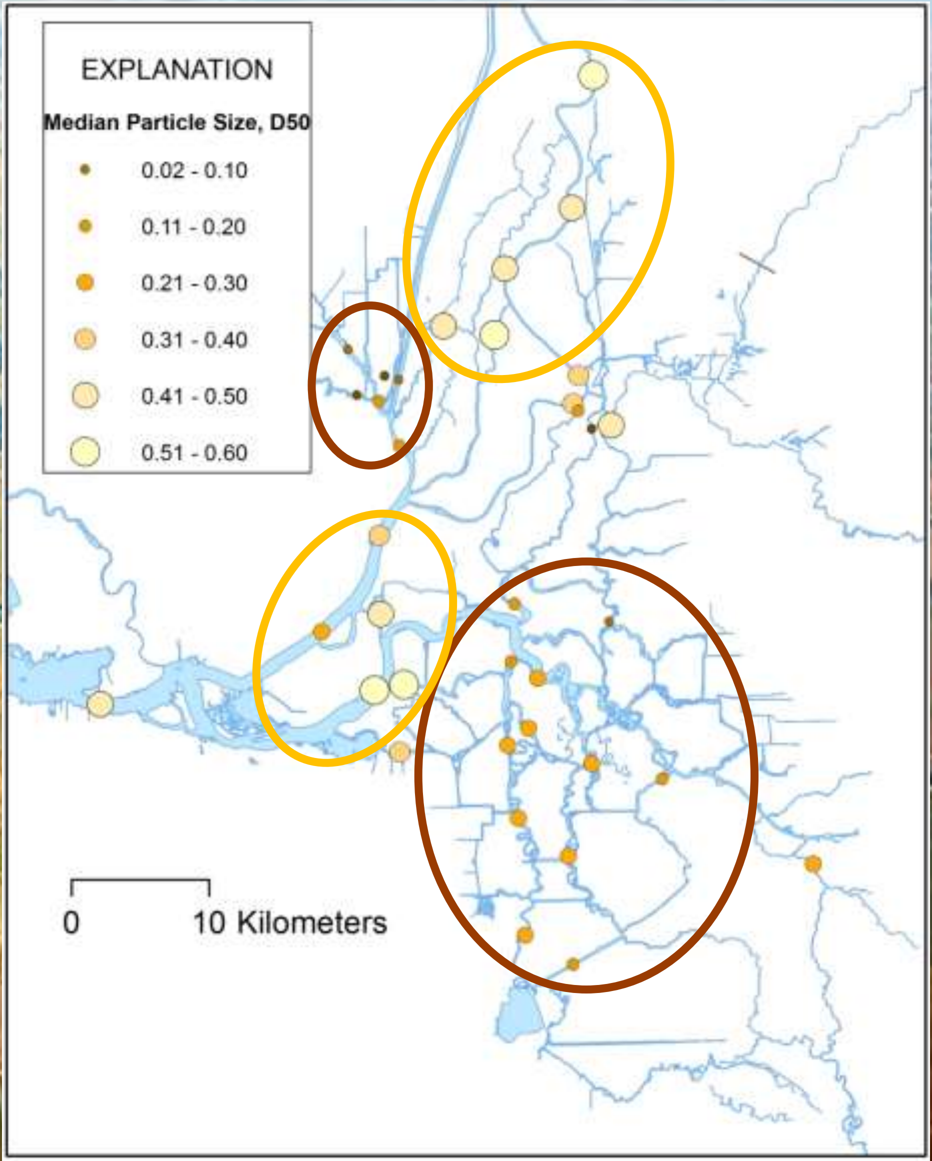
Background

Results from USGS bed-material sampling

Summary of previous findings:

- Coarse material found in North Delta, and near confluence
- Fine material found in South Delta and Cache Slough complex

- Unclear why certain bed materials were found in some locations and not in others.
- Warranted further investigation.



Historical changes to the Delta and watershed…

- Draining tidal marsh
- Levees
- Subsidence
- Hydraulic mining
- Dam construction
- Channelization
- Land-use changes
- Salinity changes
- Floodplain reduction
- Hydrograph alterations

- Bank stabilization
- Flooded islands
- Man-made channels
- Channel widening
- Channel dredging

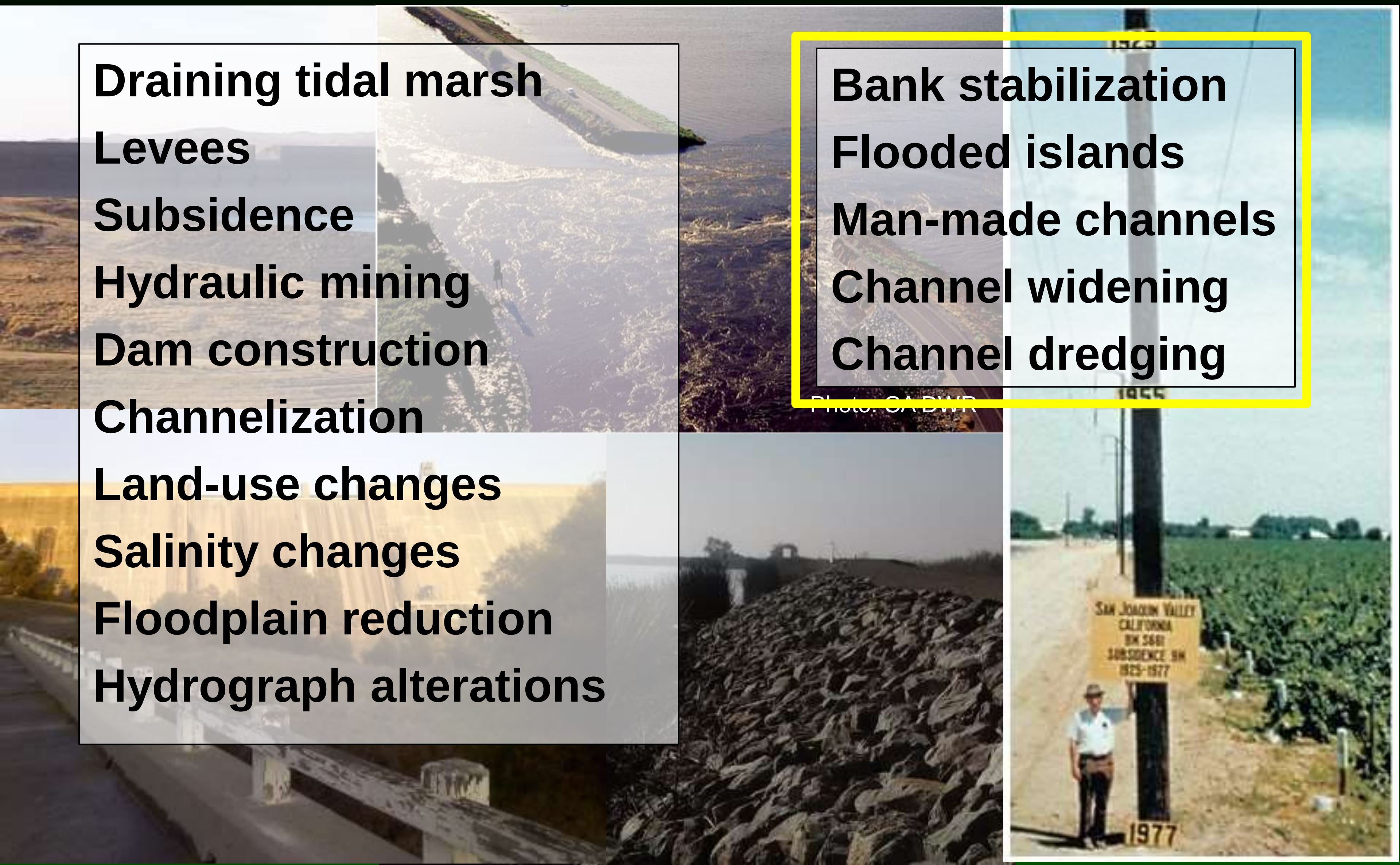


Photo: CA DWR

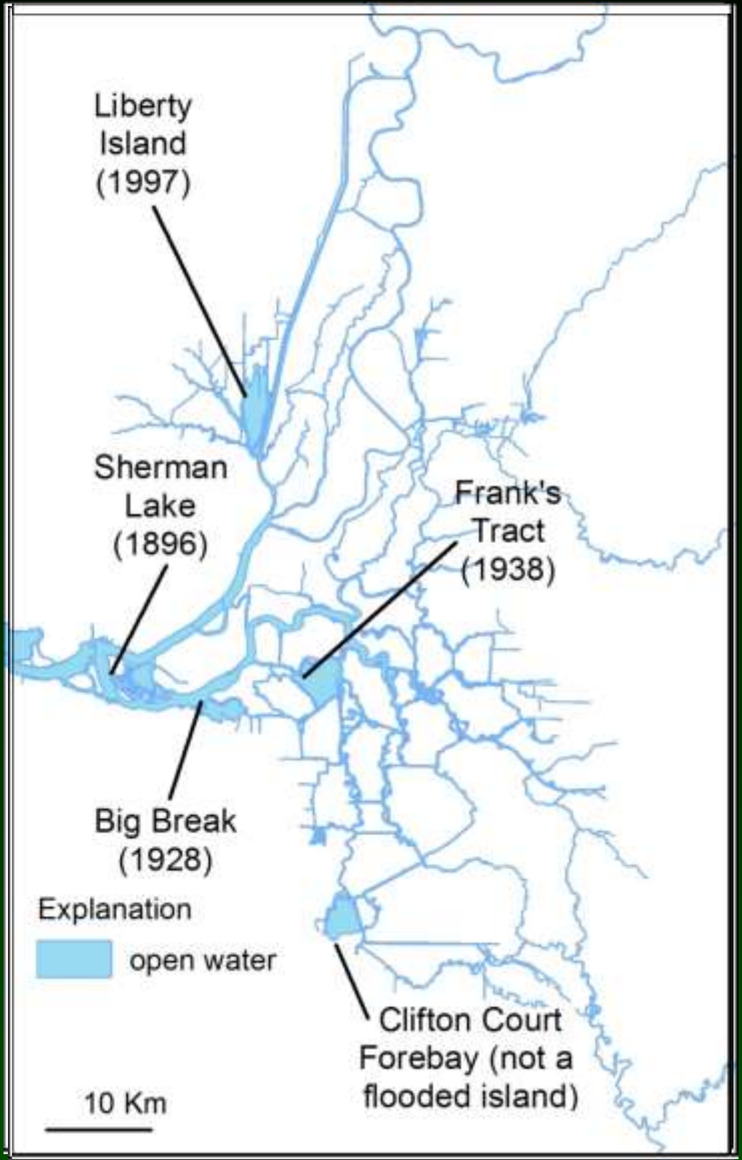
Historical Changes continued…

1800s through 1900s

- Marshes were drained
- New channels were constructed
- Deep-water shipping channels
- Leveed islands subsided and flooded (some permanently)

State of the Delta early 1800s

Complex network of channels with large expanse of tidal and freshwater wetlands



(Modified from Whipple et al. 2012)

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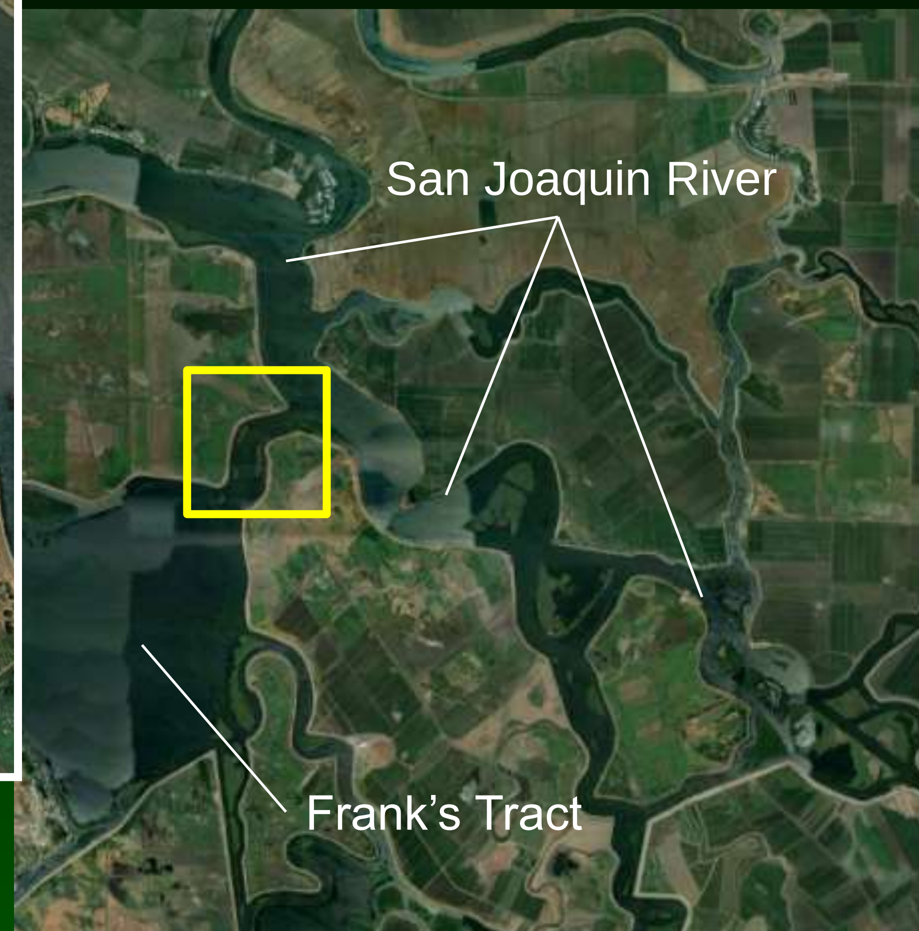
Historical Changes continued…

Many channels were widened
Example: Old River near Frank's Tract



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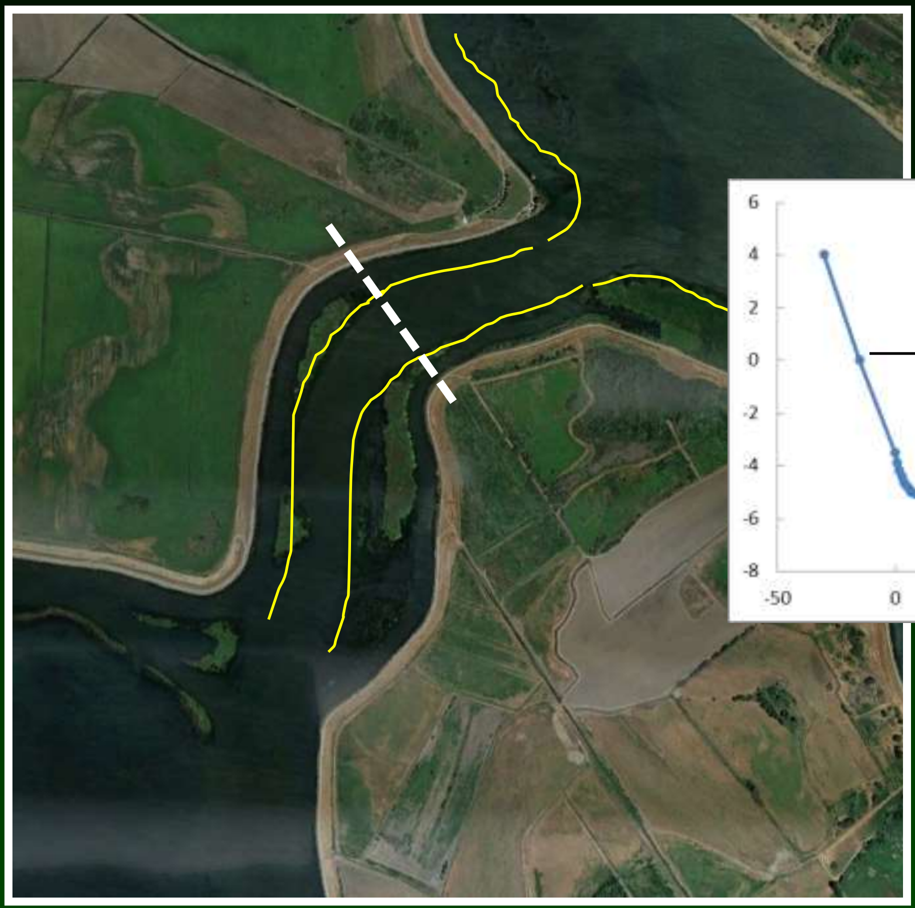
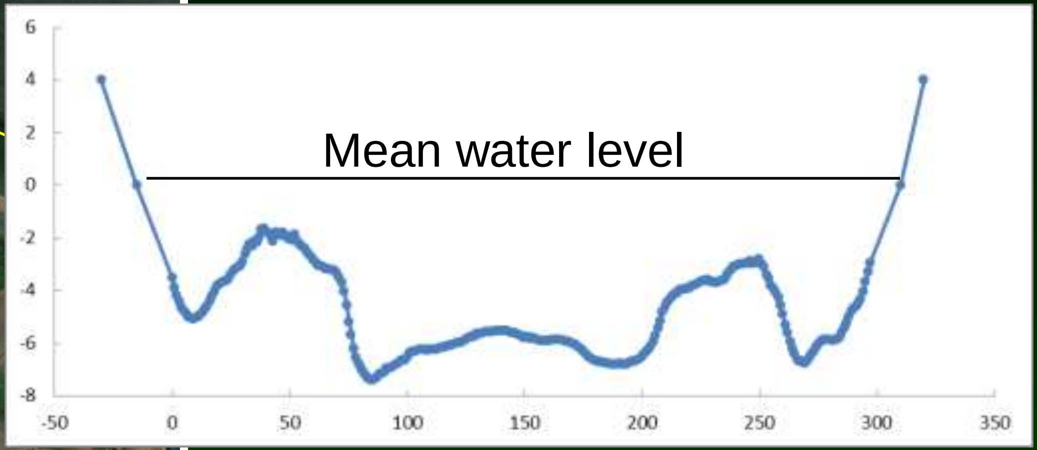


Channel cross-section



Original channel width?

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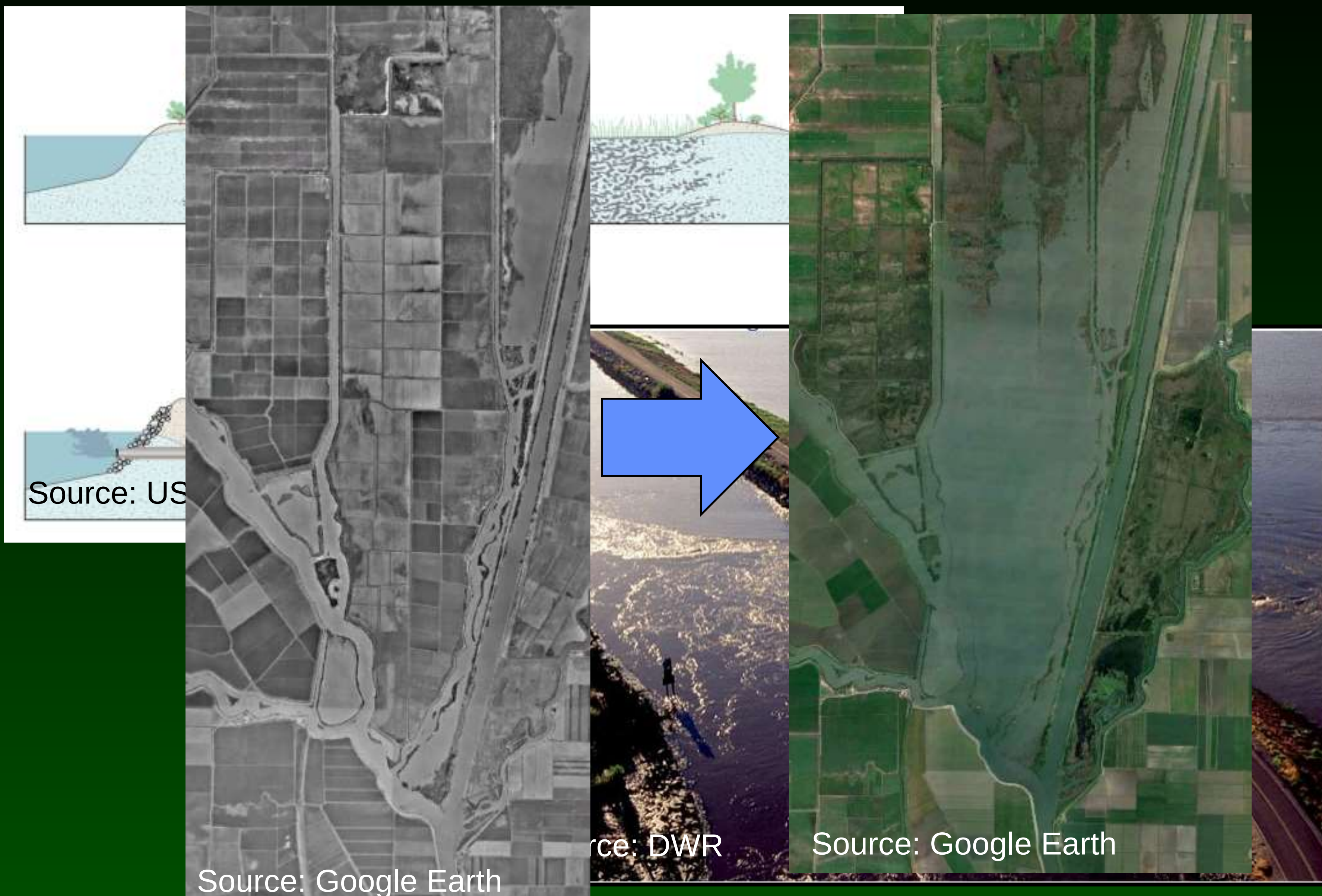
Flooded islands



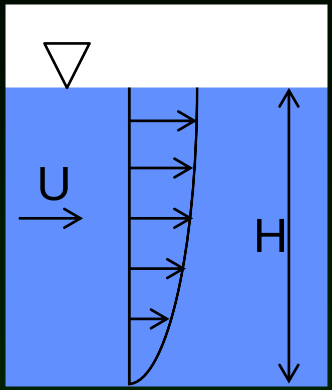
Methods

Bed shear velocity and critical shear velocity

Shear velocity, u_* (Keulegan, 1938)

$$\frac{U}{u_*} = \frac{1}{\kappa}\ln\left(11\frac{H}{k_s}\right)$$

Known:
- H = depth
- κ = 0.41 (von Karmon coefficient)
- U = average velocity
- k_s = roughness coefficient
  = $3 \cdot D_{90}$ (van Rijn, 1984)



Critical shear stress, τ_{cr}, (Brownlie, 1981)

$$\frac{\tau_{cr}}{\rho g R D} = 0.22 R_{ep}^{-0.6} + 0.06 e^{\left(-17.77 R_{ep}^{-0.6}\right)}$$

$$where \;\; R_{ep} = \frac{\sqrt{gRD}D}{\nu}$$

Known:
- ρ = 1000 kg/m³ density of H_2O
- g = 9.81 m/s² (gravity)
- R = 1.65 (submerged specific weight)
- D = particle size, D_{50}
- ν = 1E-6 m²/s, (kinematic viscosity)

Critical shear stress, τ_{cr}
converted to critical shear velocity, u_{cr}

$$u_{cr} = \sqrt{\frac{\tau_{cr}}{\rho}}$$

Methods

List of data sources used to create a sediment budget

Suspended

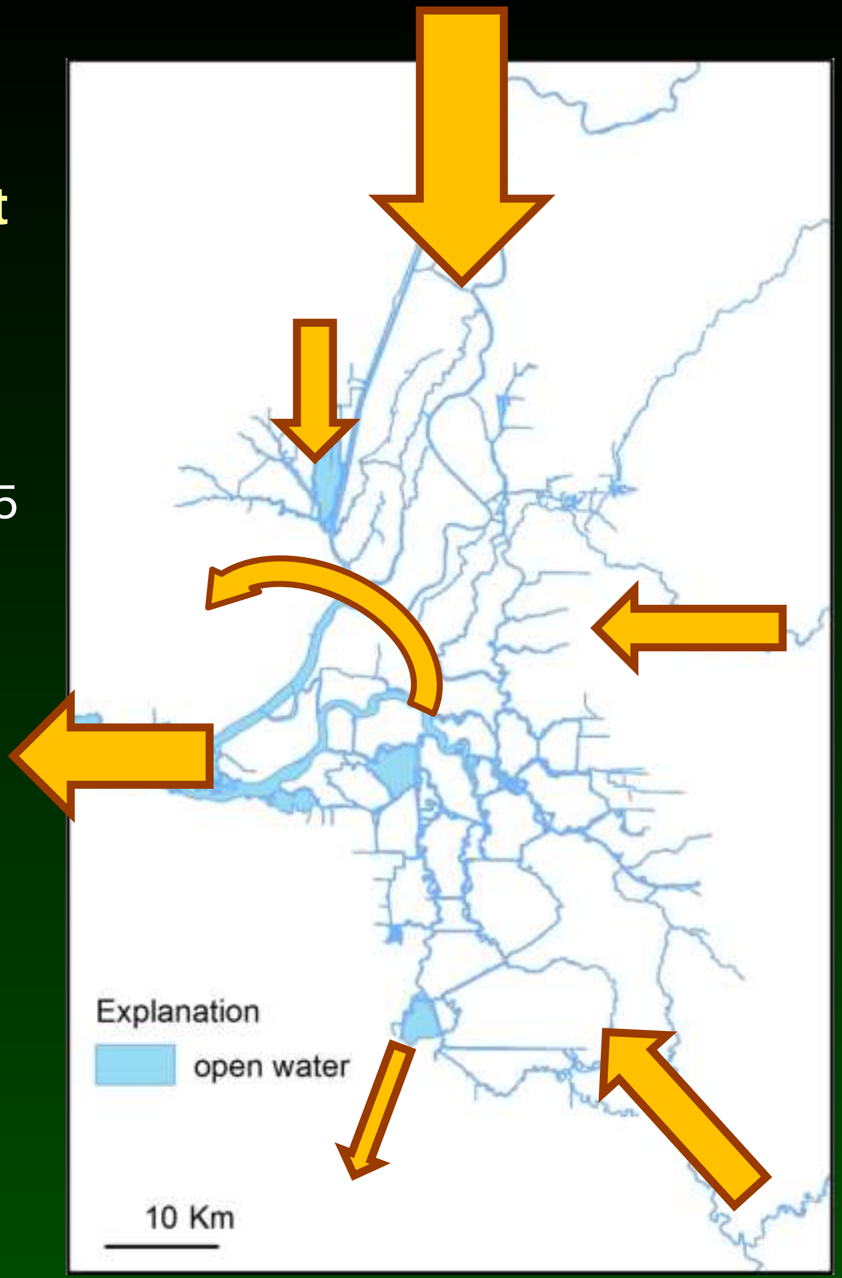
- USGS streamgages
- Wright and Schoellhamer 2005
- McKee et al 2013

Bedload estimates:

- Van Rijn 1984 method

Dredged material

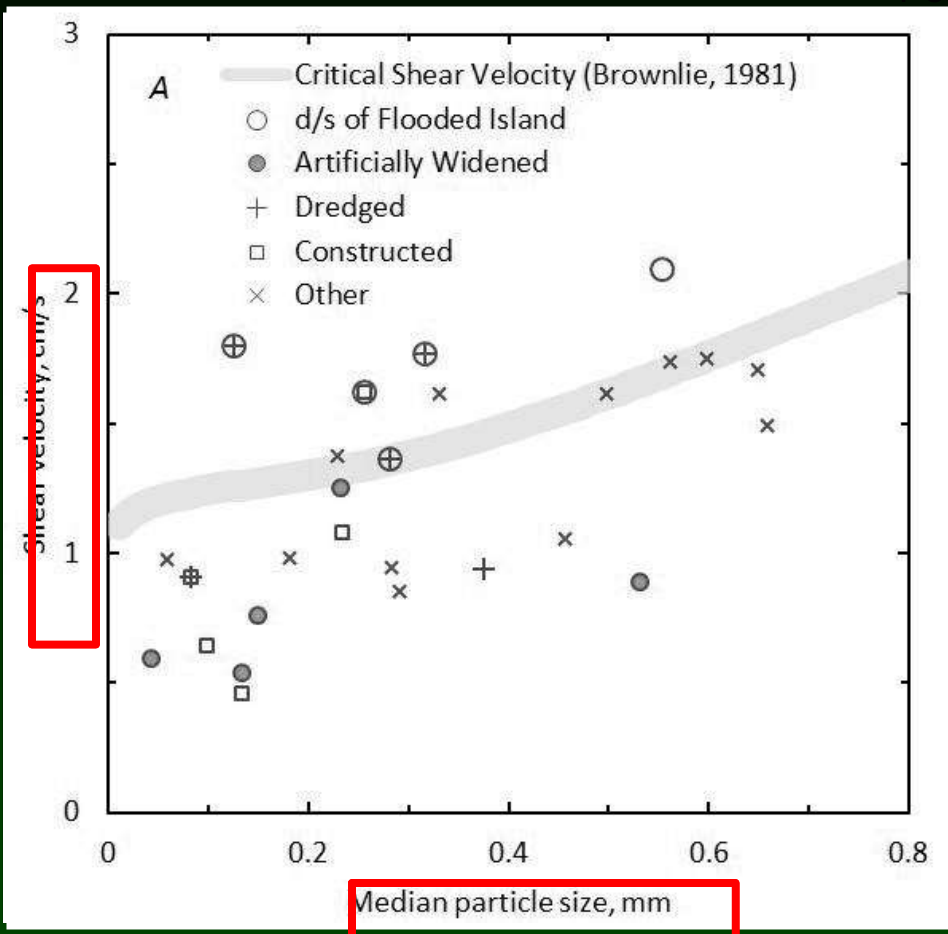
- USACE records



Results

Shear velocity vs critical shear velocity

Pearson' r = 0.77



Erosional or transport reaches

Critical shear velocity

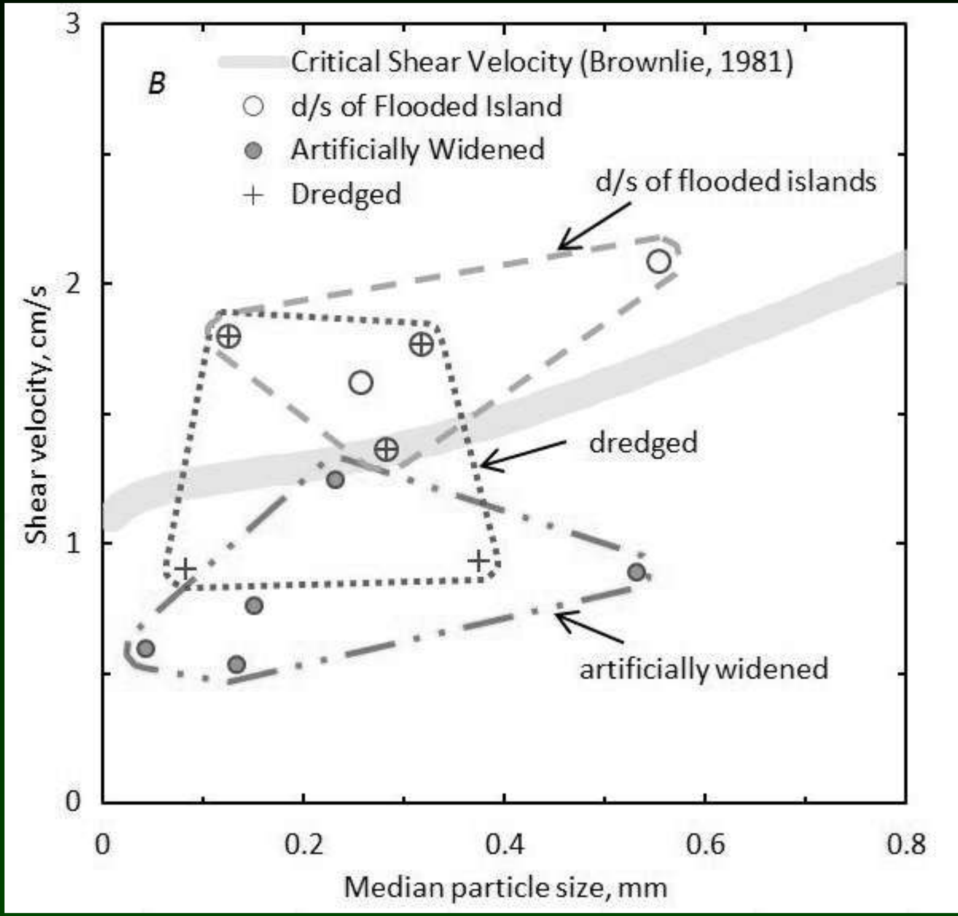
Depositional

Sites were categorized based on characteristics (e.g. dredged, downstream of flooded island, etc.)

Some sites don't fit in any of these categories

Results

Shear velocity vs critical shear velocity



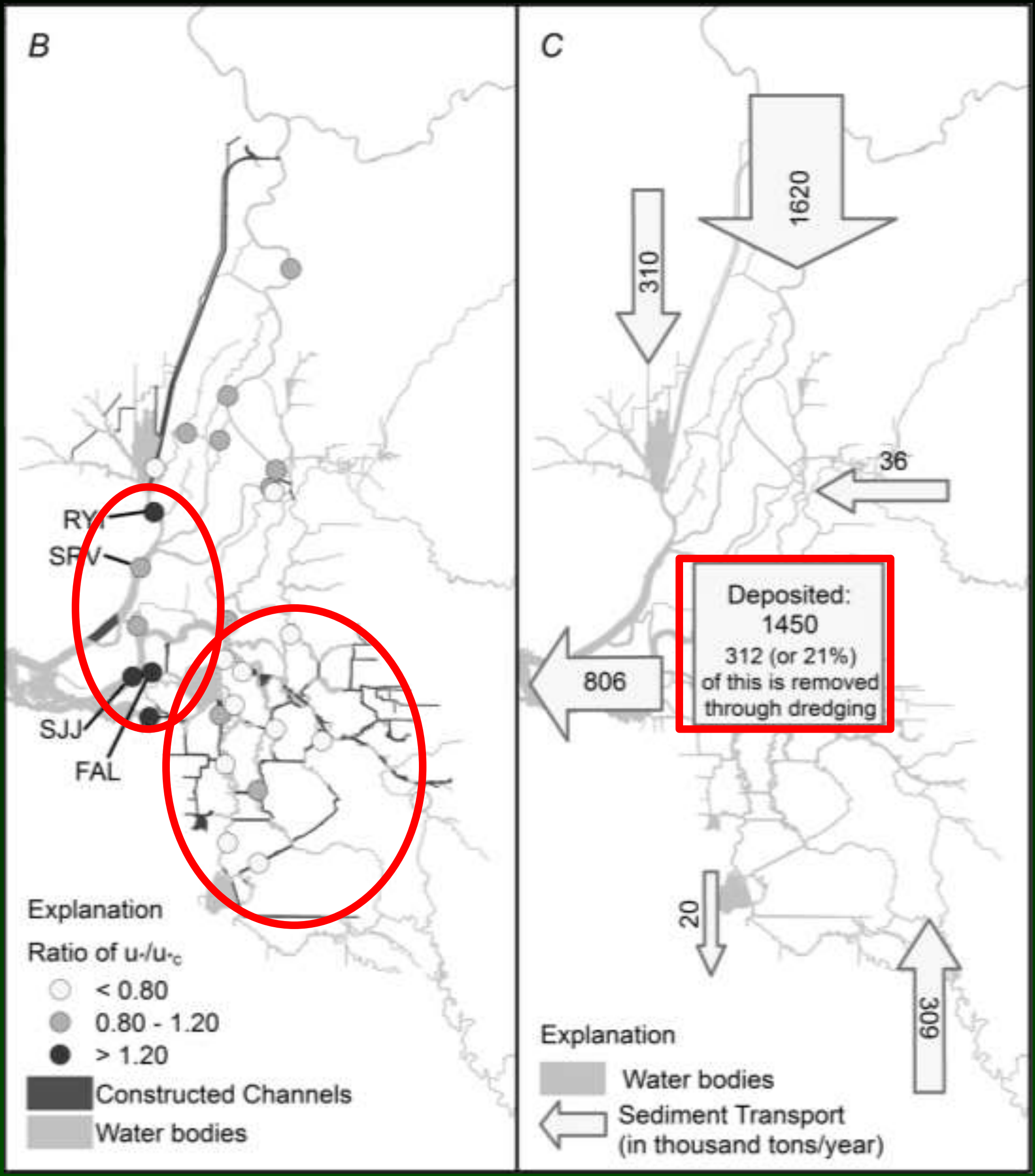
- Channels were widened during marsh reclamation (~late 1800s)
- Frank's Tract flooded in 1938

Generally, channels have not returned to an equilibrium state:

- Channels can not laterally adjust through erosion due to bank reinforcement
- Sediment supply is not sufficient for any significant accretion

Results

- Channels with highest shear velocity are all downstream of flooded islands
- Channels with lowest shear velocity are generally all artificially widened/deepened channels or are constructed channels
- On average, approximately 2/3rd of sediment (1997-2010) was deposited in the Delta
- Of the sediment deposited, about 20% was removed through dredging

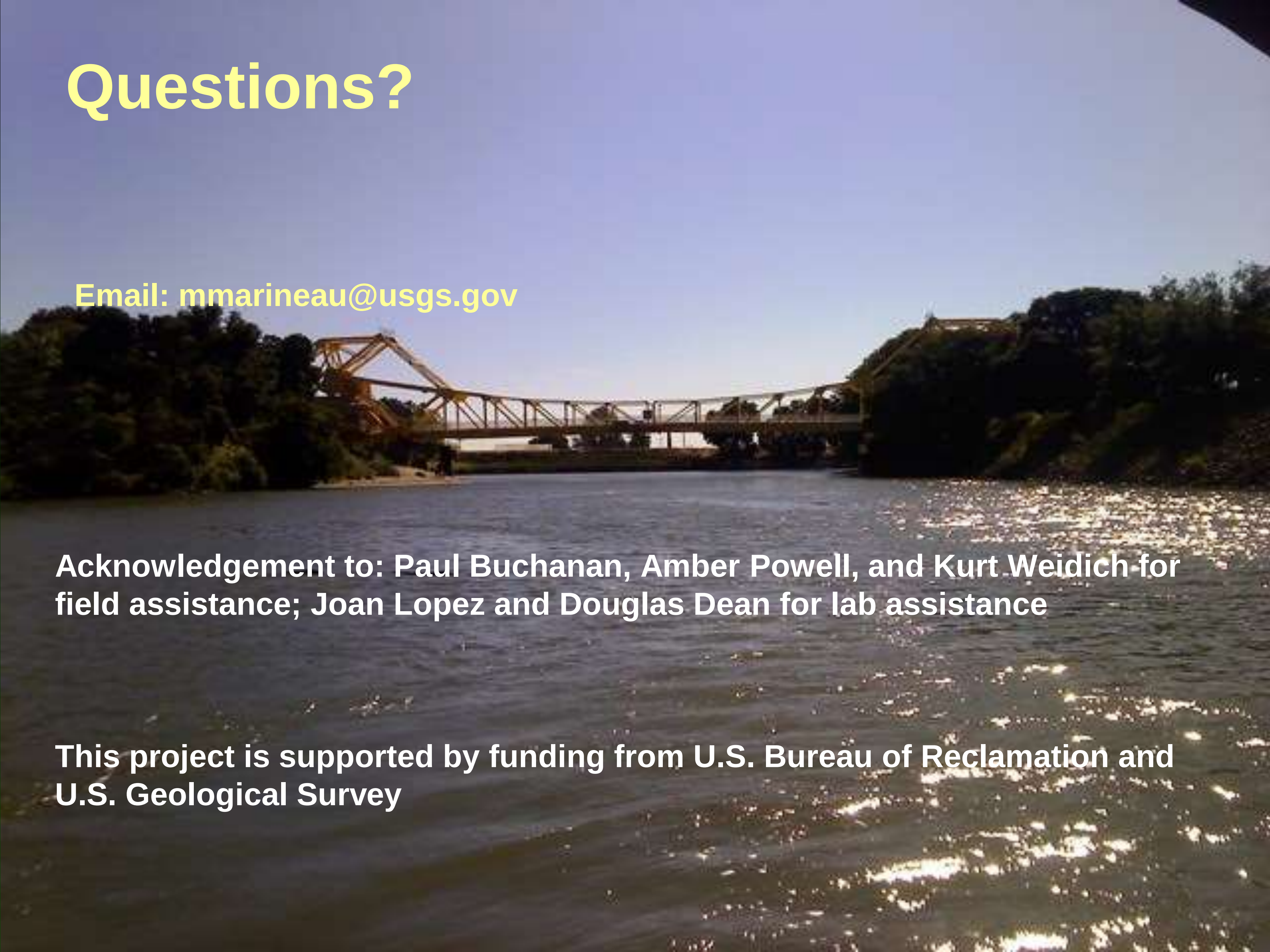


Conclusions

- **Flooded islands increase the shear velocity of channels downstream**
  - **May affect fish migration**
  - **Increased sediment transport and coarsened bed – possible impacts to food webs and aquatic wildlife**
  - **Additional future island flooding is possible** ***(e.g. Mount and Twiss, 2005)***
- **Deepened and widened channels decrease channel velocity**
  - **Creates depositional environment**
  - **Prevents sediment from transporting downstream or to restoration areas**
  - **May increase vulnerability of channels to invasion by exotic weeds**

Conclusions

- 1,450 tons/yr of sediment is deposited in the Delta
  - Delta is a depositional environment, but today there may be too little sediment available for restoration or keep up with sea level rise
- Approximately 20% of deposited sediment is removed through dredging
  - Deep-water channels account for only 7% of the Delta by area, therefore a disproportionate amount of the deposition occurs in these areas



Questions?

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Acknowledgement to: Paul Buchanan, Amber Powell, and Kurt Weidich for field assistance; Joan Lopez and Douglas Dean for lab assistance

This project is supported by funding from U.S. Bureau of Reclamation and U.S. Geological Survey

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