An Overview of Delta Hydrodynamics and Transport

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Workshop on the State of the Science on Fish Predation on Salmonids in the Bay-Delta

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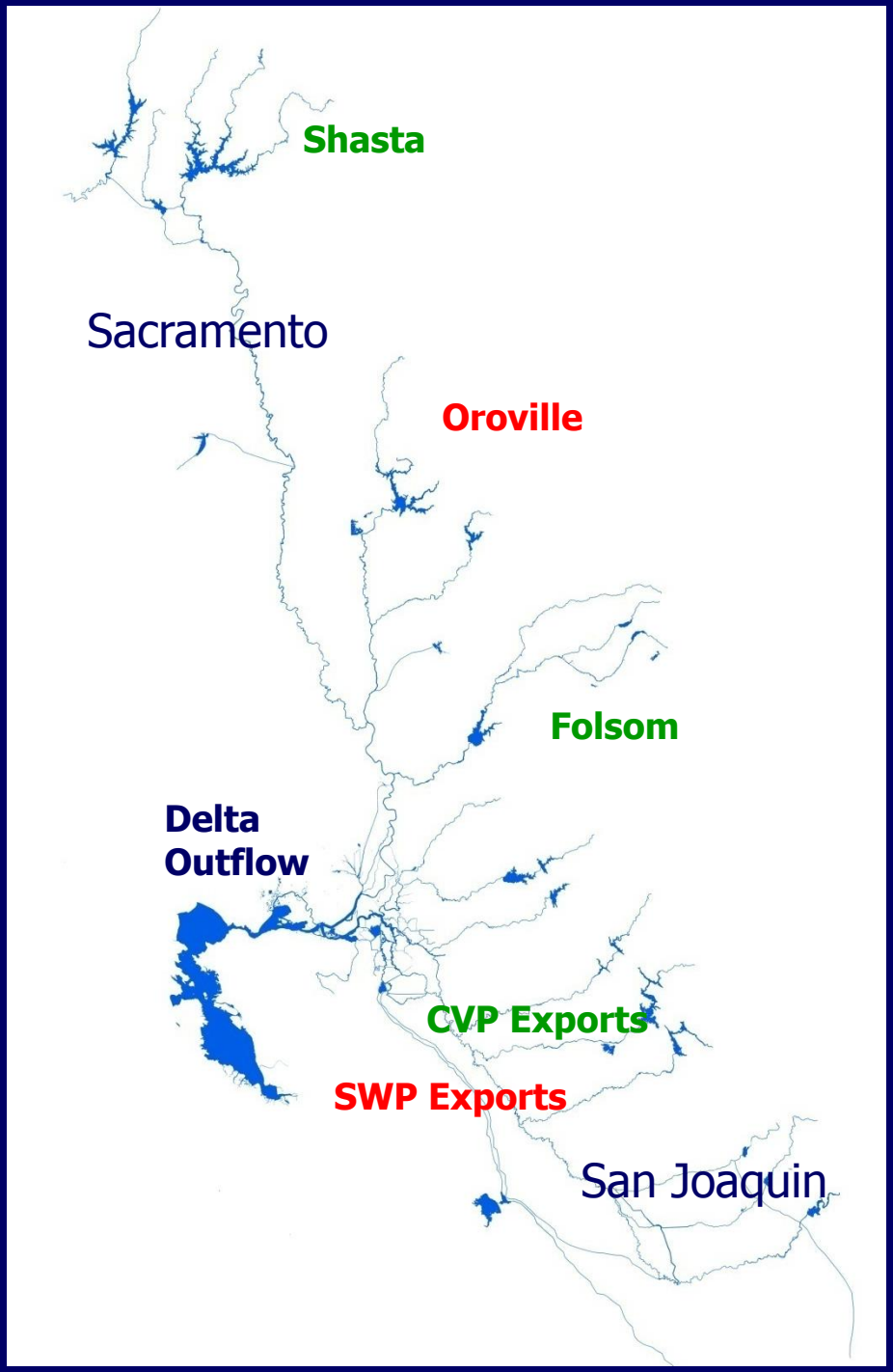
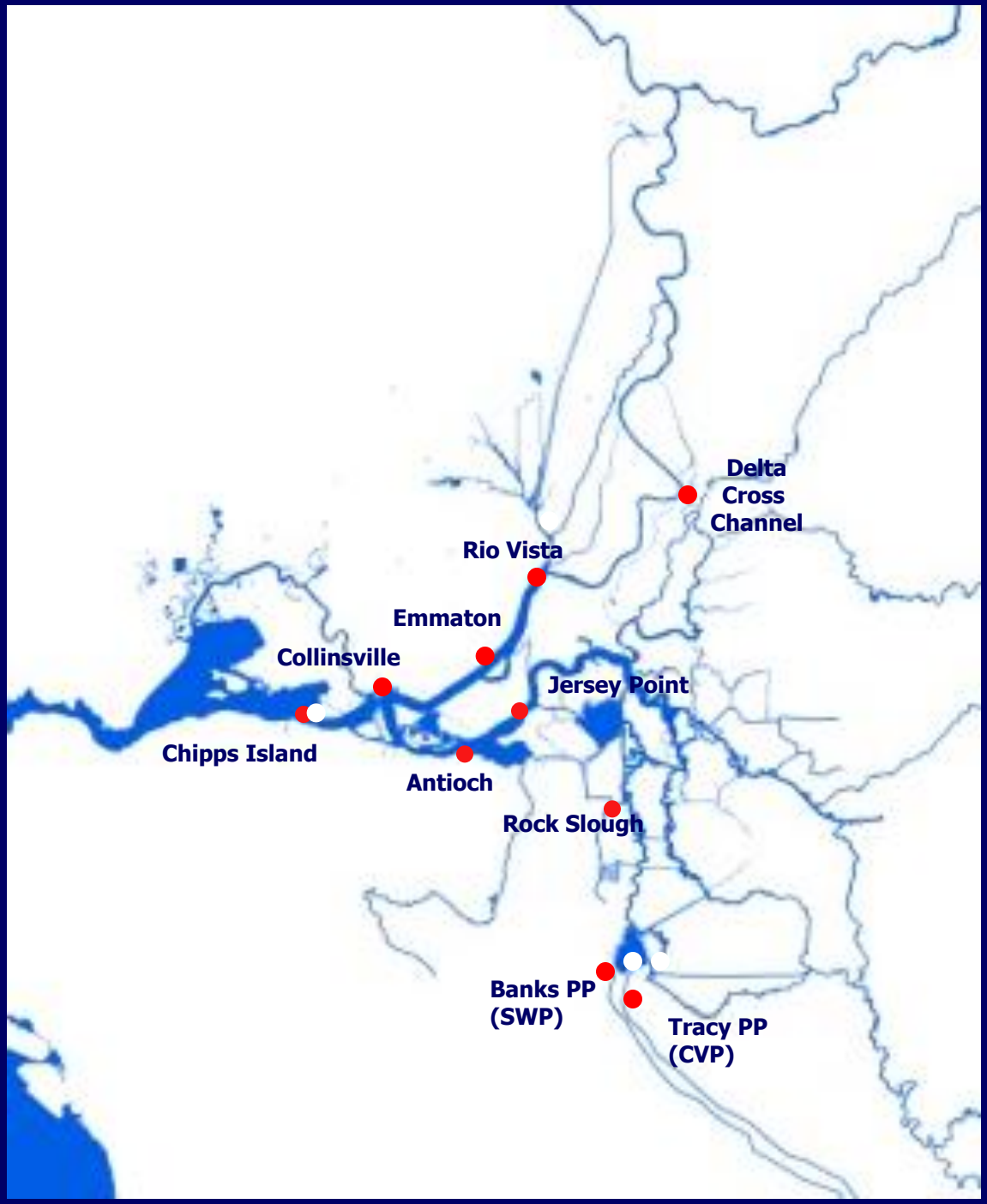
How the Delta Works

* Primary Mechanisms
  * Net Flow
  * Tidal Mixing
  * Gravitational Circulation
* Managing Salt Accumulation over the Dry Season
* Water Exports Affect Water Source Distribution
* Some Residence Time Results

California Central Valley River Systems



Sacramento - San Joaquin Delta



Delta Time Series Data

* Commonly Available Data
  * **Stage**
  * **Flow**
  * **Salinity (EC)**
  * Turbidity
  * Sediment Concentration
  * Temperature
* What to Look For
  * Important net-flow splits (e.g., Sac. River to Delta Cross Channel)
  * Gate/barrier operations (e.g., Clifton Court Gates)
  * Delta Island Consumptive Use
  * Delta Exports
  * Low flow, high flow, and transition periods
  * The yearly cycle of salt intrusion and flushing
  * Spring-neap tidal variation

Observed versus Computed…
What can you see in the wiggly lines?

Stage

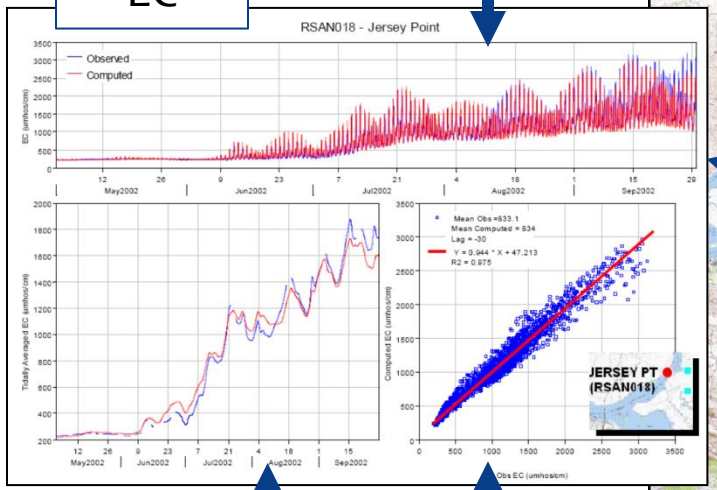
Tidal Time Scale

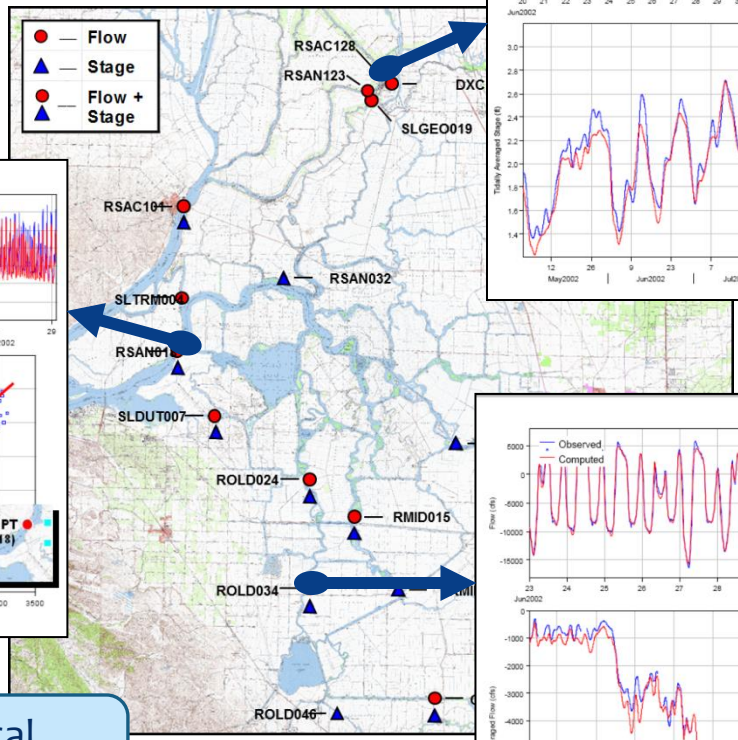
EC

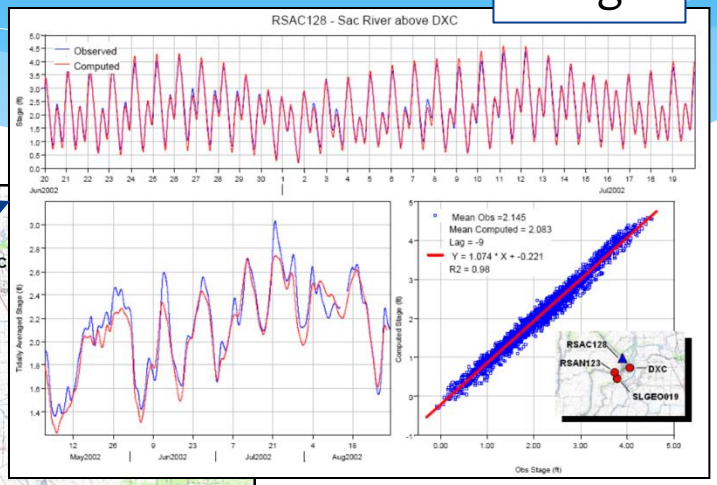
Flow

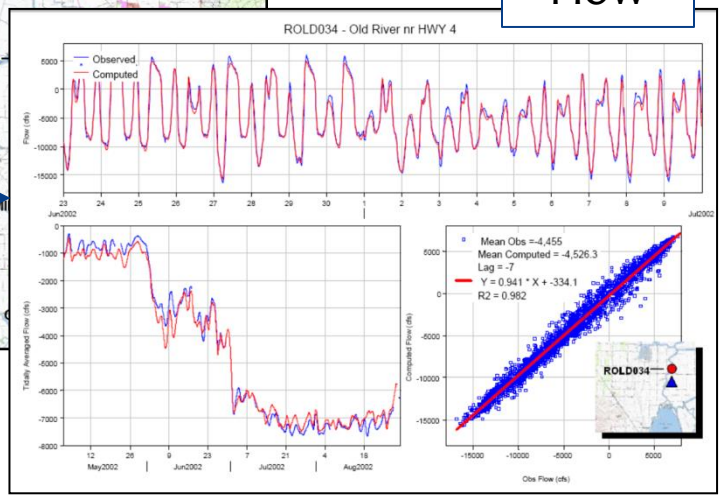
Tidally Averaged Time Scale

Statistical Comparison







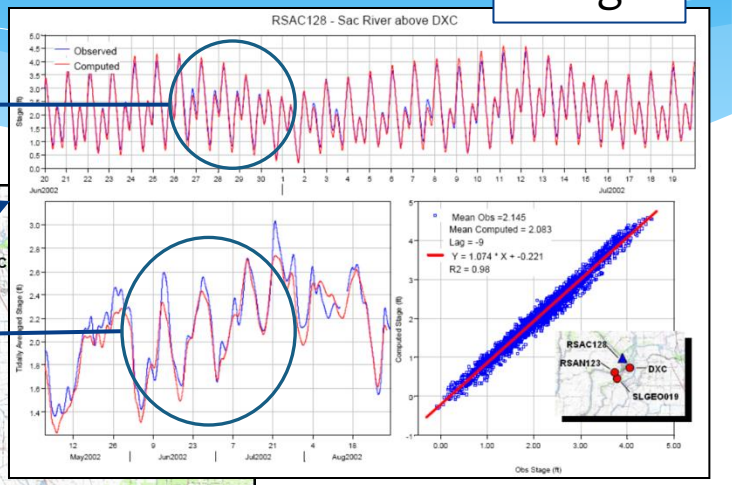


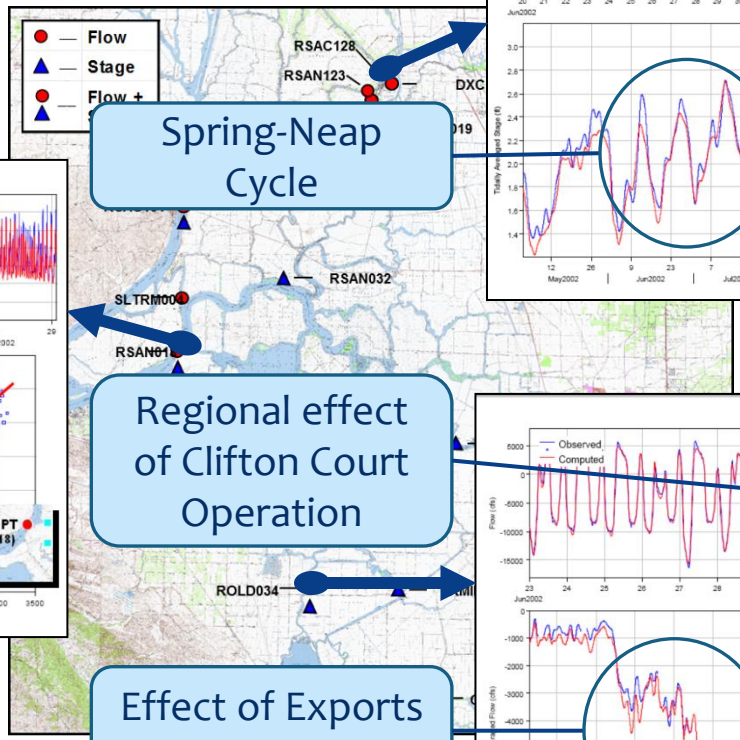
Example plots from RMA Model Calibration, Water Year 2002

Observed versus Computed…
What can you see in the wiggly lines?

Stage

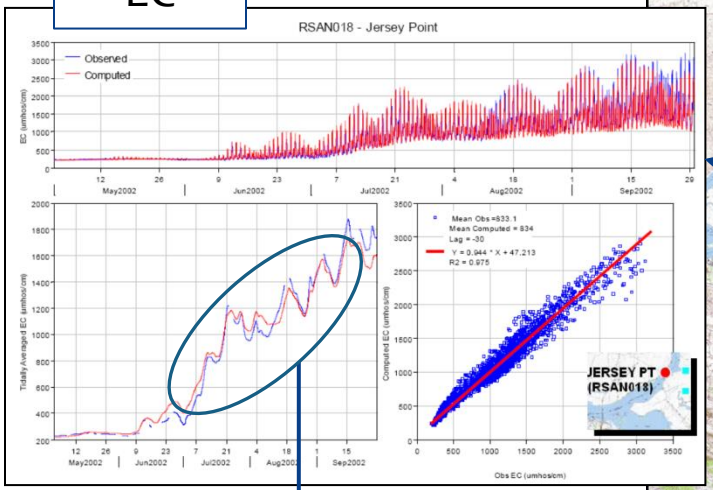
Tide Phase and Amplitude





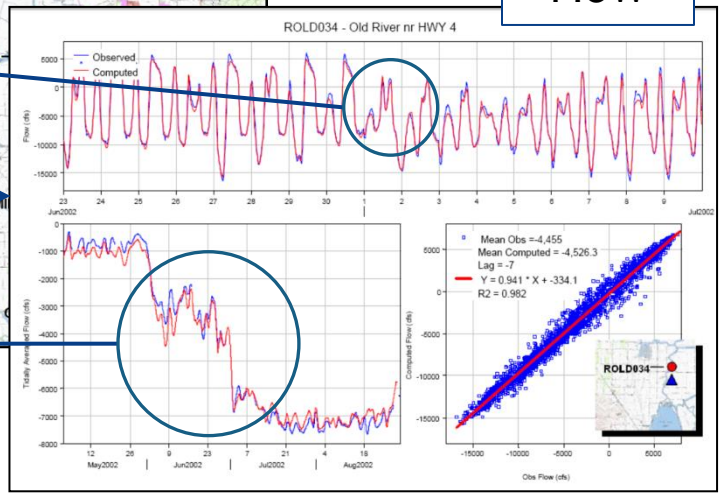
Spring-Neap Cycle

EC



Regional effect of Clifton Court Operation

Flow



Effect of Exports on net Flow

Rate of salt intrusion

Example plots from RMA Model Calibration, Water Year 2002

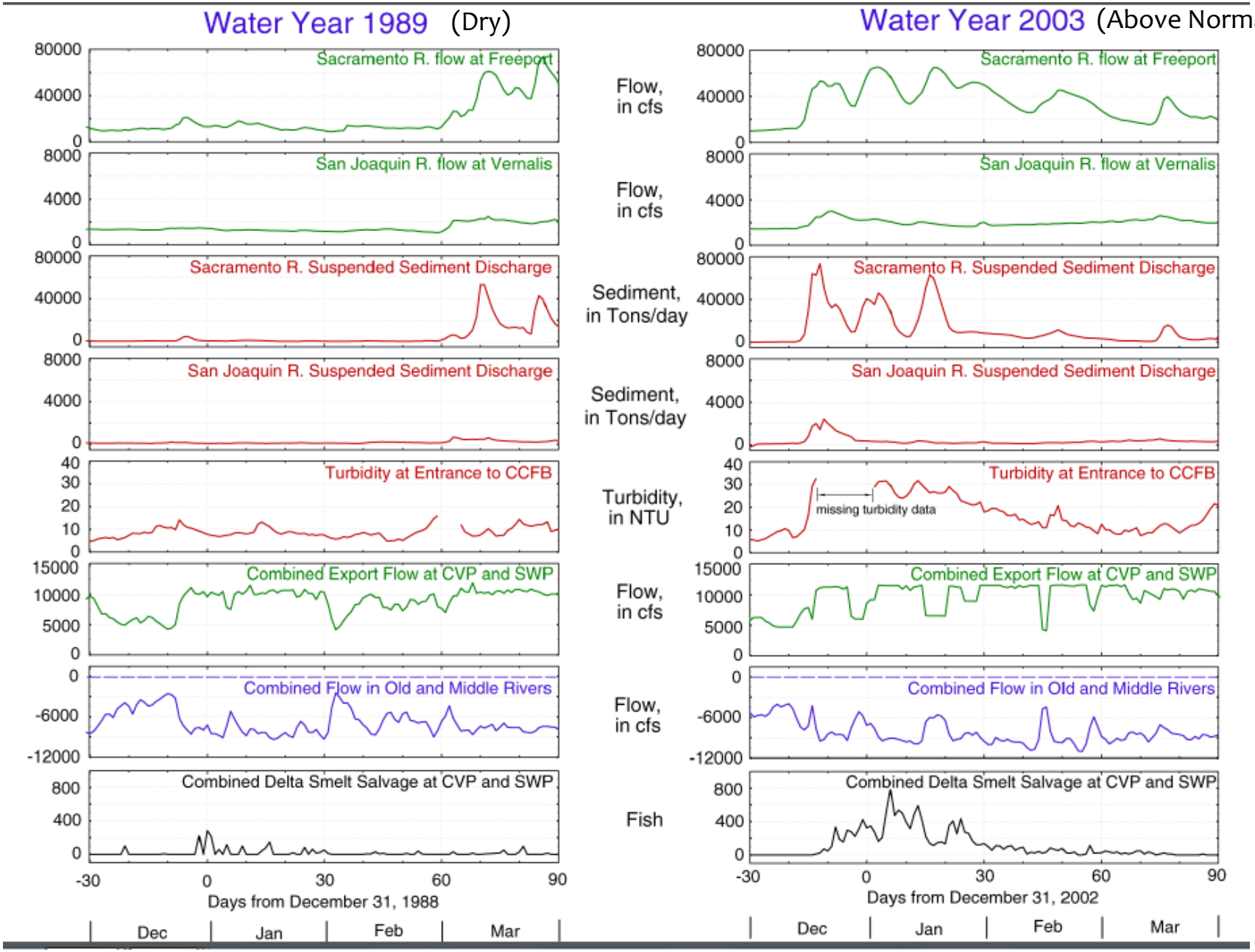
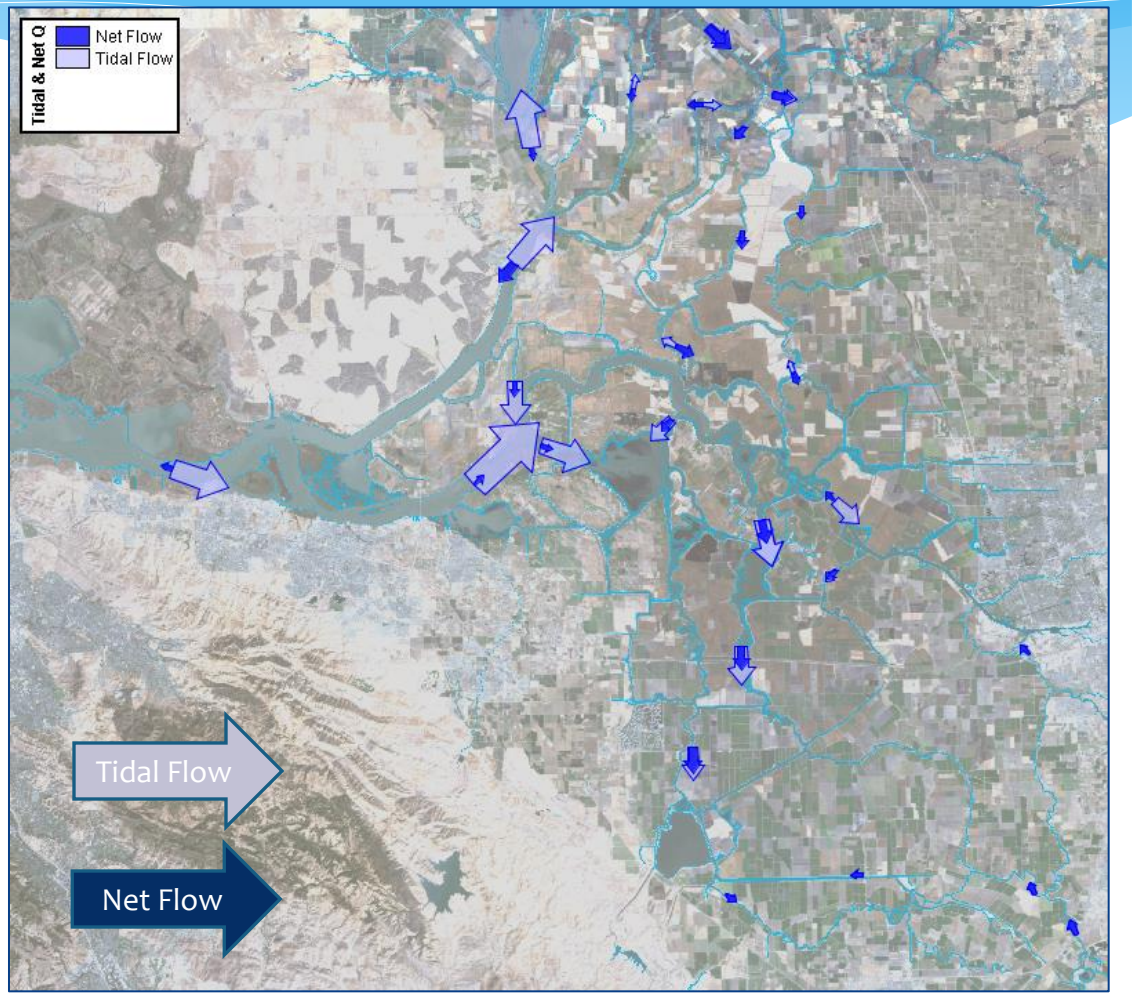


Figure Credit: Peter E. Smith, USGS, ret., Effects of Turbidity and Hydrodynamics on Distributions of Delta Smelt, 2012 CWEMF Annual Meeting

Tidal and Net Flow

Demonstration of increasing river inflows to bring the net Delta outflow from 2,000 to 100,000 cfs with typical summer exports (not an historic condition)

- Tidal flows dominate the Western Delta
- Net transport of fresh water from north to south typical of summer and fall operation
- As Sacramento Inflow increases, more of the North Delta becomes riverine
- As San Joaquin flow increases the net flows change from south to north in the southern Delta

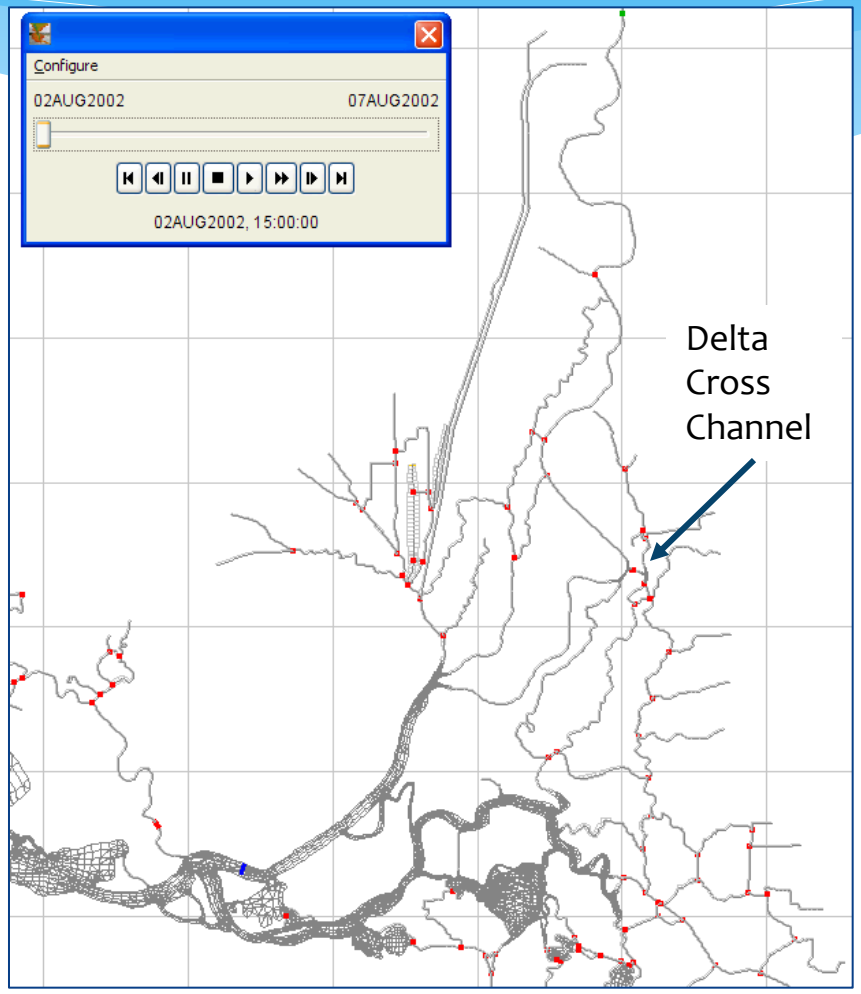


Animation created by Resource Management Associates, using RMA Model results

River and Estuary

Particles released hourly near Sacramento during a low flow period with the Delta Cross Channel open

- Riverine flow in the Sacramento River down to the Cross Channel
- Some particles pushed in to the Cross Channel and Georgiana Slough primarily on flood tide
- Once particles reach the Rio Vista on the Sacramento River and San Andreas on the San Joaquin River the motion is dominated by tidal flows



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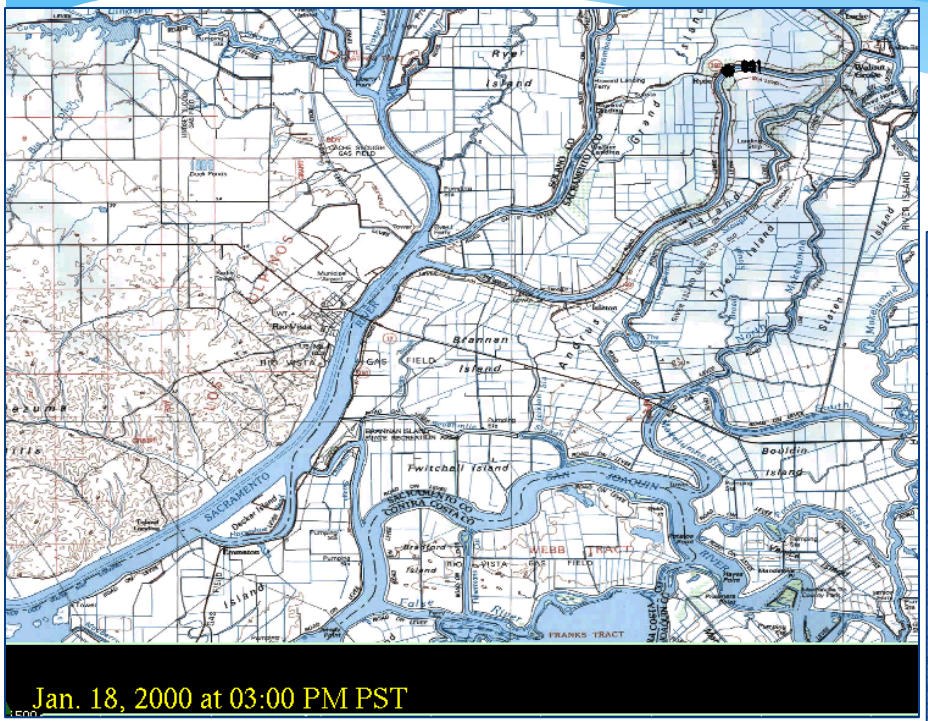
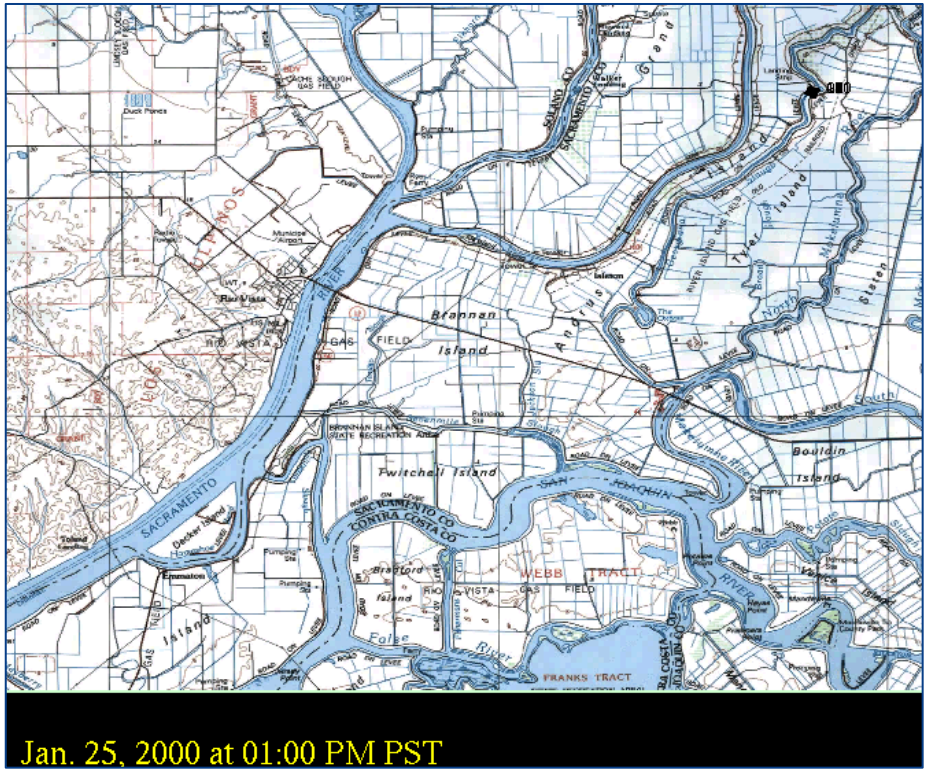
Out-migrant Salmon Tracks

Observations from radio-tagged salmon release



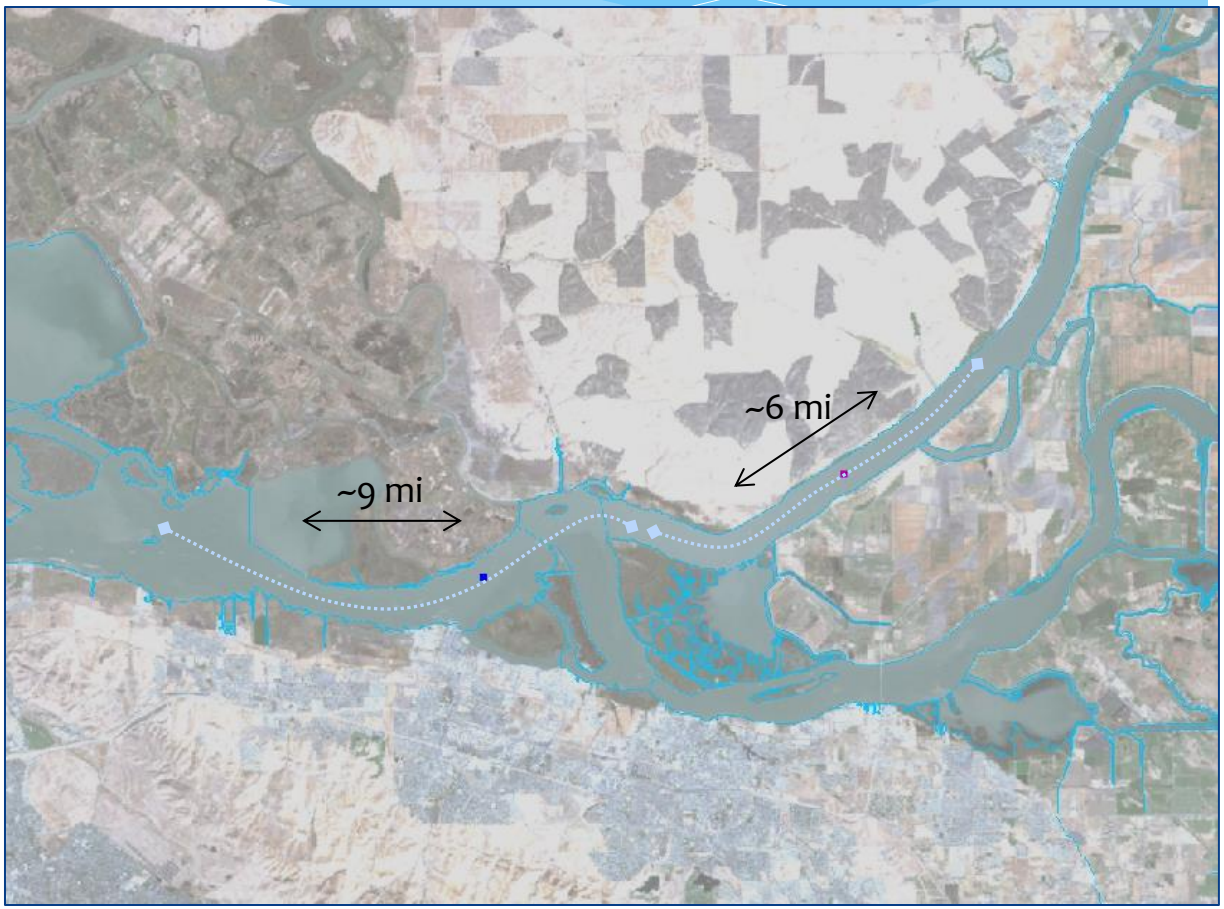


Animation created by Dave Vogel, Natural Resource Scientists, Inc., with John Donovan, USGS. Report Reference: Vogel, D.A. 2001. Juvenile Chinook salmon radio-telemetry study in the northern Sacramento - San Joaquin Delta, January - February 2000. Contract report for the U.S. Fish and Wildlife Service. Natural Resource Scientists, Inc. May 2001. 34 p. plus figures and appendices.

Excursion and Mixing

Groups of Particles released at two locations on the lower Sacramento River near the center of the channel

- Tidal Excursion is on the order of 6 to 9 miles(!) in this area of the Delta
- The water velocity varies vertically and laterally in a channel
- Turbulent mixing causes a group of particles released at one location experience slightly different velocities causing the group to spread over time

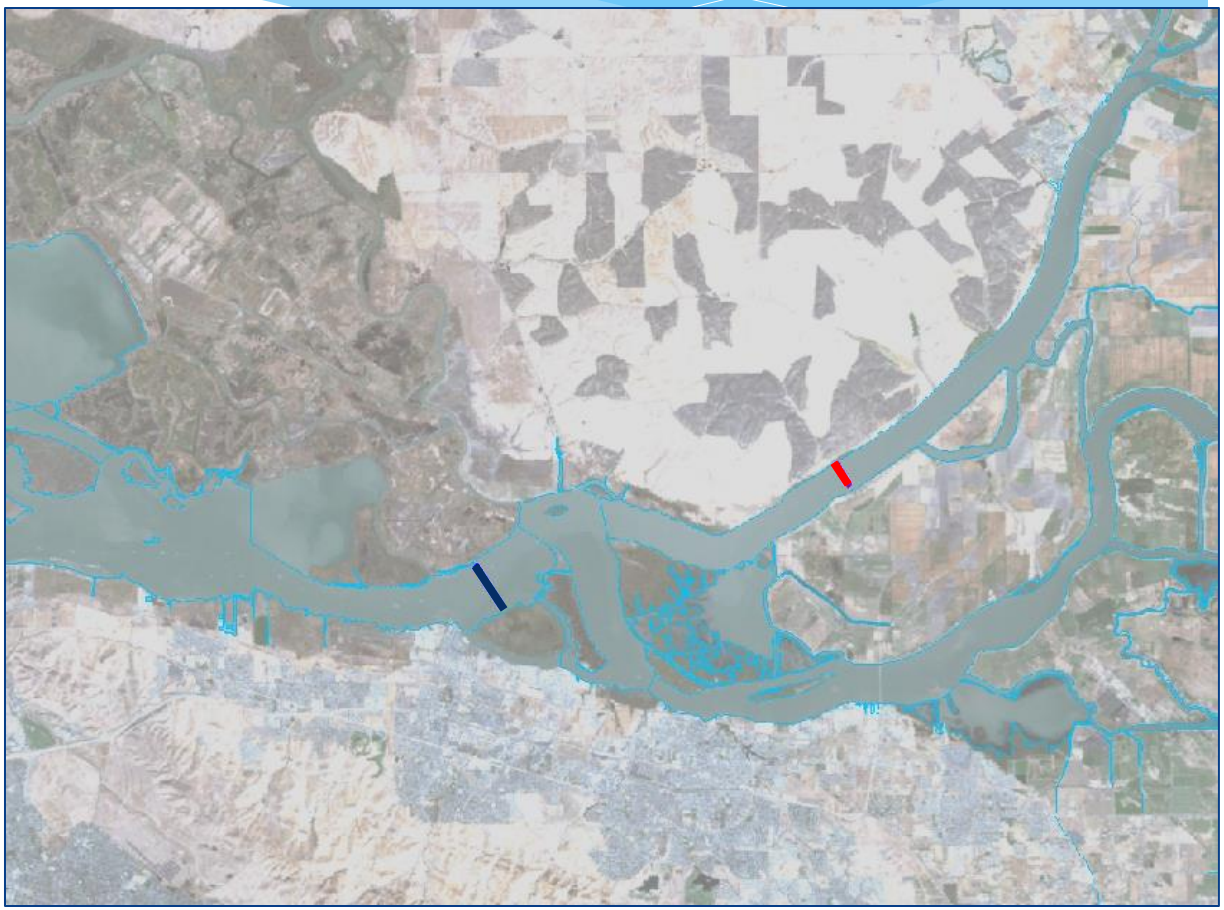


Animation created by Resource Management Associates, using RMA Model results

Excursion and Mixing

Particles released hourly at two cross sections of the lower Sacramento River and stopping after traveling for one tidal cycle

- The distribution of particles after traveling for one tidal cycle (~24.75 hours) illustrates the impact of tidal mixing, one of the key processes that brings ocean salinity into the Delta

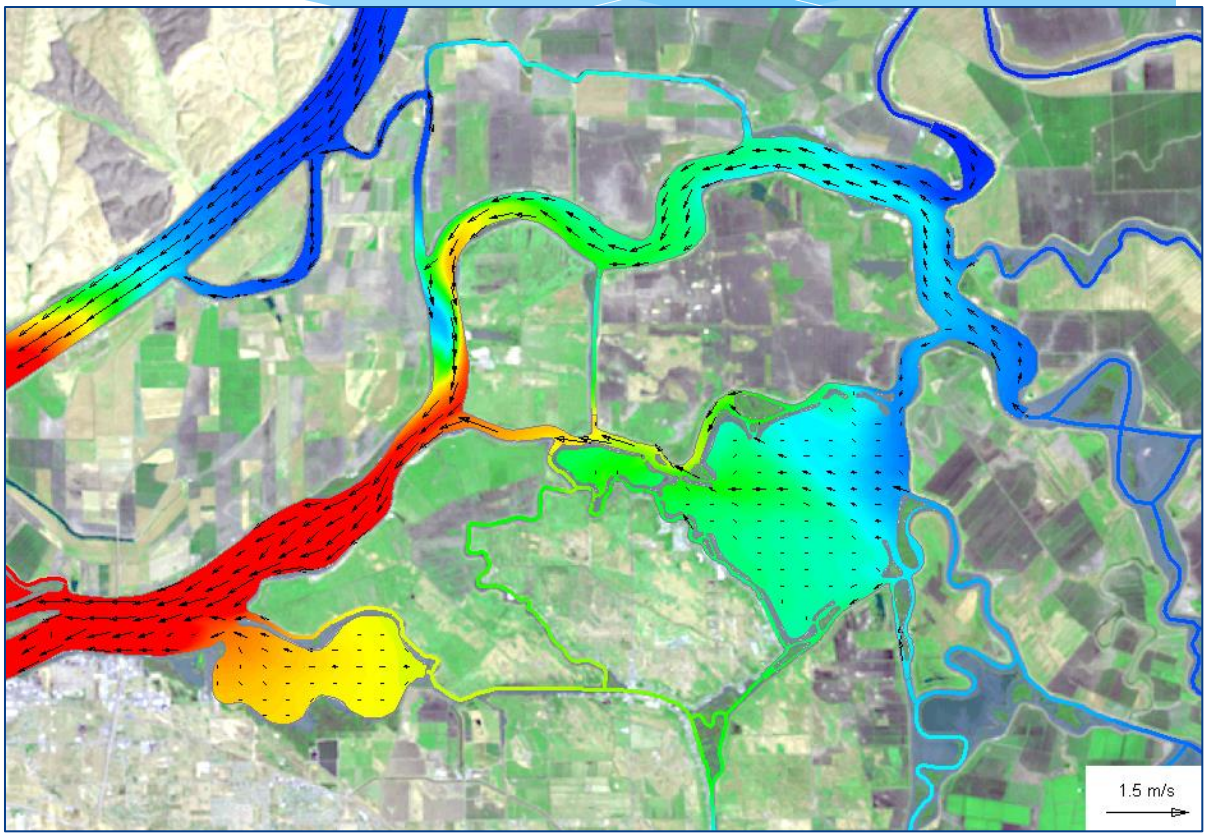


Animation created by Resource Management Associates, using RMA Model results

Salinity

Mixing in the Central Delta during a typical low flow period

- Fresh water moves from north to south drawn by the south Delta exports and in-Delta demand
- Sacramento River water moves through Threemile Slough to the San Joaquin on flood tide
- Tidal flows move higher salinity water from the lower San Joaquin to False River where it is drawn into Franks Tract

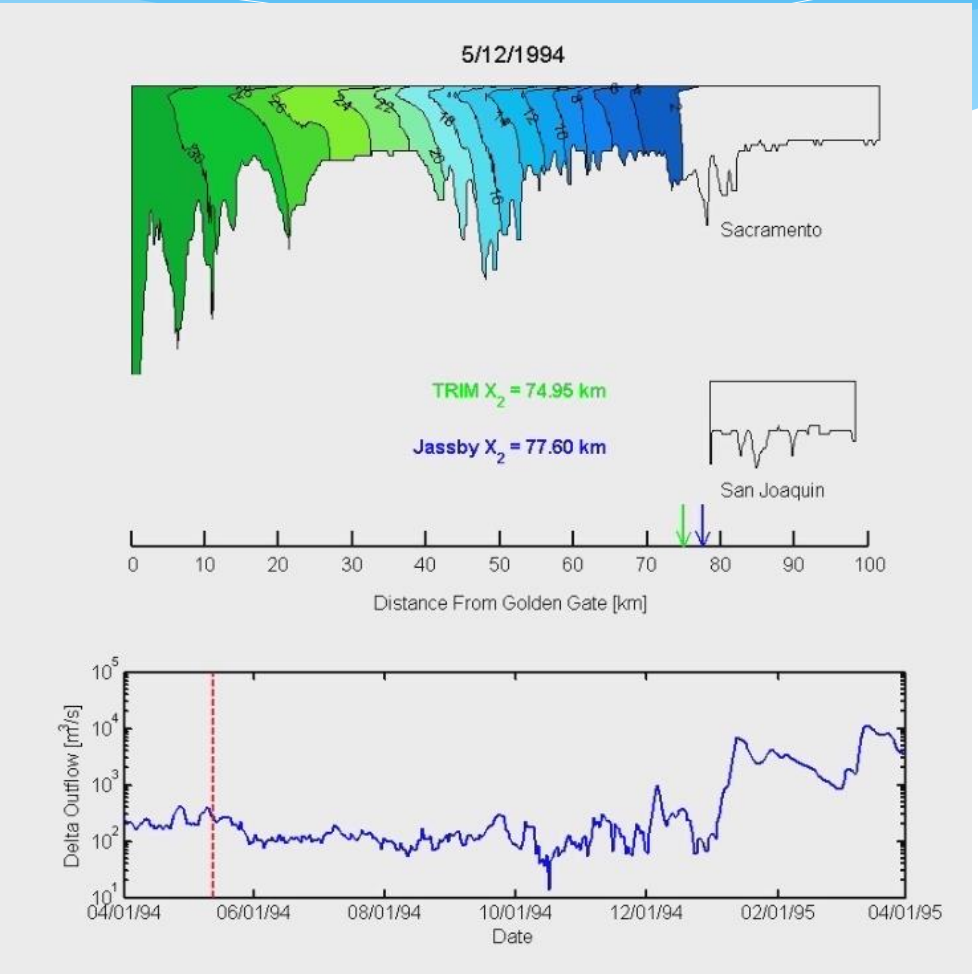


Animation created by Resource Management Associates, using RMA Model results

Gravitational Circulation

Tidally Averaged Salinity Profile

- Salt water is heavier than fresh water and will tend to push upstream under the fresh water outflow creating vertical stratification
- Energy from tides and riverine flow can overcome stratification
- The balance of net Delta outflow, tidal mixing, and gravitational circulation controls the intrusion of ocean salt into the Delta

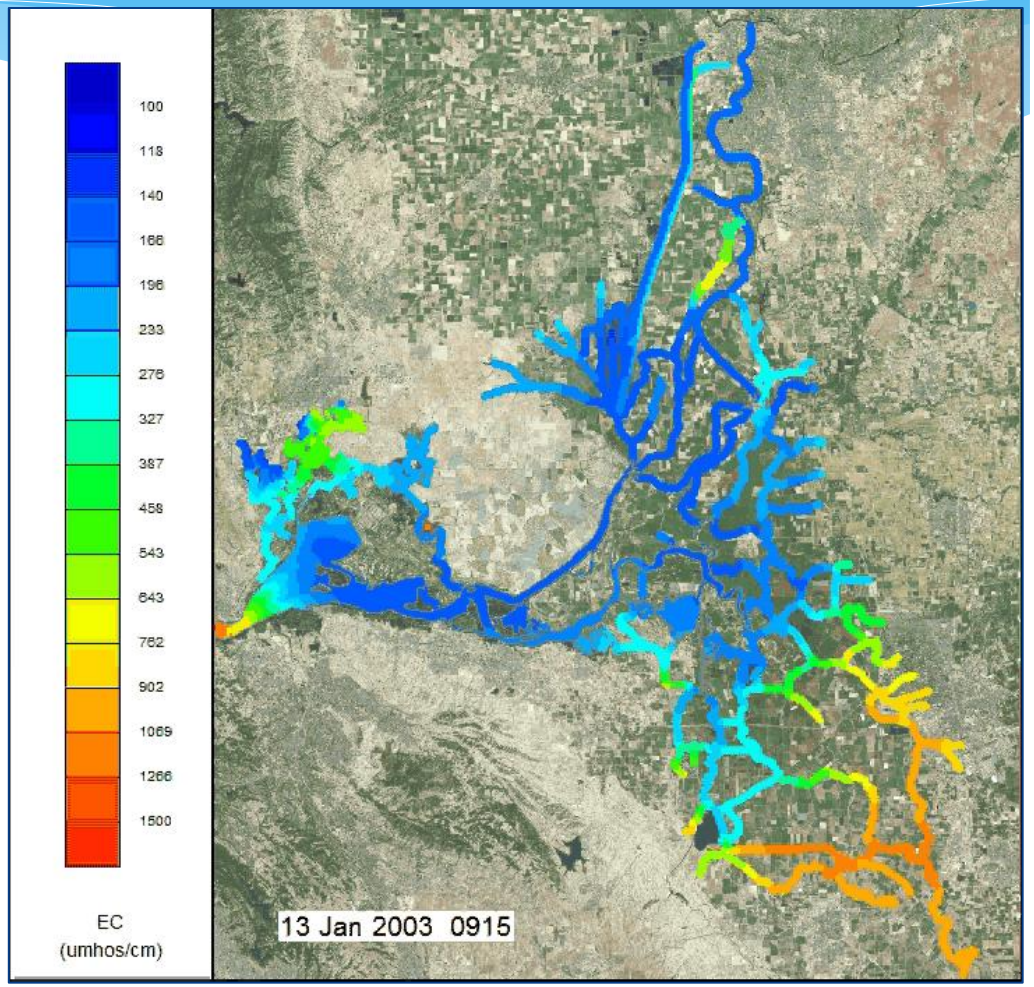


Animation created by Edward Gross using TRIM3D results

Salinity

Tidally averaged Delta salinity distribution (as Electrical Conductivity) , 2002 Historic Conditions

- Sacramento River water drawn into the south Delta by exports
- San Joaquin River inflow typically higher in salt than other tributary inflows
- Salt from the ocean boundary moves slowly eastward over the summer and fall period

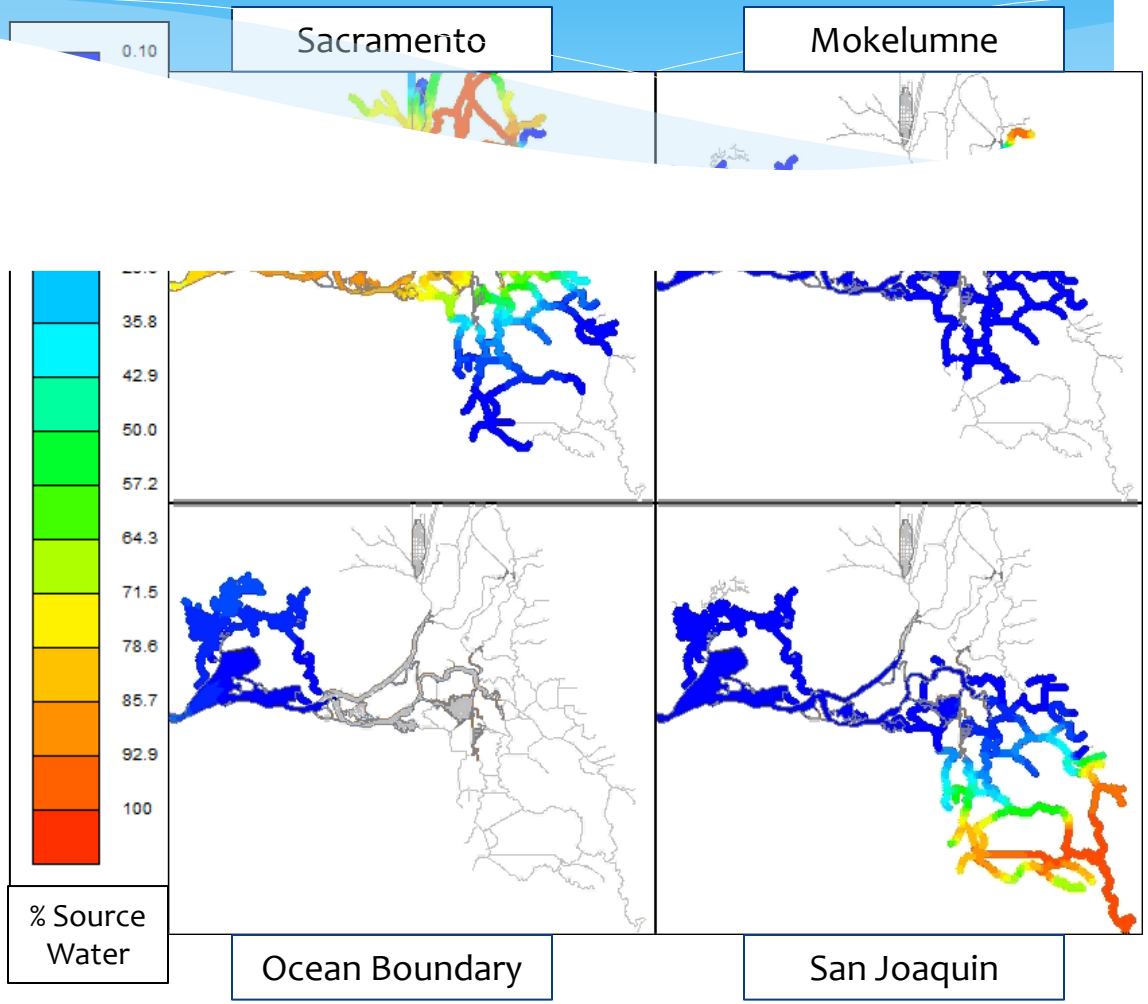


Animation created by Resource Management Associates, using RMA Model results

Source Water Fingerprinting

Illustration of the impact of south Delta Exports on the distribution of source water (not an historic condition)

- River inflow held constant while south Delta exports increased from 0 to maximum pumping (lowest net Delta outflow ~3000 cfs)
- With increasing exports
  - Most of San Joaquin and Mokelumne flows taken in by exports
  - Sacramento Water drawn downs Old and Middle River
  - Seawater drawn farther into western Delta

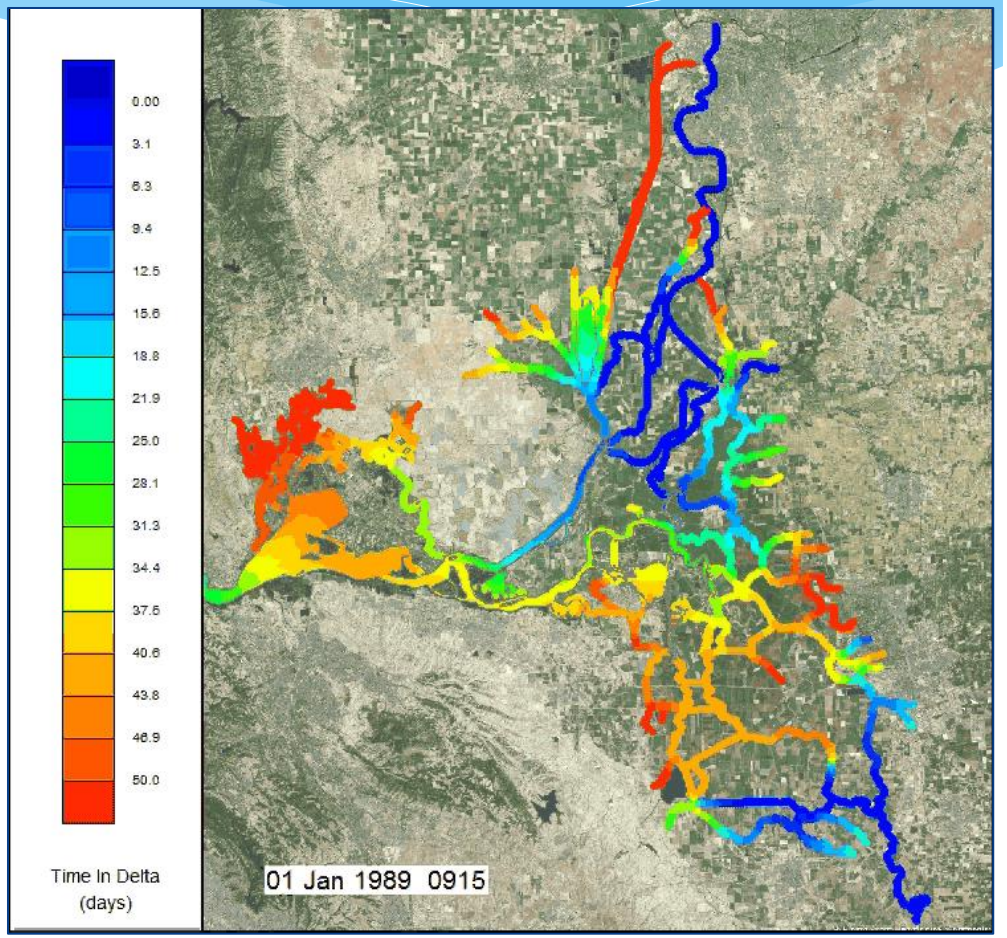


Animation created by Resource Management Associates, using RMA Model results

Exposure

Amount of time water has been in the Delta (between River inflow locations and Martinez), Historic 2003 conditions

- Exposure time is lowest in the riverine areas of the Delta
- The longest exposure times occur in dead end sloughs
- Exposure time in western Delta is low during periods of high net Delta outflow and increases significantly through the summer and fall
- Exposure time in the south Delta is mitigated by south Delta exports

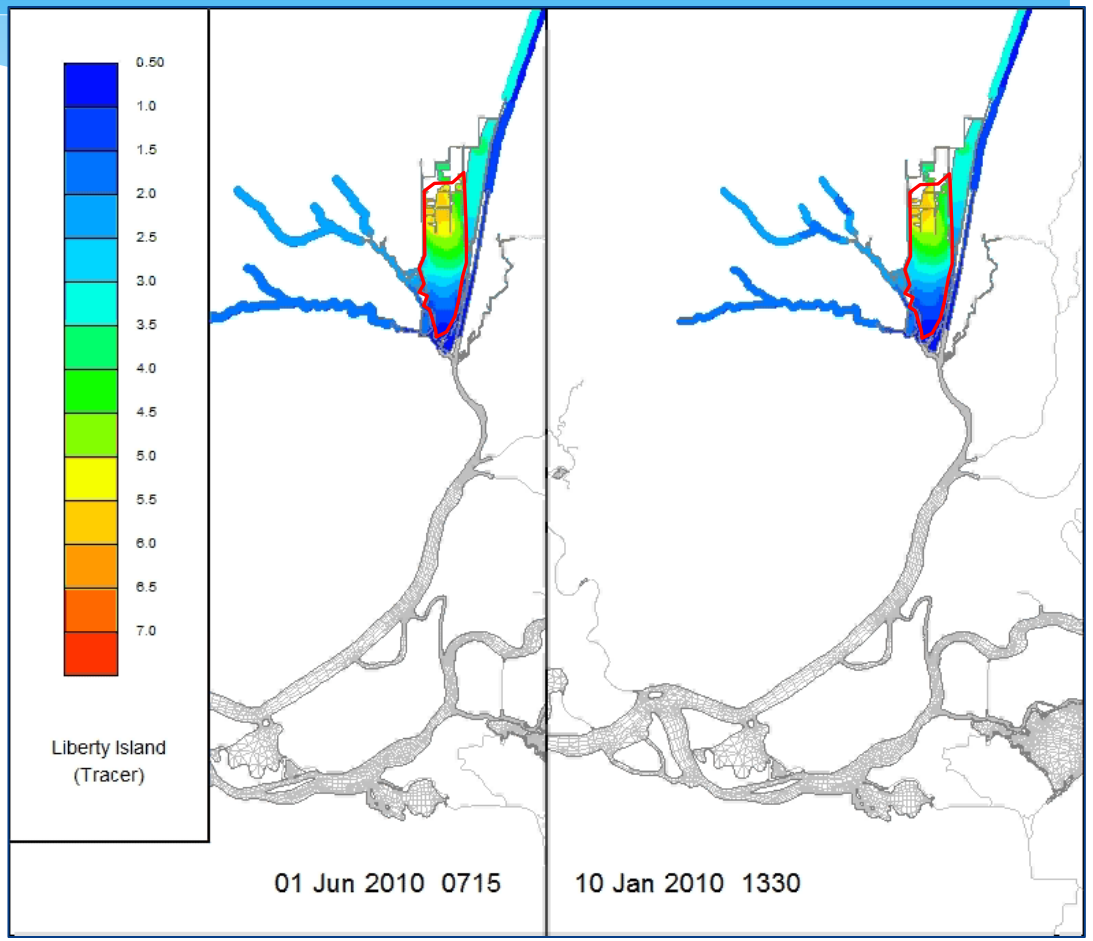


Animation created by Resource Management Associates, using RMA Model results

Exposure Time and Influence

Liberty Island

- Tracer loading in Liberty Island increases concentration by 1 unit per day, which can be interpreted as the exposure time to Liberty Island
- Outside of Liberty Island, the tracer indicates the region influenced by processes occurring in Liberty Island
- This approach is just one of many analysis techniques related to residence time and influence of discrete regions of the Delta



No Flow in Yolo Bypass

Low Flow in Yolo Bypass

Questions?

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