Modeling is for developing Insights

Invited Panel Presentation

State Water Resources Control Board Workshop 3:

Analytical Tools for Evaluating the Water Supply, Hydrodynamic, and Hydropower Effects of the Bay-Delta Plan Questions

November 2012

Panelists

Jon Burau (USGS)
John DeGeorge (RMA)
John Durand (UC Davis)
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Jay Lund (UC Davis)
Pete Smith (USGS – ret.)
William Smith (MWH)
Mark Stacy (UCB)
Staff - Chris Enright (DSC)

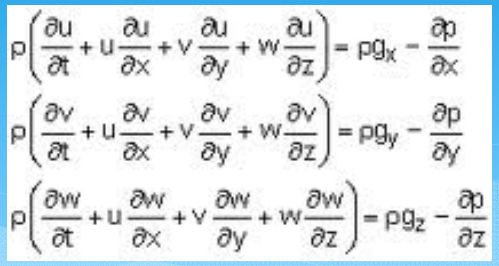
$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0, \quad \text{----- Continuity Equation (1)}$$

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla)\mathbf{u} = -\frac{1}{\rho}\nabla p + \mathbf{F} + \frac{\mu}{\rho}\nabla^2 \mathbf{u}, \quad \text{----- Equations of Motion (2)}$$

$$\rho\left(\frac{\partial \varepsilon}{\partial t} + \mathbf{u} \cdot \nabla \varepsilon\right) - \nabla \cdot (K_H \nabla T) + p\nabla \cdot \mathbf{u} = 0. \quad \text{----- Conservation of Energy (3)}$$

$$\text{Minimize } f(\vec{X})$$
$$\text{S.T. } \vec{g}(\vec{X}) \leq \vec{b}$$

Overview



* Models and management
  * Modeling is for insights, not numbers
* How the Delta Works 1 – Basic Physics
* Getting better-established insights for the Board from modeling results
* How the Delta Works 2 –Management Examples
* Insights, estimates, and controversy
* Questions

How the Delta Works, Part One

(Movement and Connections)

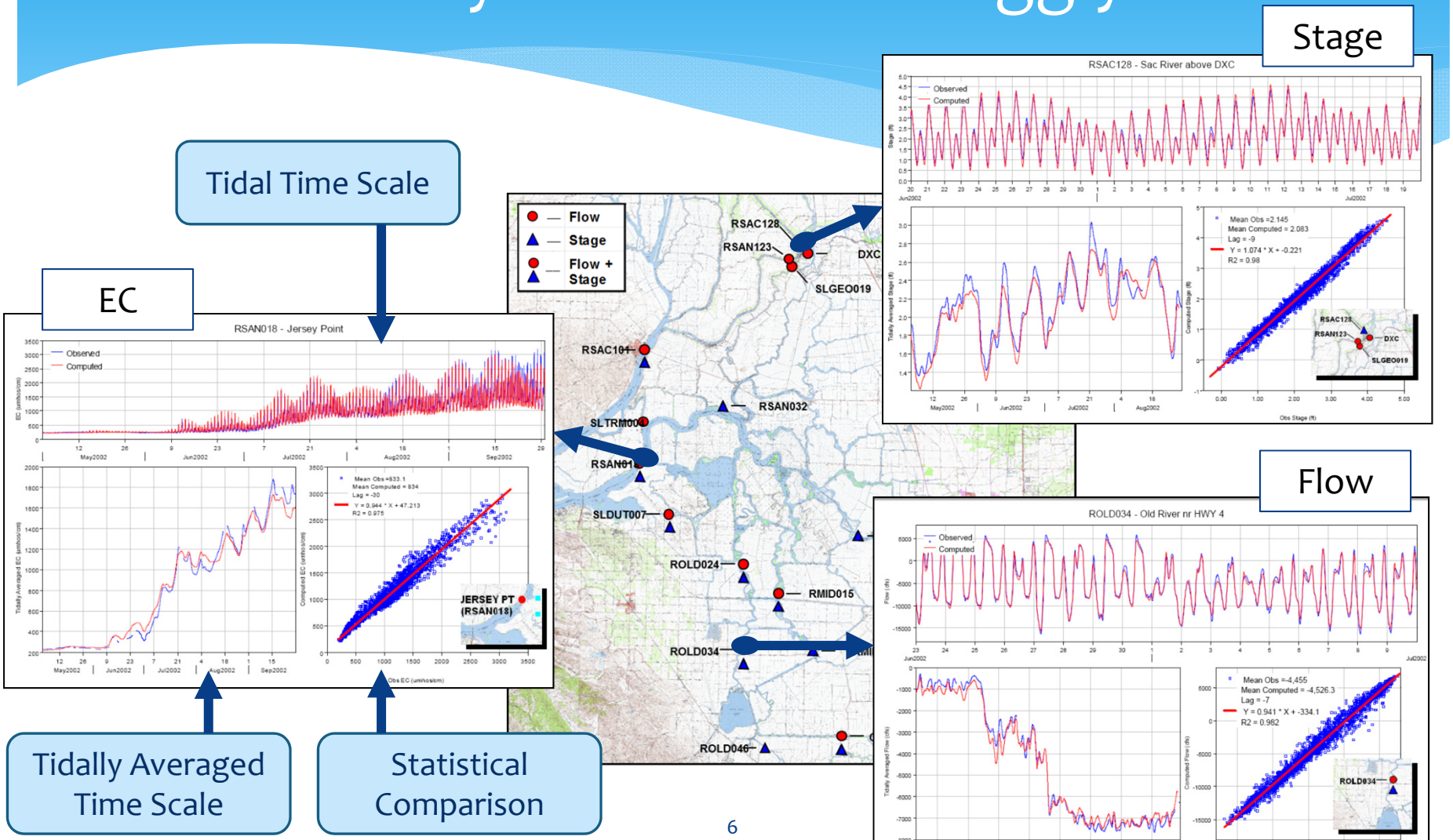
* The Delta is Rivers flowing into an Estuary
* Mixing and Movement drives much of water quality and ecosystem
* Primary Mechanisms
  * Net Flow
  * Tidal Mixing
  * Gravitational Circulation
* Animations from model results (and observed data) can illustrate these mechanisms

But first, why would you believe what a model shows you??

Key Aspects in Calibrating/Testing a Delta Model

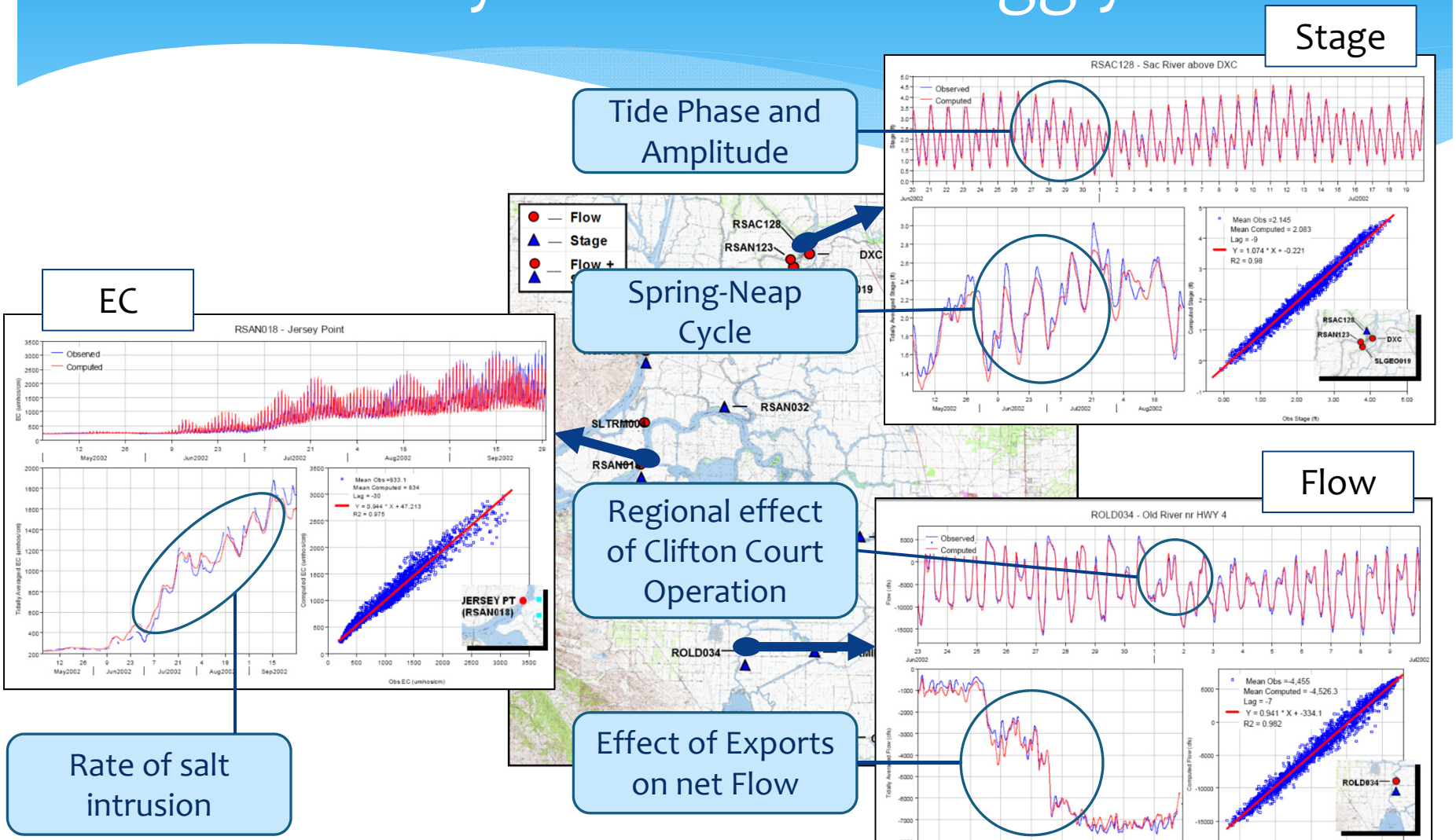
* Matching point observations on tidal and tidally averaged basis
  * Stage
  * Flow
  * Salinity (EC)
* Look for how well a model represents
  * Important net-flow splits (e.g., Sac. River to Delta Cross Channel)
  * Gate/barrier operations (e.g., Clifton Court Gates)
  * Delta Island Consumptive Use
  * 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?



Example plots from RMA Model Calibration, Water Year 2002

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

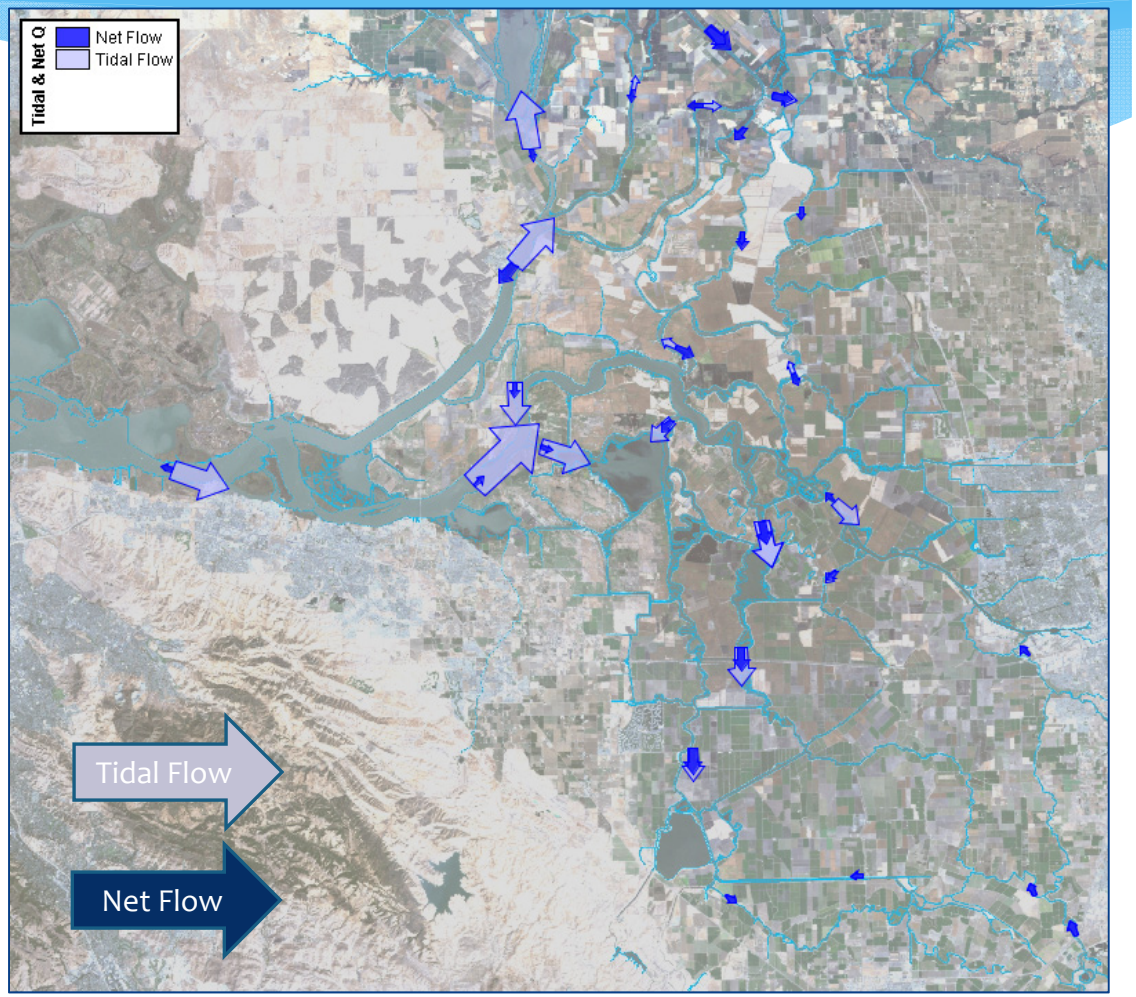


Example plots from RMA Model Calibration, Water Year 2002

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

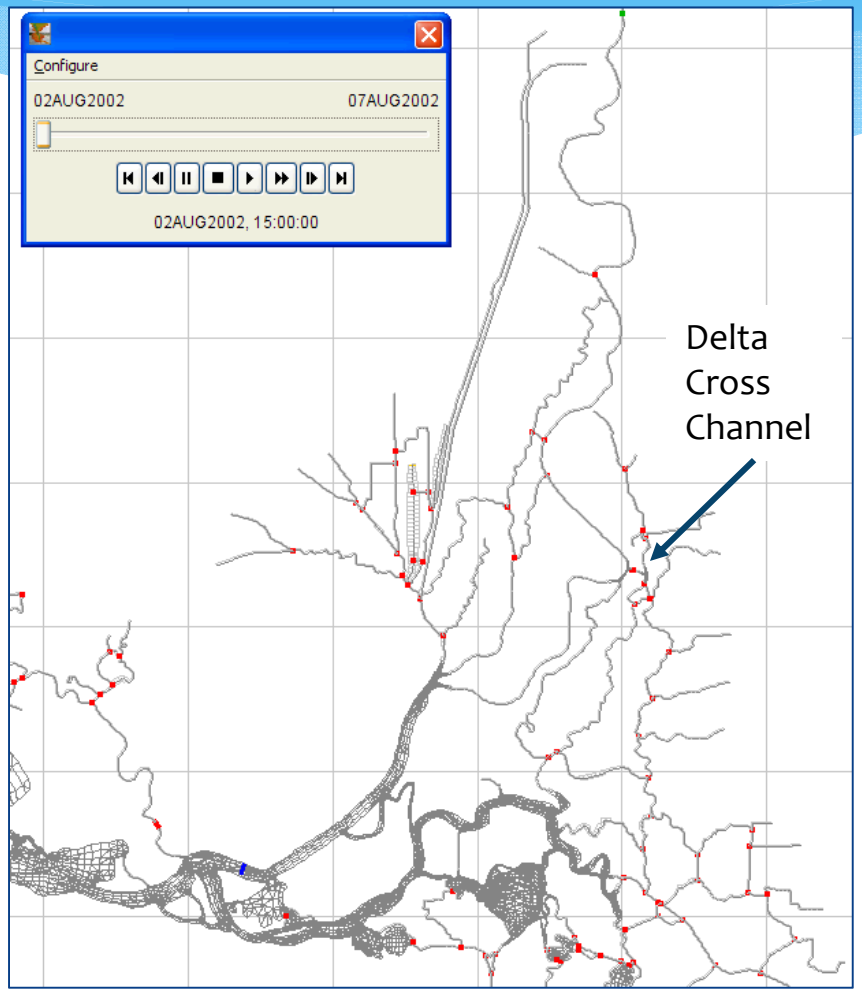


Animation created by Resource Management Associates, using RMA Model results

River and Estuary

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

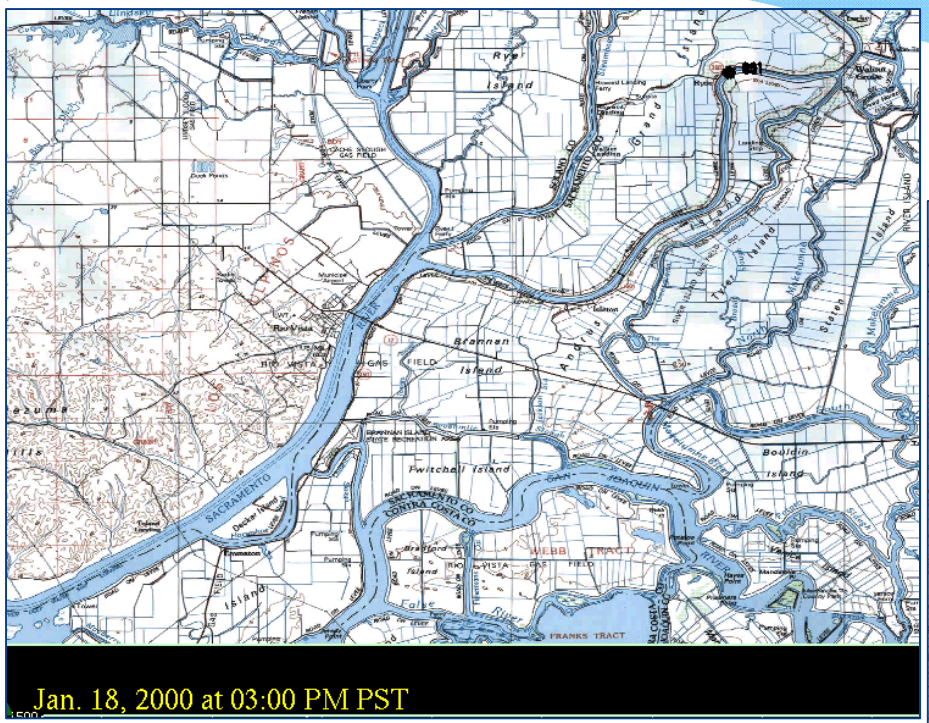
- Riverine flow in the Sacramento River down to the Cross Channel
- Some particles pushed in to the Cross Channel and Georgiana Slough primarily on flood tide
- Once particles reach the Rio Vista on the Sacramento River and San Andreas on the San Joaquin River the motion is dominated by tidal flows

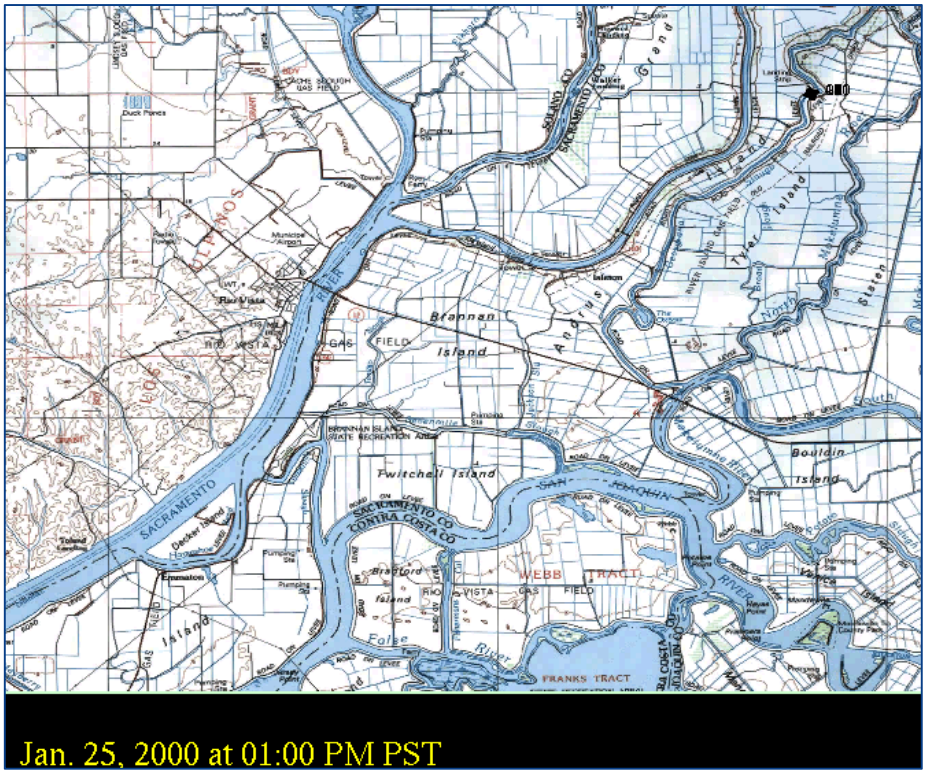


Animation created by Resource Management Associates, using RMA Model results

Out-migrant Salmon Tracks

Observations from acoustic tagged salmon release



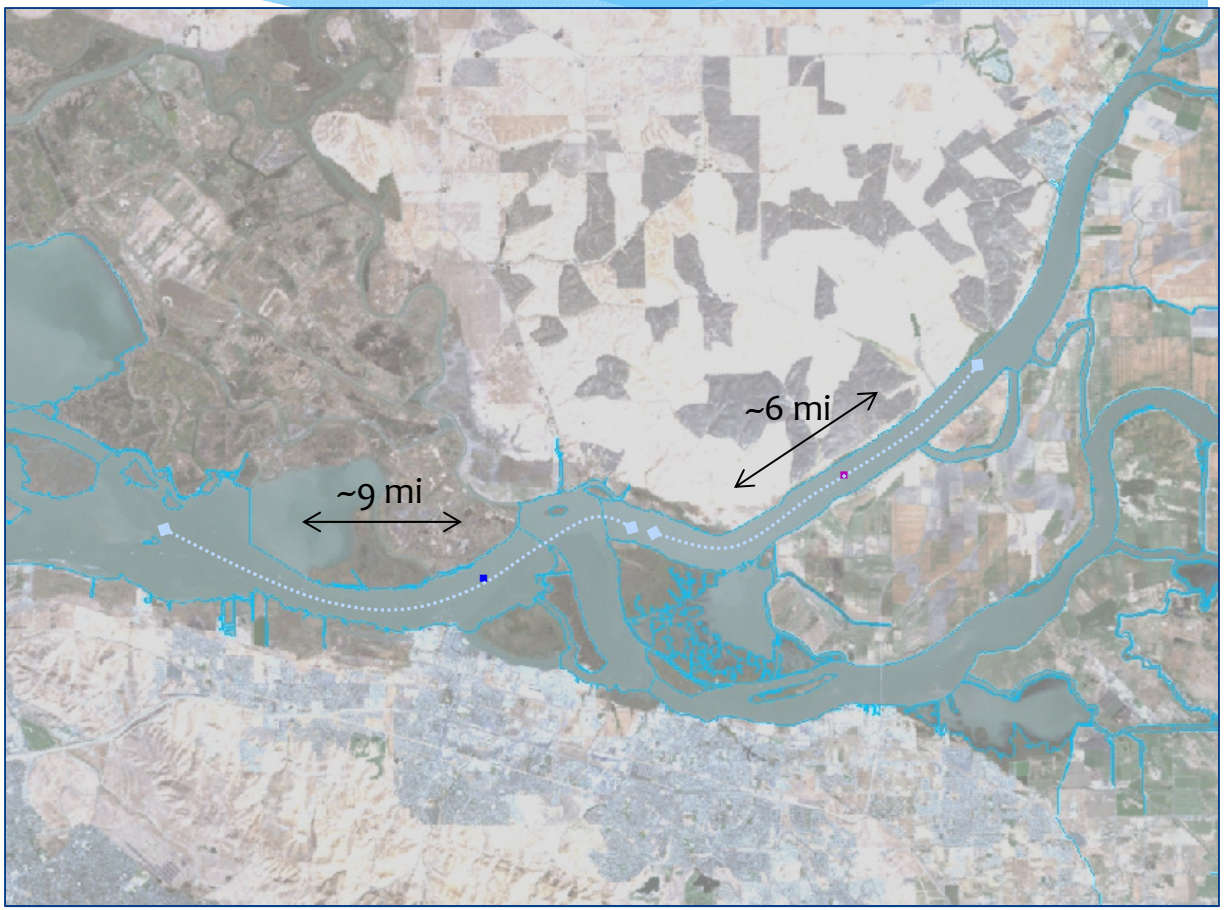


Animation created by Jon Burau, USGS, from acoustic monitoring data

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

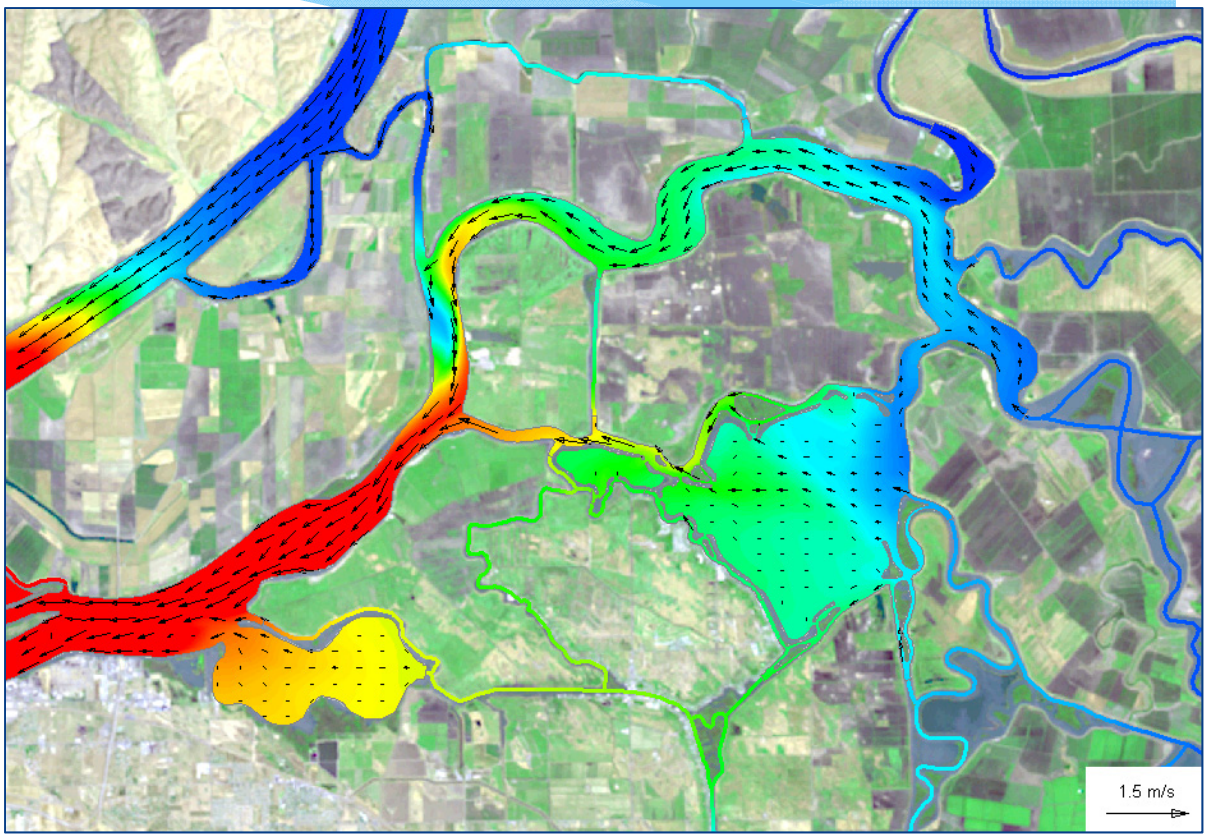
- The distribution of particles after traveling for one tidal cycle (~24.75 hours) illustrates the impact of tidal mixing, one of the key processes that brings ocean salinity into the Delta

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

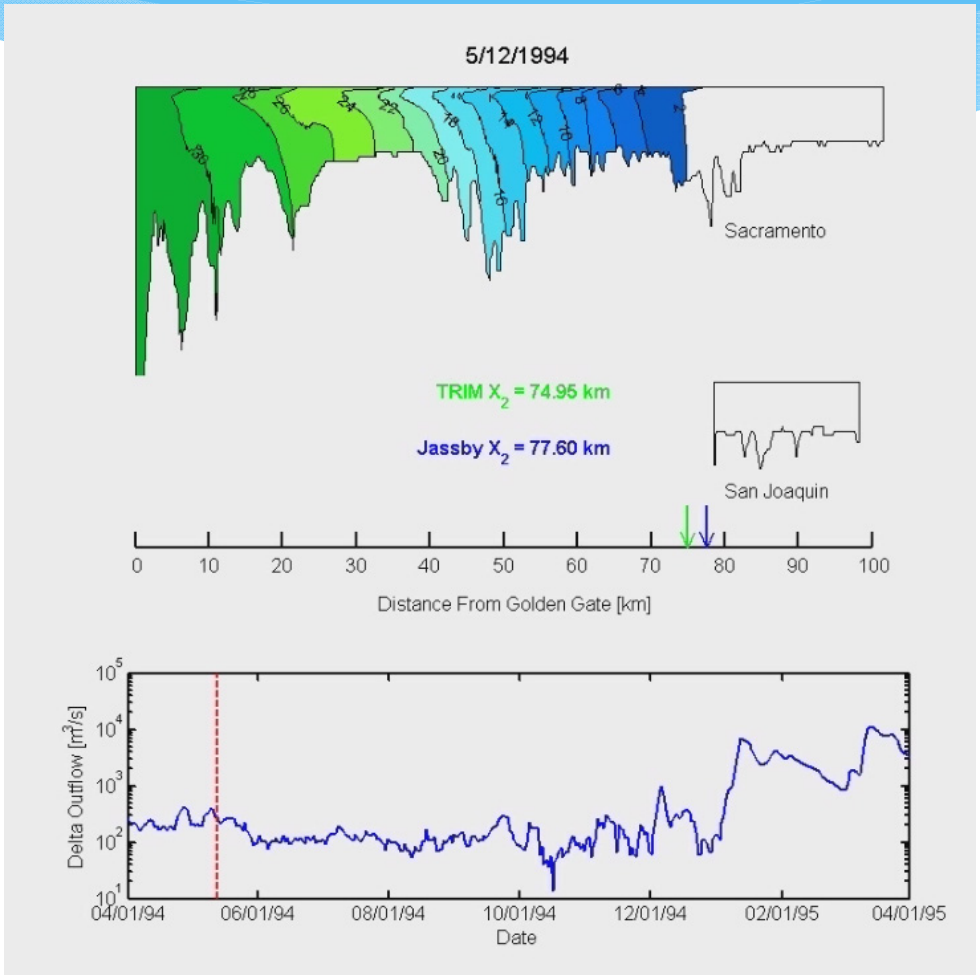


Animation created by Resource Management Associates, using RMA Model results

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

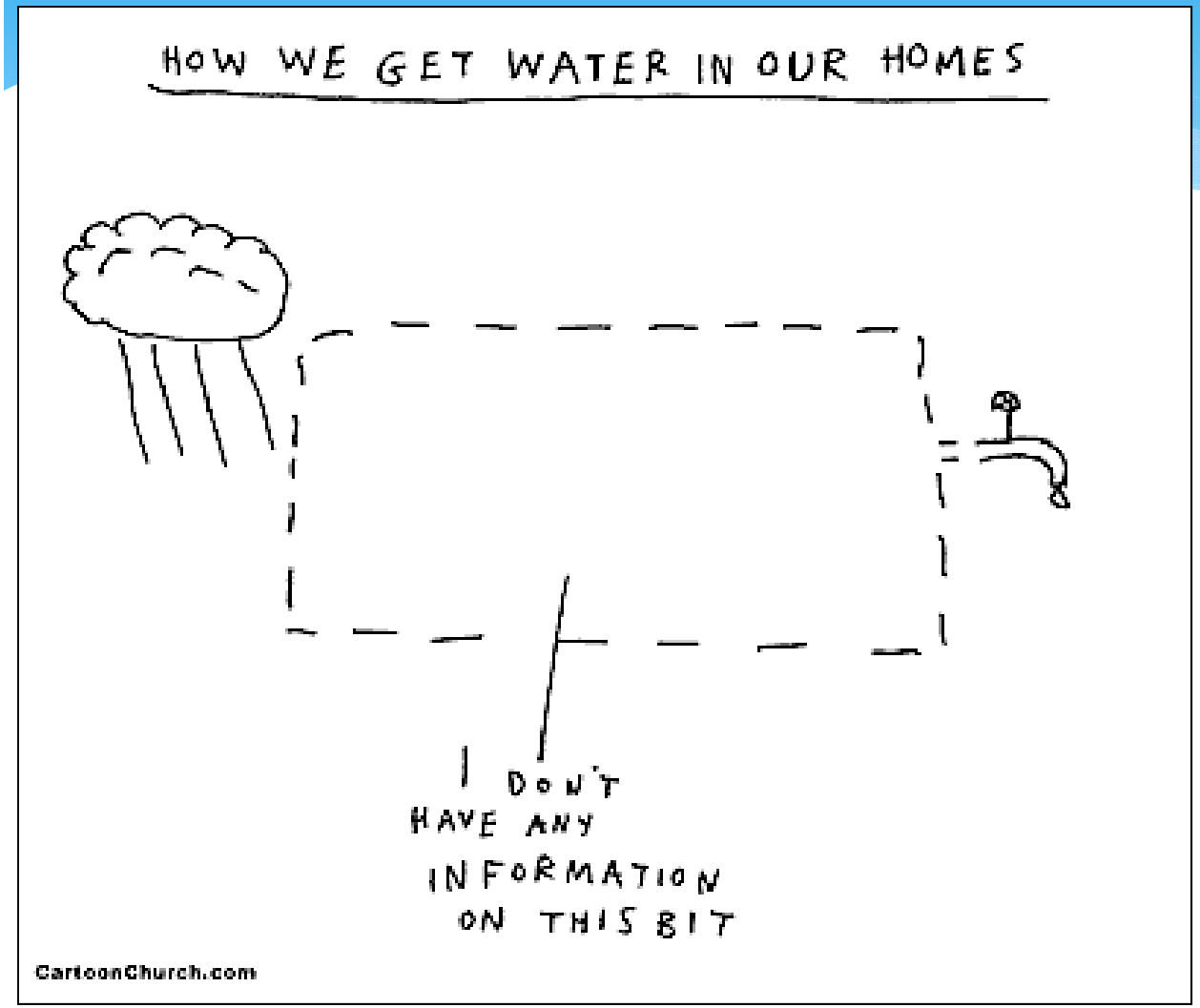
Managing Models for the Board

12 thoughts organized into:

* Framing comments on modeling
* Near-term recommendations
  * Managing models for Board deliberations
* Preparing for the Future

Report has some thoughts on specific models

Framing Comments on Modeling

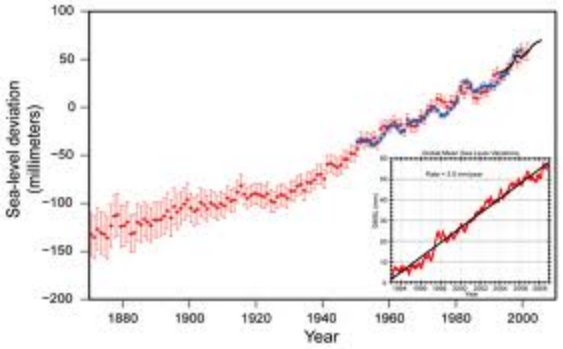


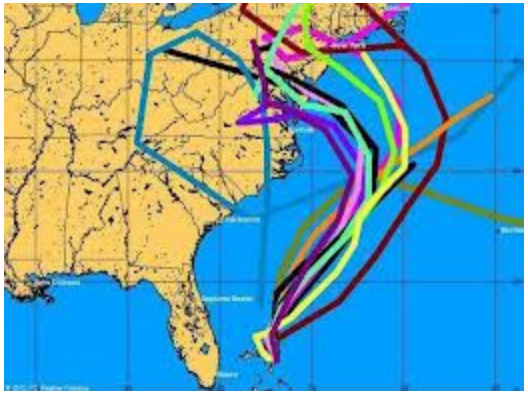
How do we explore a large, complex, controversial problem?

1. Models do not stand alone

"What is the best model?"

* Model, input data, modeler are all important
* Modeler is often the most important



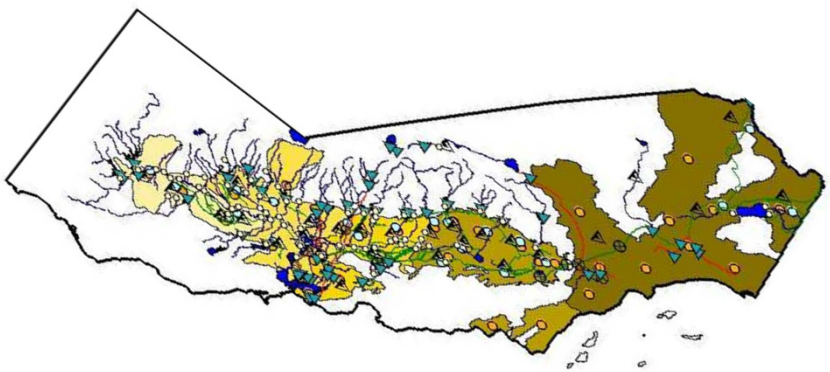


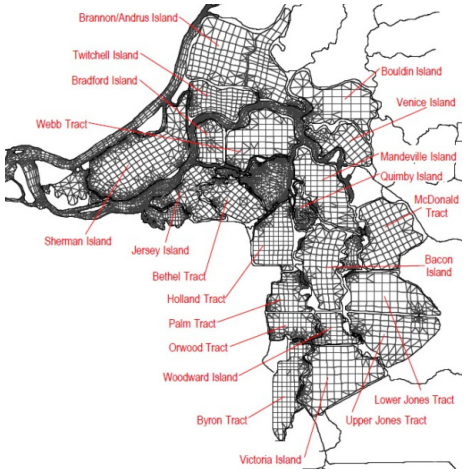
2. Different models for different problems

* There is no one best model
* Having a variety of models available helps explore and test insights and estimates

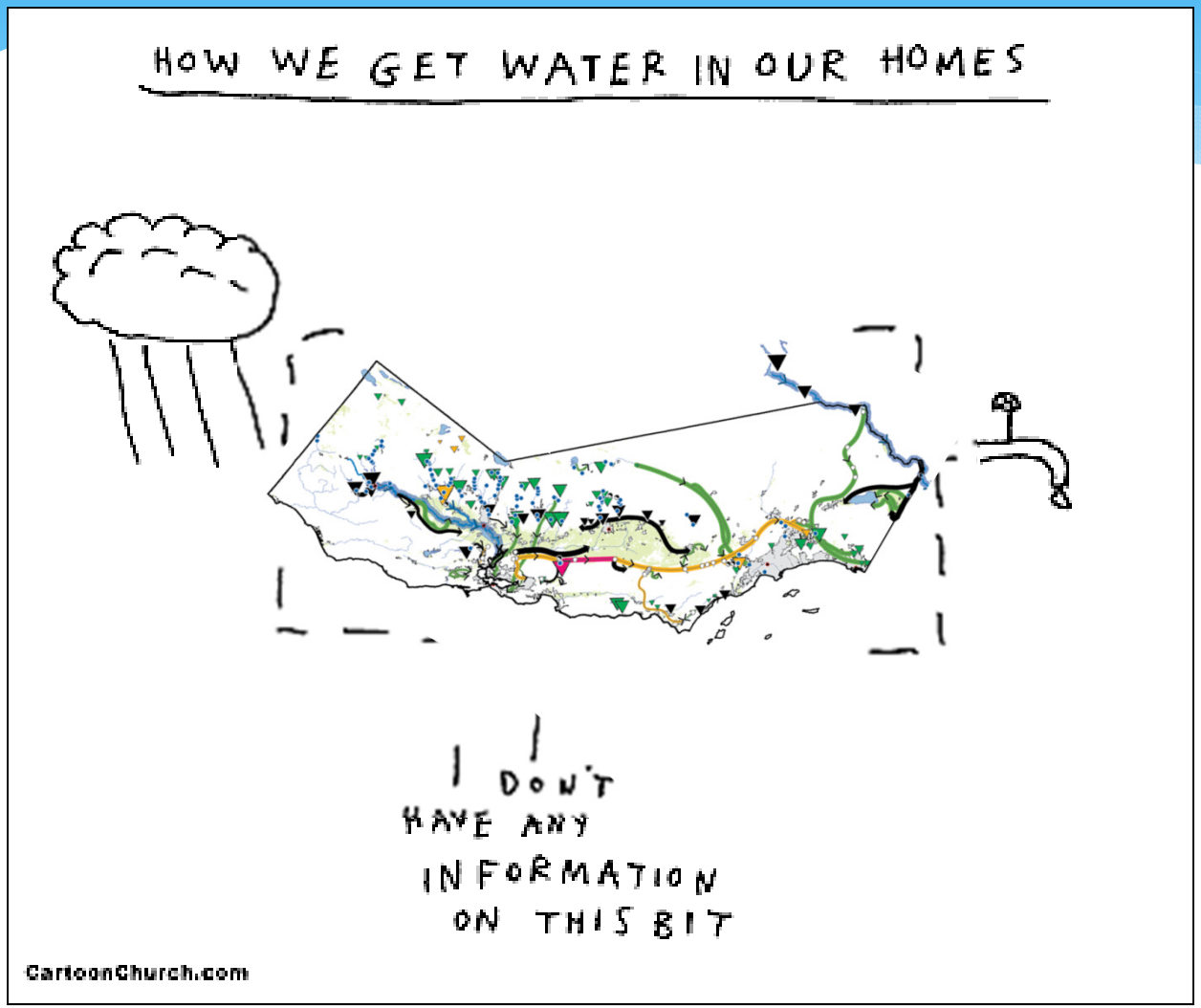
3. Models summarize understanding

* Models summarize and integrate understanding with greater precision and transparency
* Design of most complex systems rely on computer models – buildings, bridges, aircraft, …
* Models needed for adaptive management and planning





Near-Term Recommendations



Getting more useful insights from modeling efforts

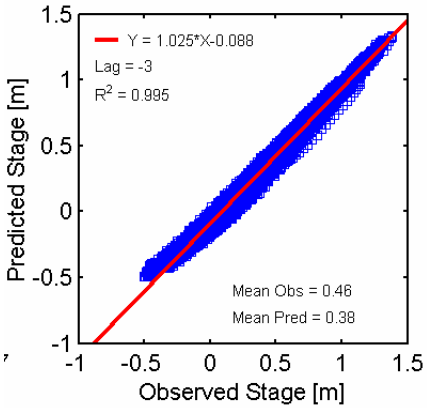
4. Show How the Delta Works

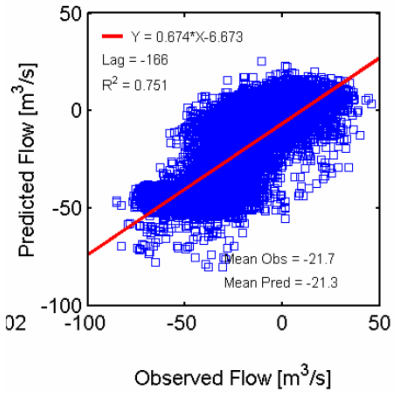
* Many policy discussions are not based on a full understanding of physical processes in the Delta
* Developing a library of model visualizations on "How the Delta Works" might help improve:
  * Broader understanding of the Delta
  * Ability of policy discussants to benefit from model-based insights

5. Models must be documented and interpreted more critically

* Many available models can provide critical insights
* But models should be:
  * More thoroughly documented
  * More explicitly tested
  * More thoughtfully and critically interpreted

  in both model development and application





6. Each model application should include strengths, weaknesses, and limitations

* All model results are imperfect
* Modelers should best know model weaknesses and limitations and state them with their results
* Inadequate presentation of weaknesses and limitations reflects poorly on model and modeler reliability
* Boards and agencies should insist on more complete interpretations of results, including weaknesses
* We suggest tests for Delta hydrodynamic models

7. What are we looking for? - Need clear statements of desired states

* Modeling is a search for insights
* What are the Board's desired states for the Delta?
* Clear statement of objectives improves:
  * Exploration and discussion of solutions
  * Estimation of implications and impacts
* Otherwise, presented model results may simply be searches for stakeholders' desired outcomes

8. Board can make better use of modeling

* Strategically:
  * Use a group of independent experts to advise on modeling issues
  * Employ independent experts to assess and summarize the body of presented modeling results
  * Encourage stakeholder groups to present consolidated, organized, and documented sets of modeling results, with syntheses for policy
* Independent technical assessments can raise overall quality of testimony and insights from results

9. The State needs a plan for Delta-related modeling

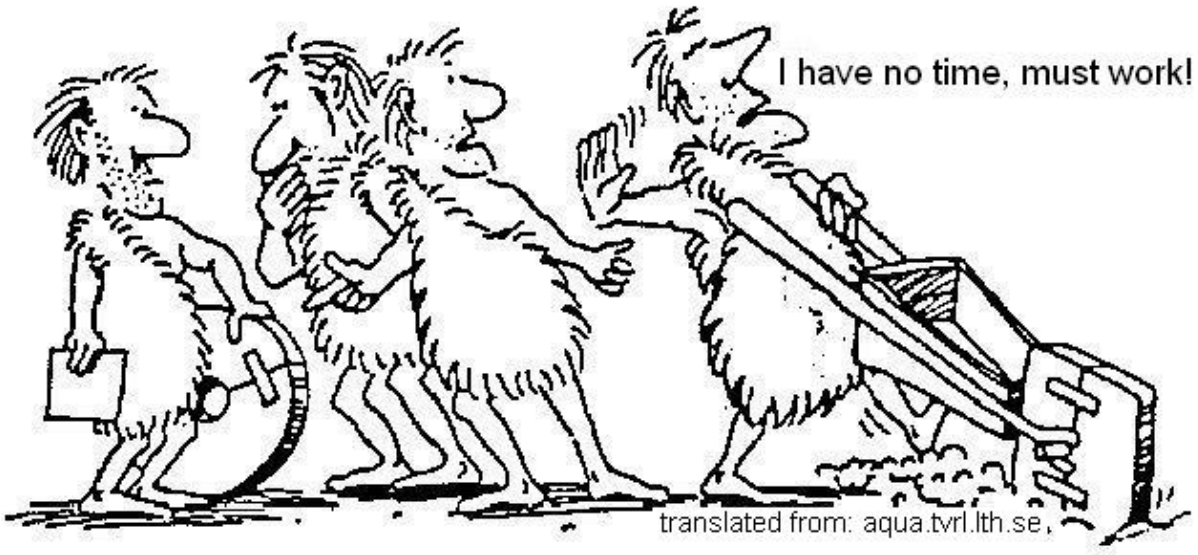
* Plan should include:
  * Plan for near-term modeling efforts and testing
  * Plan for long-term model and data development (5-15 years)
* Modeling needs exceed the capacity of any one agency, so approach should be "community-based"
* "Community-based" modeling should dampen combat science

9. The State needs a plan for Delta-related modeling (cont.)

* "Community-based" modeling involves:
  * More than one developer
  * Database of commonly used, QA/QC'd data
  * Set of generic tools for data development and presentation of model results
  * Other components, included in our documentation

Preparing for the Future (5-15 years)

* The Delta is a changing problem
* Useful models and data take time to develop



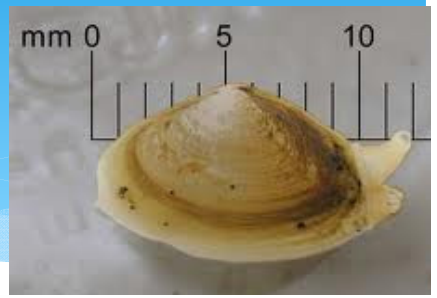
10. Integrate our understanding by integrating our models

* Integrated understanding requires an integration of modeling
* Better ability to:
  * Find insights and solutions which cross model boundaries
  * Evaluate implications of proposed solutions
  * Test models, modeling results, and insights
* This will require stronger state leadership

11. Model and data development are too important for any one agency

* Each agency has limited financial resources and expertise for modeling and data development
* Interests of individual agencies are often too narrow to develop broader insights and solutions
* Community based modeling efforts seem promising for overcoming these limitations
* State Board is in a good position to encourage cooperative data and model development efforts

12. Major changes will occur in parts of the Delta and Bay



* Preparation is needed
* Adapting to changes will be easier with forward-looking and adaptive analytical capabilities
* Adaptive management requires that analytical work looks ahead to future

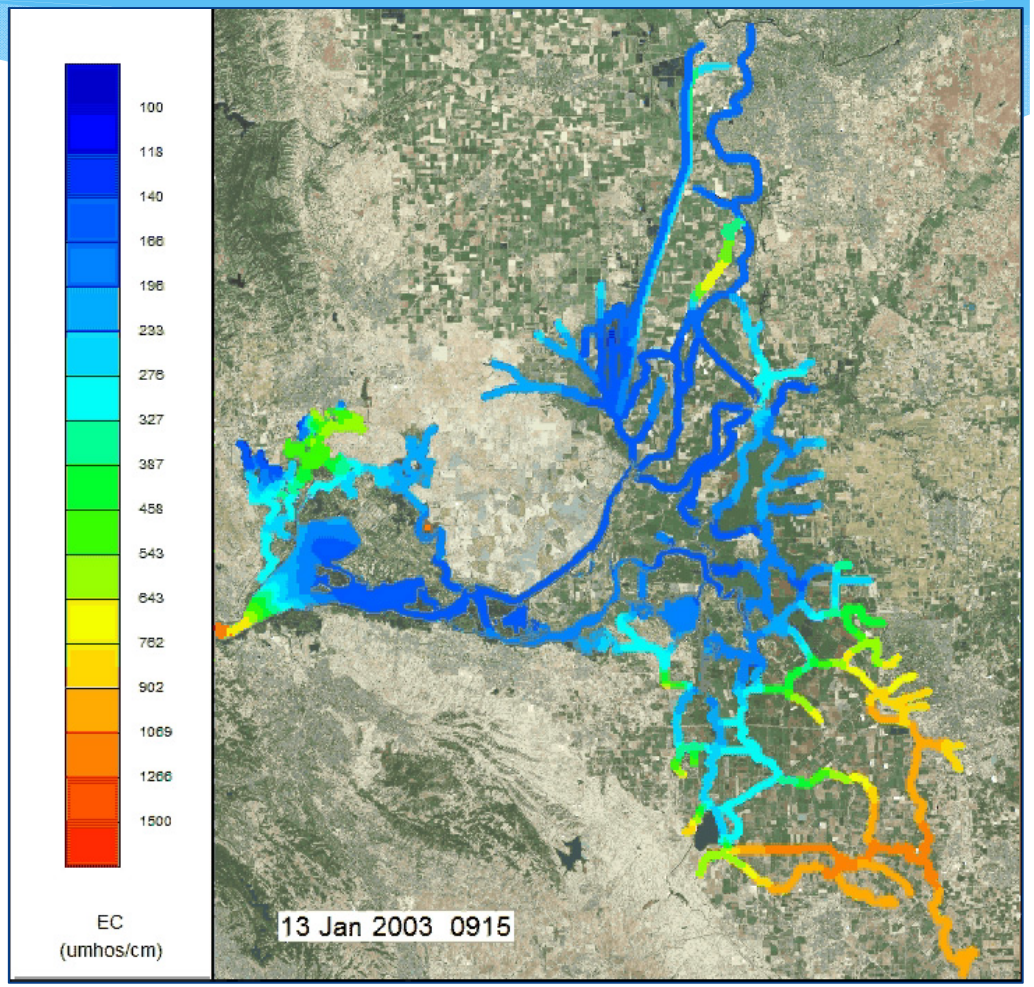
How the Delta Works, Part Two
(Some Management Issues)

* Managing Salt Accumulation over the Dry Season
* Water Exports Affect Water Source Distribution
* Some Residence Time 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

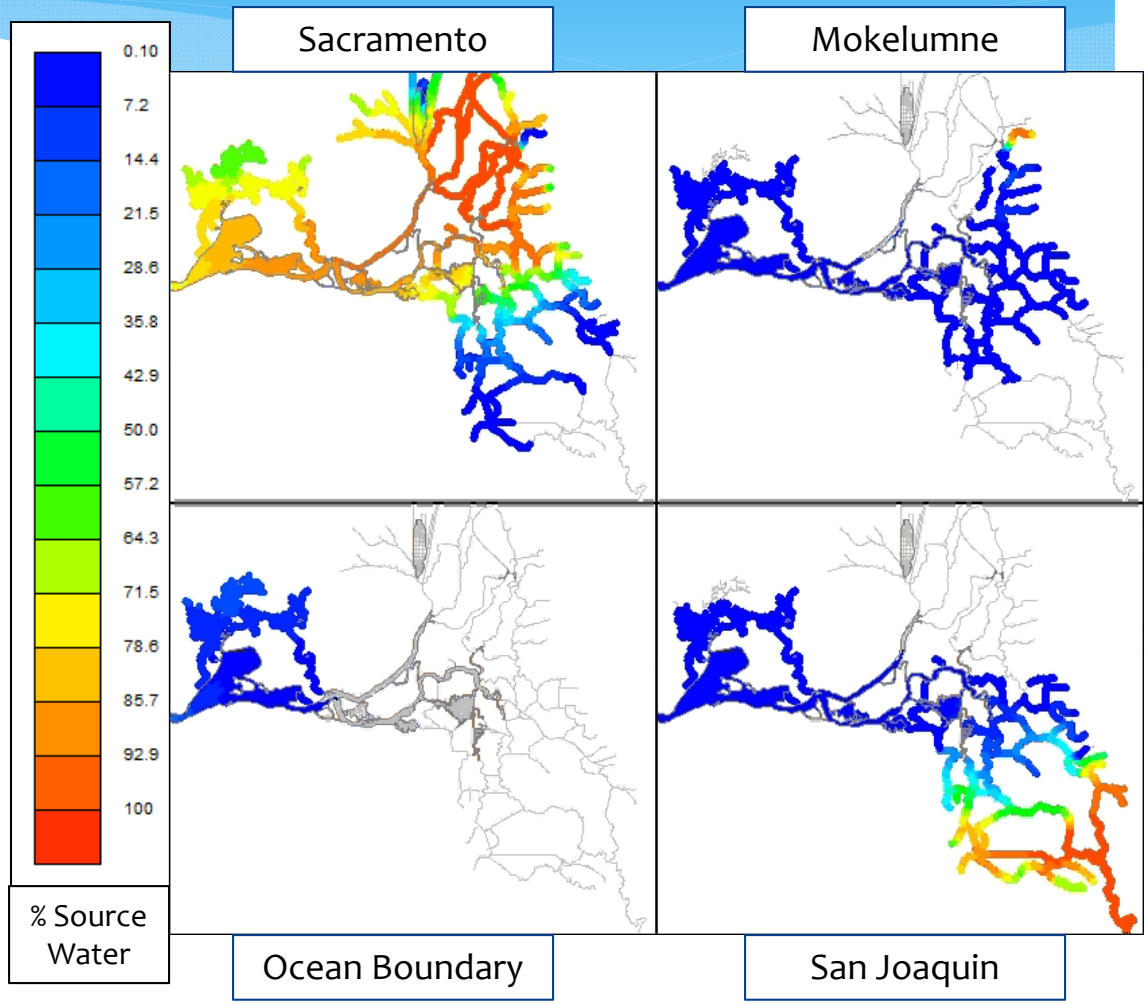


Animation created by Resource Management Associates, using RMA Model results

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

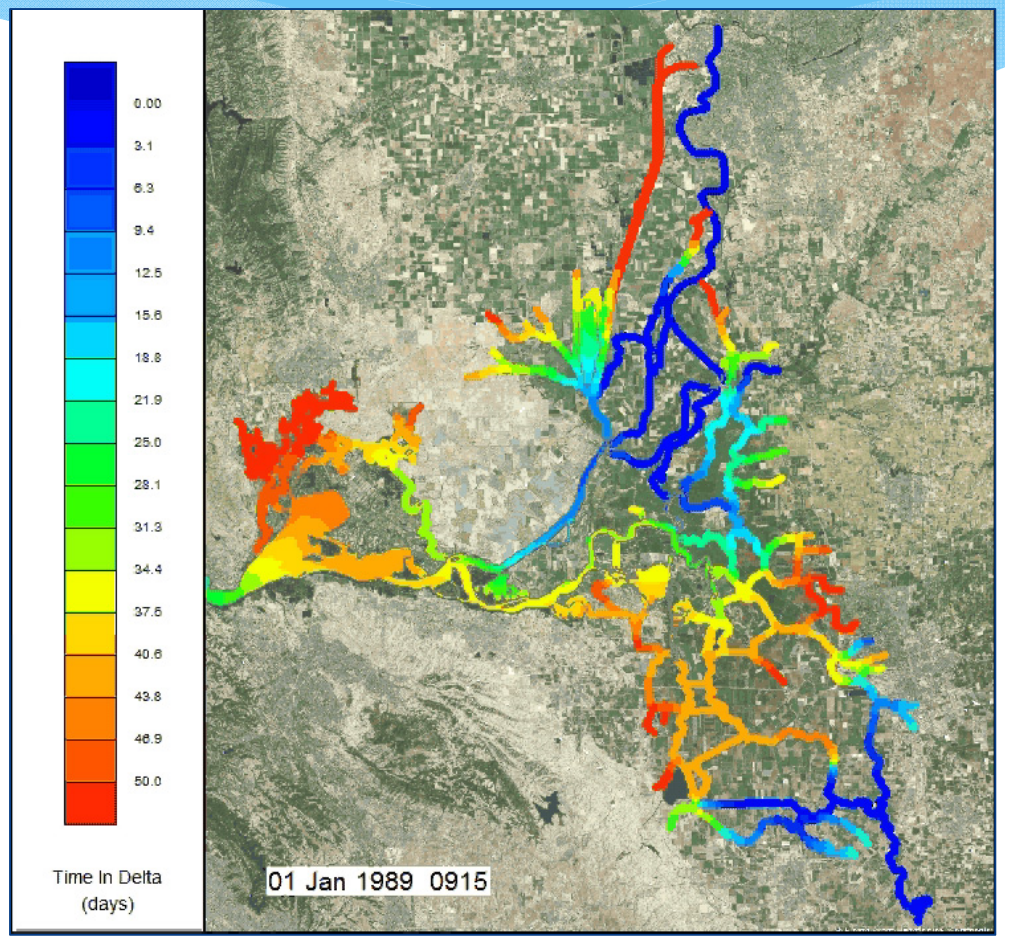


Animation created by Resource Management Associates, using RMA Model results

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

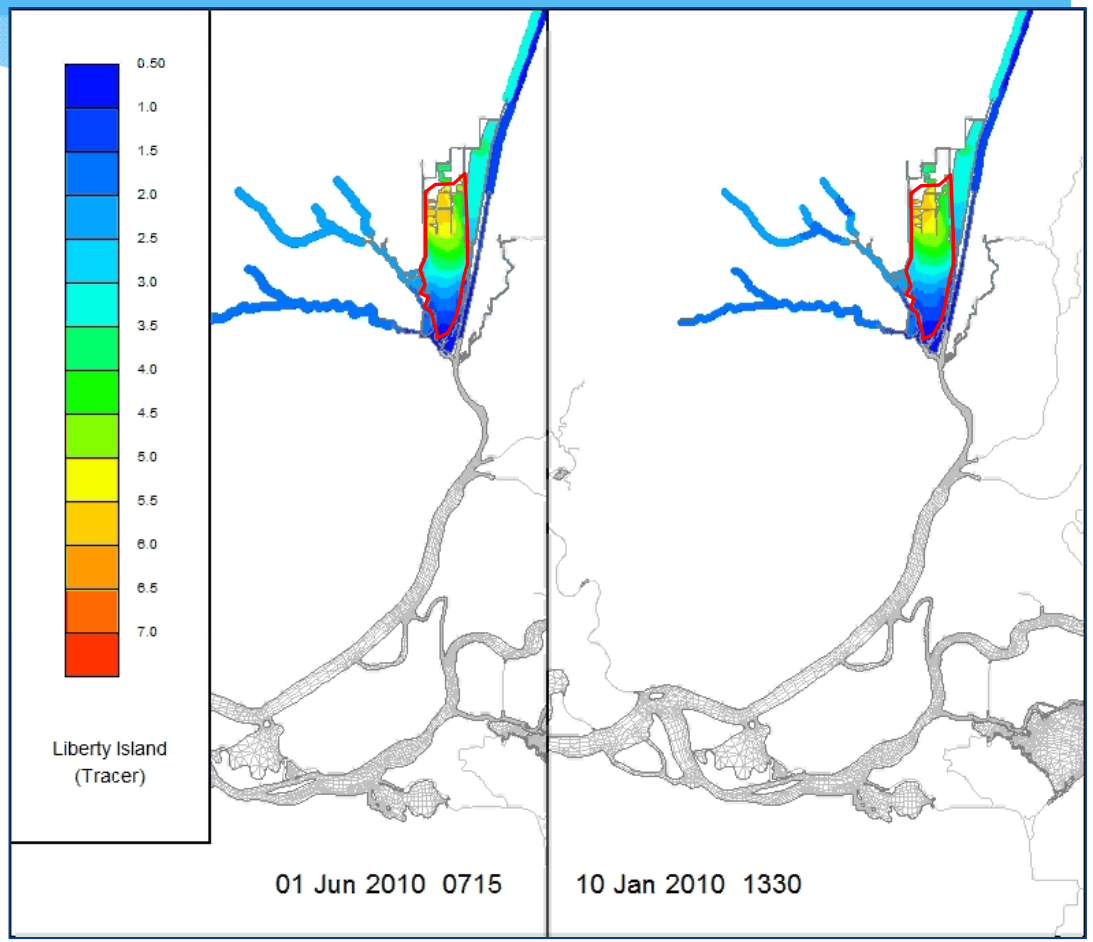


Animation created by Resource Management Associates, using RMA Model results

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

Insights, Estimates, and Controversy

* Board procedures should:
  * Increase the demonstrable quality and discussion of modeling results and conclusions
  * Improve the organization and coherence of modeling work and insights
  * Improve the long-term development of analytical tools and data among many groups
  * Organize policy-making to better employ modeling results