

Salinity Intrusion in the Western Sacramento – San Joaquin Delta and Suisun Bay

Deanna Sereno^{1,2}, Dr. Greg Gartrell¹, and Dr. Richard Denton³

1 Contra Costa Water District; 2 Corresponding author: dsereno@ccwater.com; 3 Richard Denton & Associates, *Water Resources Engineering*

Introduction

The earliest salinity measurements in the Sacramento-San Joaquin Delta (Delta) and Suisun Bay were made by the California & Hawaiian Sugar Refining Corporation (C&H) as they traveled up the Sacramento and San Joaquin Rivers to obtain their freshwater supply (DPW, 1931). C&H measurements provide a continuous record of the spatial and temporal variability of salinity intrusion from 1908 through June 1920 and therefore provide historical context to the salinity regime of the recent past and present conditions.

This analysis evaluates the DSM2 model as a method to simulate this salinity intrusion parameter and compares the fluctuating salinity observations of C&H with recent monitoring data (from the IEP data vault) and modeling results (from DSM2 simulations) to determine how the managed salinity regime of the recent past and the anticipated regime of present, under the current 2008/09 OCAP Biological Opinions, compares to the regime of the early 1900's.

Methods

For this analysis, salinity intrusion is defined as the distance upstream from Crockett, California (near the western end of Suisun Bay) to the location of the isohaline with surface salinity of 50 milligrams of dissolved chloride per liter of river water (mg/L) (see map in center panel).

- ◆ C&H Observations (**Past**, early 1900's) – direct observations of distance to a specified surface salinity, ranging from 20 to 50 mg/L chloride between 1908 and 1918, measured from Crockett upstream along the San Joaquin River. For simplicity, the monthly average recorded distance is represented as distance to 50 mg/L chloride in this analysis.
- ◆ IEP Monitoring Data (**Recent Past**, 1965-2006) – daily average surface salinity at fixed stations along the Sacramento River is interpolated to determine the location of 350 μ S/cm EC.*
- ◆ DSM2 Simulations – daily average, depth-averaged salinity at fixed locations (every DSM2 node) along the Sacramento River is interpolated to determine the location of 350 μ S/cm EC.**
 - Historical Simulation (**Recent Past**, 1990-2006)
 - Planning Simulation (**Present**, under 2008/09 OCAP Biological Opinions)

* Co-located measurement of chloride concentration and electrical conductivity (EC) by MWQI indicate that 50 mg/L chloride is approximately equal to 350 μ S/cm EC.

** Surface and bottom salinity measurements at Port Chicago, Pittsburg, and Collinsville indicate that surface and depth-averaged salinity are approximately equal when surface salinity is 350 μ S/cm EC.

Suisun Bay and Western Delta with DSM2 Grid and IEP Monitoring Stations



Salinity Intrusion in the Past (early 1900's) in comparison to the Recent Past

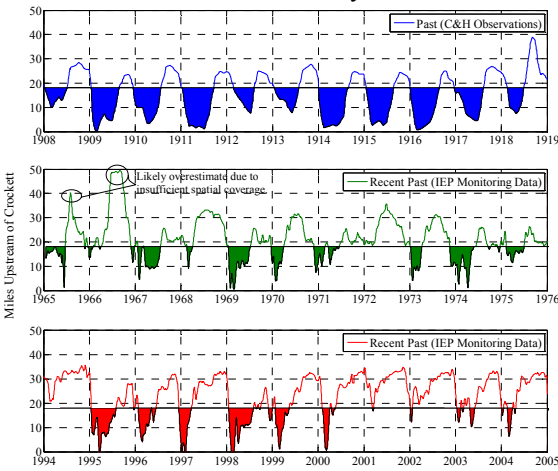
To compare salinity intrusion during different time periods, it is critical to select periods with similar hydrological conditions. The earliest salinity measurements were taken during a relatively wet period (1908 to 1918), with a few dry years; therefore, we selected the two wettest decades in the recent past for comparison (CCWD, 2010).

Time Series of Salinity Intrusion

In each panel to the right, the horizontal line, at approximately 18 miles, is the distance from Crockett to the Delta. The shading represents the spatial extent and duration of the presence of fresh water within Suisun Bay, downstream of the Delta.

From 1908 through 1918, C&H was able to collect fresh water for a large portion of the year within Suisun Bay, without having to travel all the way from Crockett to the Delta. However, in many recent years (e.g., 2001-2004) fresh water is seldom available within Suisun Bay.

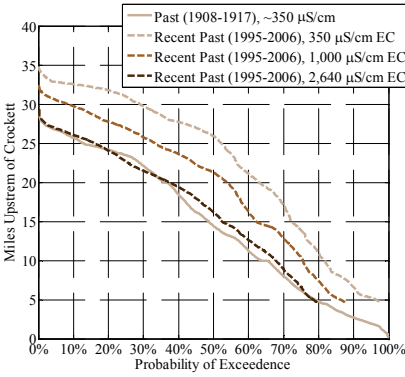
This comparison between the Past and two decades in the Recent Past illustrates that extent and duration of fresh water below the Delta has been greatly reduced since the early 1900's.



How does the spatial and temporal distribution of salinity intrusion as measured by C&H compare to recent historical salinity intrusion?

The temporal and spatial distribution of salinity intrusion is shown to the right. During 1908-1917, on a monthly-averaged basis, C&H barges had to travel above Suisun Bay, into the Delta, (approximately 18 miles above Crockett) about 40% of this time period to reach water with salinity less than 50 mg/L chlorides (about 350 μ S/cm EC). In contrast, from 1995-2006, DSM2 historical simulations suggest that barges would have to travel upstream into the Delta approximately 68% of the time to reach water with salinity of 350 μ S/cm EC.

The location of the 50 mg/L chloride isohaline during 1908-1917 approximately corresponds to the location of X2 (2,640 μ S/cm EC, or 700 mg/L chlorides) during 1995-2006. This is equivalent to more than a 7-fold increase in salinity from the early 1900's to the recent past.



Salinity Intrusion in the Present (under 2008/09 OCAP BO RPAs)

in comparison to the Past (early 1900's) and Recent Past

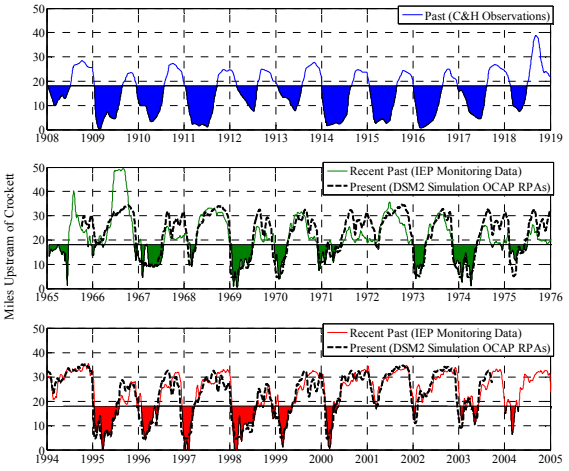
Salinity intrusion under present-day conditions, including reasonable and prudent alternatives (RPAs) identified in the 2008/09 OCAP Biological Opinions, is estimated for a range of hydrology using results of operational modeling from the Department of Water Resources' Draft State Water Project Reliability Report (DWR, 2009) as input for a DSM2 Planning Simulation.

Time Series of Salinity Intrusion

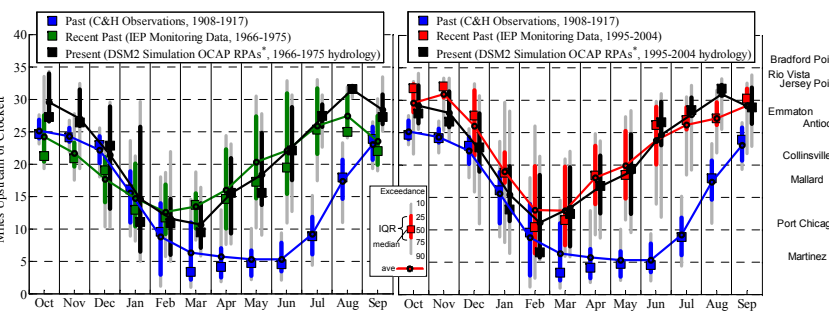
In the middle and bottom panels to the right, salinity intrusion under present-day conditions is illustrated with a black dashed line over the historical salinity intrusion observed in the Recent Past.

The present-day OCAP simulations illustrate how the new "Fall X2" requirements in fall months following relatively wet water years will reduce salinity, e.g., in the fall of 1997 and 1999. However, simulated fall salinity under OCAP BO RPAs is still more saline than the historical 1908-1917 and historical 1966-1975 periods.

Winter freshening, predominantly in January, may be a result of reduced Delta exports to meet new instream flow requirements (i.e. "OMR").



Monthly Distribution of Monthly Average Salinity Intrusion



Conclusions

- ◆ The earliest measurements of salinity intrusion can be used as a baseline to provide historical context to salinity intrusion estimates of the Recent Past and Present conditions.
- ◆ Estimates of salinity intrusion using the DSM2 Historical Simulation show good agreement with estimates of salinity intrusion from the IEP fixed station monitoring network. The IEP network has the advantage of measuring surface salinity (C&H also measured surface salinity), while DSM2 simulates depth-averaged salinity. However, DSM2 has the advantage of simulating salinity at a higher spatial resolution than the IEP fixed station network.
- ◆ Estimates of salinity intrusion using the DSM2 Planning Simulation allow comparison of possible future statewide water operations to the earliest salinity intrusion measures by C&H.

References

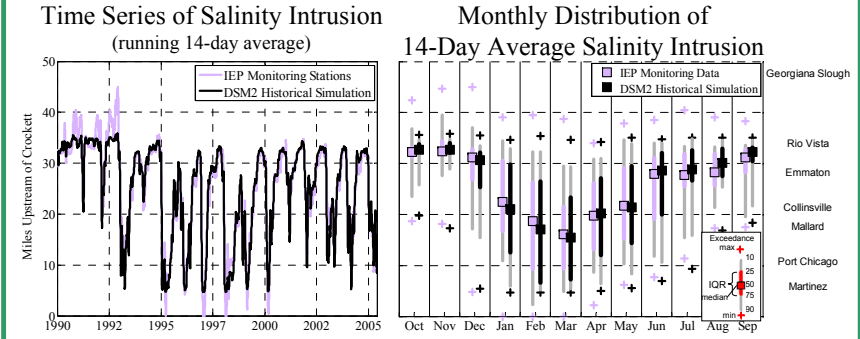
[DPW] Department of Public Works. 1931. Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay. Bulletin No. 27. State of California, Department of Public Works, Division of Engineering and Irrigation. See <http://www.archive.org/details/variationcontrol27calrich>

[DWR] Department of Water Resources. 2009. The State Water Project Delivery Reliability Report 2009. State of California, The Resources Agency, Department of Water Resources. See <http://baydeltaoffice.water.ca.gov/swpreliability/index.cfm>

[CCWD] Contra Costa Water District. 2010. Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay. Water Resources Department, Contra Costa Water District, Technical Memorandum WR10-001. See www.cwater.com/salt.asp

Salinity Intrusion in the Recent Past Estimates from Monitoring Data and DSM2 Historical Simulation

The ability of the DSM2 model to accurately simulate the movement of the 350 μ S/cm EC isohaline is evaluated by comparing salinity intrusion estimates from the DSM2 Historical Simulation output to estimates from IEP Monitoring Data.



Overall, a fairly good fit ($r^2=0.95$) with very similar monthly distribution of daily salinity intrusion.

Limitations:

During very low salinity intrusion, model overestimates due to:

- Boundary salinity assumed at constant 175 μ S/cm EC, but during high flows, salinity has been as low as 50 μ S/cm EC.
- Fresh water wedge measured by surface EC sensors is not captured in DSM2 dynamics.

During very high salinity intrusion, monitoring data may overestimate due to large gap between monitoring stations on Sacramento River above Rio Vista.

