Hugo B. Fischer Award Presentation

Michael L. MacWilliams, PhD, PE

April 17, 2023

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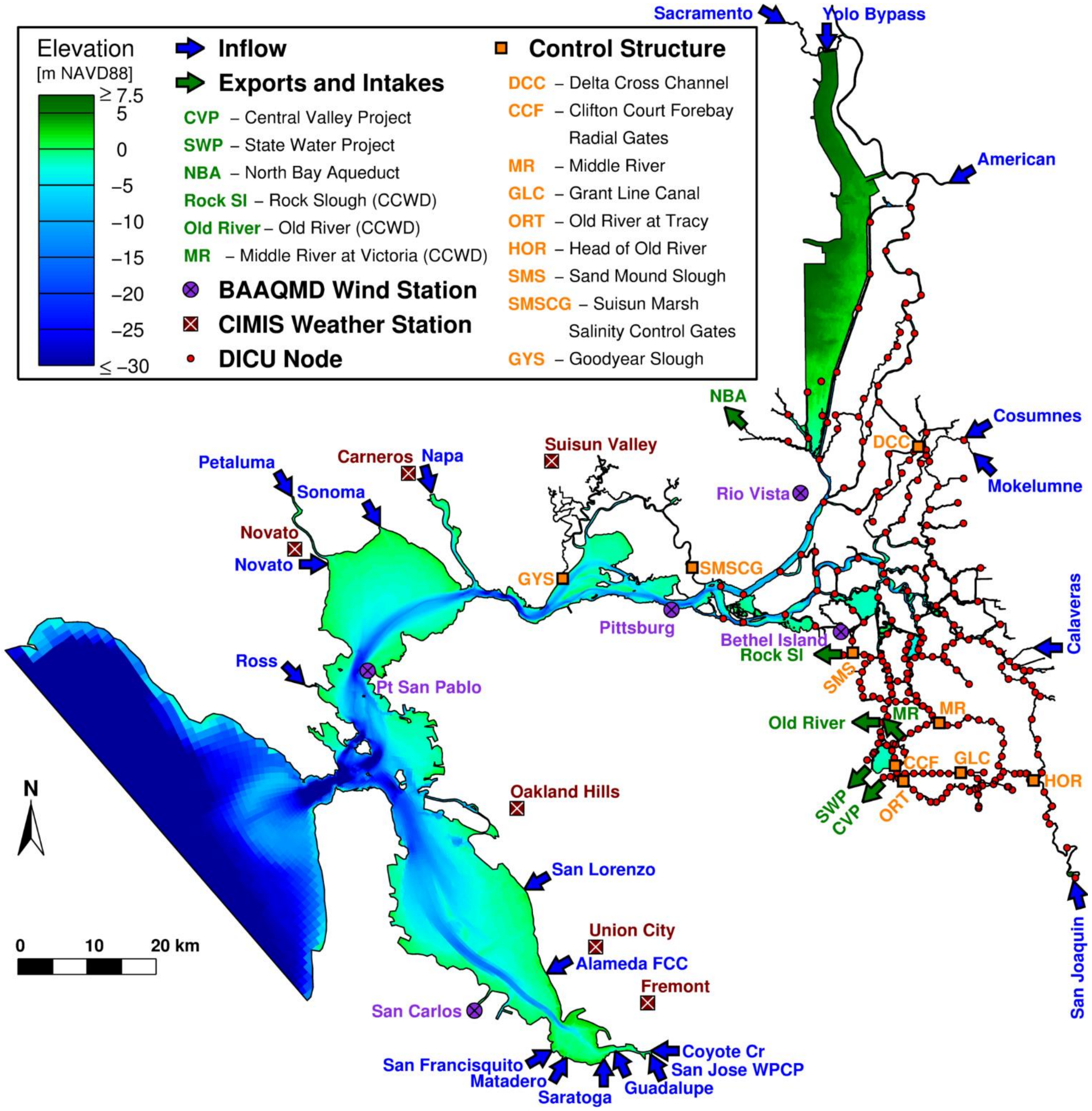
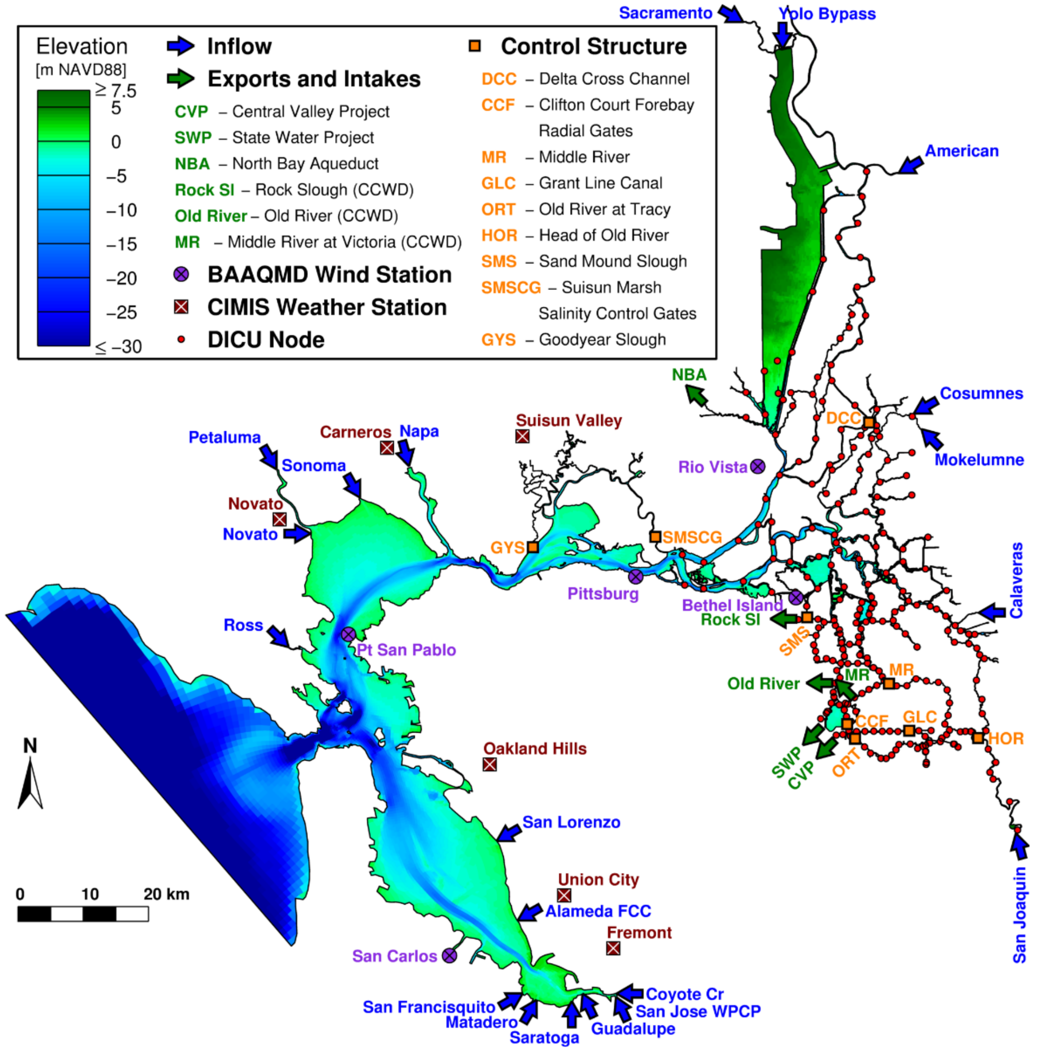


Thank You!

- J. Keith Rigby
- Robert Street
- Peter Kitanidis
- Vincenzo Casulli
- Ed Gross
- Ralph Cheng
- Wim Kimmerer
- John DeGeorge
- Richard Rachiele
- Steve Monismith

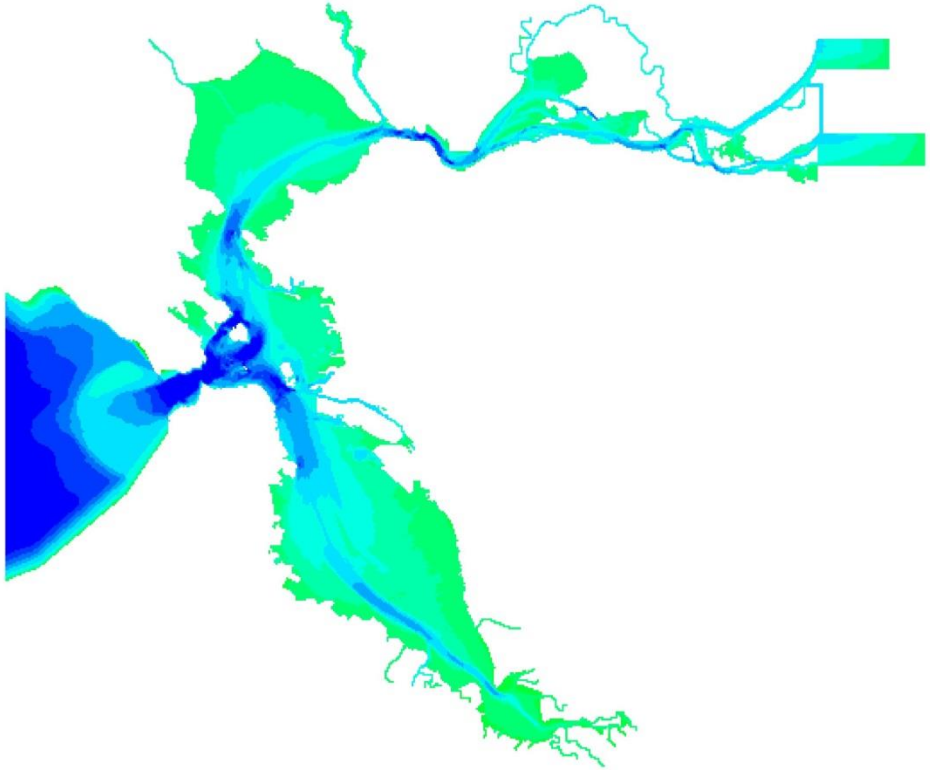
- Frank Wu
- Bruce Herbold
- Aaron Bever
- Ted Sommer
- UnTRIM User Group
- Data collectors and data repositories
- Many other clients and collaborators
- My family



Twenty Years of Delta Model Advancements

2003–2005

TRIM3D



Simulating Periodic Stratification in the San Francisco Estuary

Edward S. Gross,[1] Michael L. MacWilliams[2] and Wim Kimmerer[3]

Abstract

Three-dimensional simulations of circulation in the San Francisco Estuary were performed with the three-dimensional hydrodynamic model, TRIM3D, using a generic length scale turbulence closure model. The model was calibrated to reproduce observed tidal elevations and tidal currents in the San Francisco Estuary and then was applied during a period of intensive data collection. The model predicts tidal currents accurately and realistically simulates variability in salinity at both the seasonal and tidal time scale. The model results are consistent with the current conceptual understanding of stratification in the San Francisco Estuary and approximately predict the magnitude and tidal phasing of observed stratification. The simulation results were analyzed to improve understanding of periodic stratification. During spring tides, compression of salinity gradients near high water and weak tidal currents at and following high water allow the formation of weak and transient stratification. During neap tides stronger stratification is observed and predicted. This stratification is strongest during ebb when tidal straining is effective in creating stratification. Vertical turbulent mixing may be adequate to diminish vertical stratification during strong ebb tides while stratification can persist or increase through weak ebb tides.

Introduction

The hydrodynamic modeling effort presented is part of a larger effort to better understand the effects of freshwater inflow on the abundance of estuarine biota in the San Francisco Estuary (defined as the body of water from the Delta to the Golden Gate, including South San Francisco Bay, Central San Francisco Bay, San Pablo Bay, Carquinez Strait, Suisun Bay and the Sacramento-San Joaquin Delta). Freshwater flow into the San Francisco Estuary is regulated in part using a salinity standard defined as the position of 2 psu (practical salinity units) bottom salinity. The location of 2 psu bottom salinity, known as X_2, is reported as distance along the channel in kilometers from the Golden Gate (Jassby et al. 1995). The X_2 standard was developed based on observations that the survival and abundance of several estuarine fish species correlate with X_2 (Jassby et al. 1995). Mechanisms behind these correlations are unknown, but for some species they may be linked to the timing, location, and frequency of stratification in the estuary (Kimmerer 2004). We are using the TRIM3D model to investigate plausible mechanisms involving stratification, and must therefore ensure that the prediction of stratification by the model is realistic.

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Estuarine and Coastal Modeling 2005

Source: Gross et al. 2005

Estuaries and Coasts
DOI 10.1007/s12237-008-9124-x

Is the Response of Estuarine Nekton to Freshwater Flow in the San Francisco Estuary Explained by Variation in Habitat Volume?

Wim J. Kimmerer · Edward S. Gross ·
Michael L. MacWilliams

Received: 27 June 2008 / Revised: 21 November 2008 / Accepted: 25 November 2008

Abstract Abundance of estuarine biota can vary with freshwater inflow through several mechanisms. One proposed mechanism is that the extent of physical habitat for an estuarine species increases with flow. We estimated the contribution of variation in habitat volume to the responses of eight species of estuarine nekton to changes in freshwater flow in the San Francisco Estuary. Resource selection functions for salinity and depth were developed for each species (and for five additional species) using five monitoring data sets. The TRIM3D hydrodynamic model was run for five steady flow scenarios to determine volume by salinity and depth, and resource selection functions were used as a weighting factor to calculate an index of total habitat for each species at each flow. The slopes of these habitat indices vs. flow were consistent with slopes of abundance vs. flow for only two of the species examined. Therefore, other mechanisms must underlie responses of abundance to flow for most species.

Keywords Fish · Habitat · Freshwater flow · Resource selection function · San Francisco Estuary

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M. L. MacWilliams
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Introduction

Variability in freshwater flow is the principal mode of interannual and seasonal variation of physical conditions in many estuaries (Skreslet 1986). River discharge into estuaries may be sensitive to climate change and increasing human demand (Vörösmarty et al. 2000; Scavia et al. 2002). Thus, understanding mechanisms by which estuarine ecosystems respond to freshwater flow should yield important insights into the dynamics of these ecosystems and their sensitivity to perturbation.

Biological populations in estuaries often vary with freshwater flow. Positive flow effects have been reported for phytoplankton production (Riley 1937; Mallin et al. 1993; Sin et al. 1999) and for abundance or harvest of benthic invertebrates (Aleem 1972; Gammelsrød 1992; Montagna and Kalke 1992; Wilber 1992, 1994; Reaugh et al. 2007) and fish (Stevens 1977; Houde and Rutherford 1993; Jassby et al. 1995). Negative effects on biological populations can also occur (Rose and Summers 1992), e.g., through effects of washout or osmotic stress (Deegan 1990; Kaartvedt and Aksnes 1992).

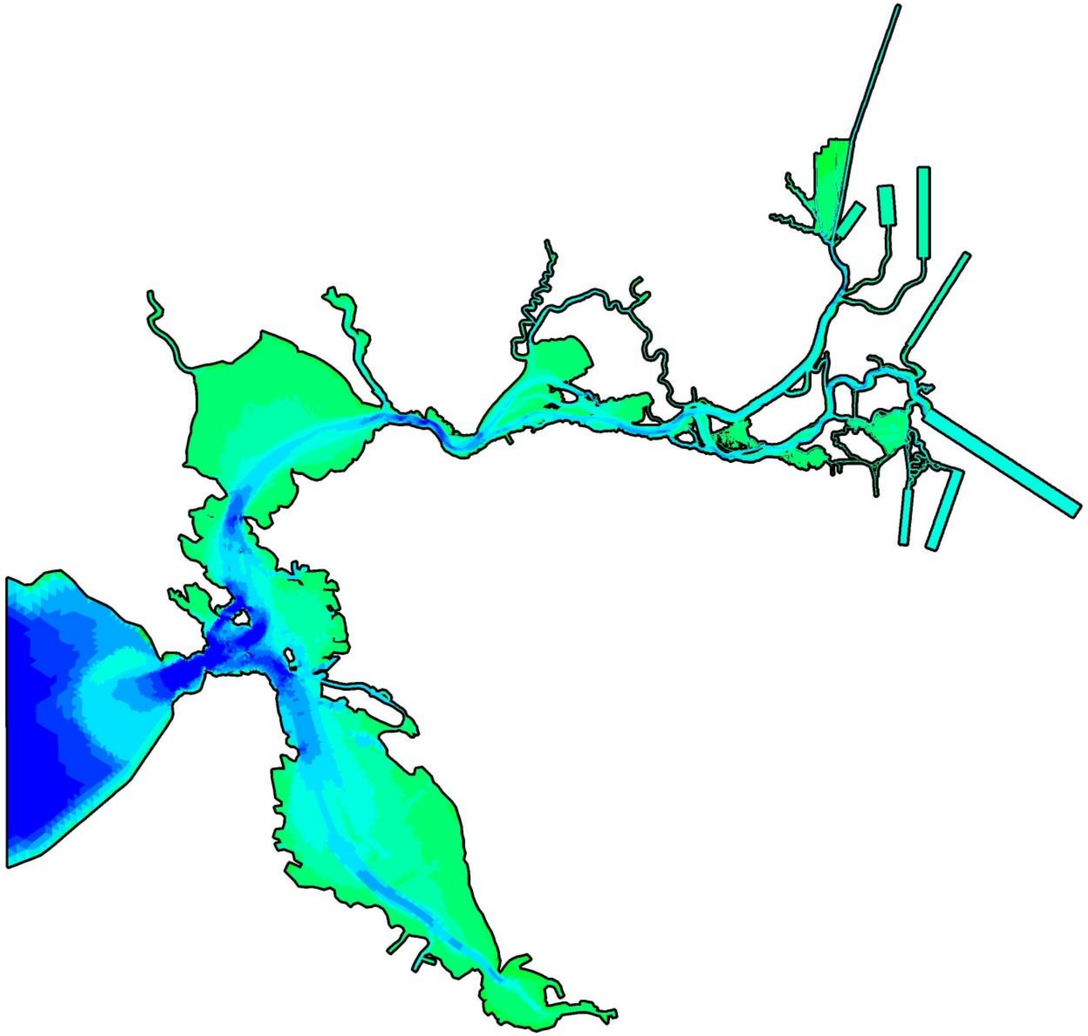
Various potential mechanisms have been proposed for positive effects of freshwater flow on biological populations (e.g., Nixon et al. 1986; Cloern 1991; Drinkwater and Frank 1994; Kimmerer 2002a, b). One proposed mechanism is the increase in area or volume of physical habitat for biota that accompanies increases in freshwater flow (mechanism no. 10, Kimmerer 2002b). This mechanism may explain increases in the abundance of Sacramento splittail, *Pogonichthys macrolepidotus*, with freshwater flow in the upper San Francisco estuary (Sommer et al. 1997). When high flow inundates floodplains adjacent to the estuary, splittail gain access to large areas of habitat, particularly for foraging and spawning (Feyrer et al. 2006).

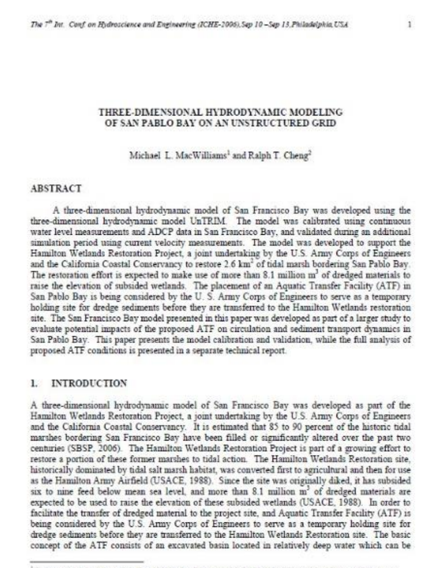
Springer

Source: Kimmerer et al. 2009

Twenty Years of Delta Model Advancements

2004–2007
UnTRIM





The 7th Int. Conf. on Hydroscience and Engineering (ICHE-2006), Sep 10 – Sep 13, Philadelphia, USA 1

THREE-DIMENSIONAL HYDRODYNAMIC MODELING OF SAN PABLO BAY ON AN UNSTRUCTURED GRID

Michael L. MacWilliams[1] and Ralph T. Cheng[2]

ABSTRACT

A three-dimensional hydrodynamic model of San Francisco Bay was developed using the three-dimensional hydrodynamic model UnTRIM. The model was calibrated using continuous water level measurements and ADCP data in San Francisco Bay, and validated during an additional simulation period using current velocity measurements. The model was developed to support the Hamilton Wetlands Restoration Project, a joint undertaking by the U.S. Army Corps of Engineers and the California Coastal Conservancy to restore 2.6 km^2 of tidal marsh bordering San Pablo Bay. The restoration effort is expected to make use of more than 8.1 million m^3 of dredged materials to raise the elevation of subsided wetlands. The placement of an Aquatic Transfer Facility (ATF) in San Pablo Bay is being considered by the U. S. Army Corps of Engineers to serve as a temporary holding site for dredge sediments before they are transferred to the Hamilton Wetlands restoration site. The San Francisco Bay model presented in this paper was developed as part of a larger study to evaluate potential impacts of the proposed ATF on circulation and sediment transport dynamics in San Pablo Bay. This paper presents the model calibration and validation, while the full analysis of proposed ATF conditions is presented in a separate technical report.

1. INTRODUCTION

A three-dimensional hydrodynamic model of San Francisco Bay was developed as part of the Hamilton Wetlands Restoration Project, a joint undertaking by the U.S. Army Corps of Engineers and the California Coastal Conservancy. It is estimated that 85 to 90 percent of the historic tidal marshes bordering San Francisco Bay have been filled or significantly altered over the past two centuries (SBSP, 2006). The Hamilton Wetlands Restoration Project is part of a growing effort to restore a portion of these former marshes to tidal action. The Hamilton Wetlands Restoration site, historically dominated by tidal salt marsh habitat, was converted first to agricultural and then for use as the Hamilton Army Airfield (USACE, 1988). Since the site was originally diked, it has subsided six to nine feed below mean sea level, and more than 8.1 million m^3 of dredged materials are expected to be used to raise the elevation of these subsided wetlands (USACE, 1988). In order to facilitate the transfer of dredged material to the project site, and Aquatic Transfer Facility (ATF) is being considered by the U.S. Army Corps of Engineers to serve as a temporary holding site for dredge sediments before they are transferred to the Hamilton Wetlands Restoration site. The basic concept of the ATF consists of an excavated basin located in relatively deep water which can be

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Source: MacWilliams and Cheng 2006

THREE-DIMENSIONAL HYDRODYNAMIC MODELING OF THE SAN FRANCISCO ESTUARY ON AN UNSTRUCTURED GRID

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John F. DeGeorge(3), Richard R. Rachiele(4)

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ABSTRACT

Three-dimensional simulations of circulation in the San Francisco Estuary were performed with the three-dimensional unstructured grid hydrodynamic model UnTRIM. The model was developed to support the Delta Risk Management Strategy (DRMS) funded by the California Department of Water Resources. The model applications build on previous TRIM and UnTRIM applications. A model grid consisting of quadrilaterals and triangles was developed that extends from the Pacific Ocean through San Francisco Bay and further into the Sacramento-San Joaquin Delta than previous TRIM and UnTRIM applications. In addition, a state-of-the-art turbulence closure was incorporated into the UnTRIM model from the TRIM model. This paper describes a portion of the hydrodynamic and salinity calibration of the resulting San Francisco Estuary UnTRIM model.

Keywords: three-dimensional, unstructured grid, estuary, salinity, UnTRIM, San Francisco Bay, Sacramento-San Joaquin Delta, turbulence closure, generic length scale, calibration

1 INTRODUCTION

The Sacramento-San Joaquin Delta is a critical resource to the state of California because the Delta is a source of drinking water for roughly 2 out of 3 Californians. However, the 2,800 km^2 of islands in the Delta region are at risk of inundation from levee failures. These deeply subsided islands are protected by levees typically 4 to 5 meters high which are, in most cases, not engineered levees and are constructed partially with peat and other weak and compressible soils. The Delta Risk Management Study has been funded by the California Department of Water Resources (DWR) to "look at sustainability of the Delta, and … assess major risks to the Delta resources from floods, seepage, subsidence, and earthquakes." Part of this effort involves the application of hydrodynamic models to estimate the effect of levee failures on salinity in the Delta. Levee failures in the Delta generally result in increased salinity as islands flood and brackish water from Suisun Bay is entrained into the Delta. Increased salinity can result in exceedence of water quality objectives for drinking water causing interruption of water exports, resulting in a large economic impact.

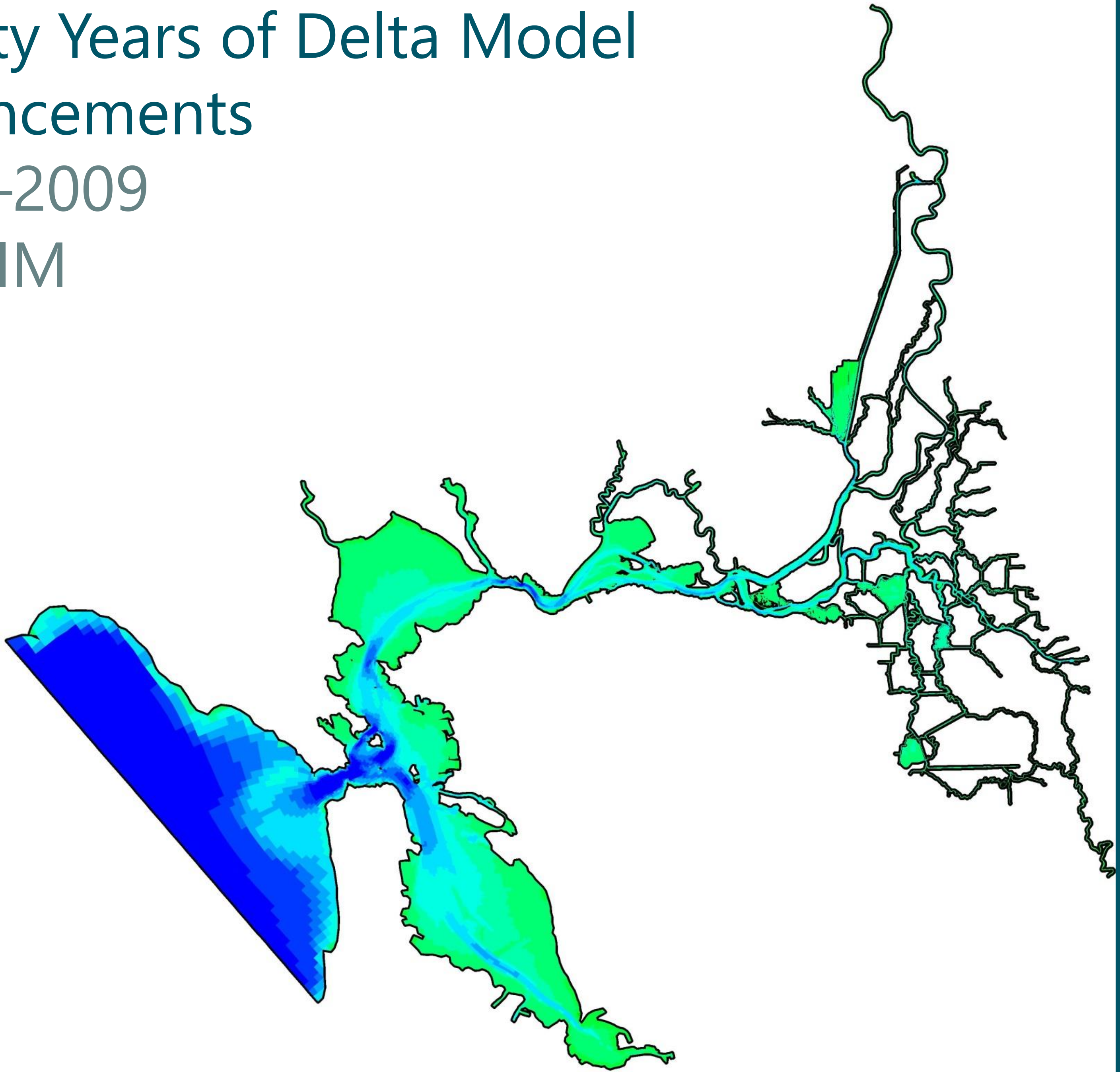
Several hydrodynamic and water quality simulation tools are applied in the DRMS project, ranging from a tidally-averaged advection-dispersion model, which can perform a year of salinity projections in 1 minute of computation time, to the sophisticated and computationally intensive three-dimensional model described here. The first phase of the DRMS work involves quantification of risk and consequences of Delta levee failures while the second phase will evaluate risk reduction actions that can be taken to reduce risks of levee failures and the impacts of levee failures.

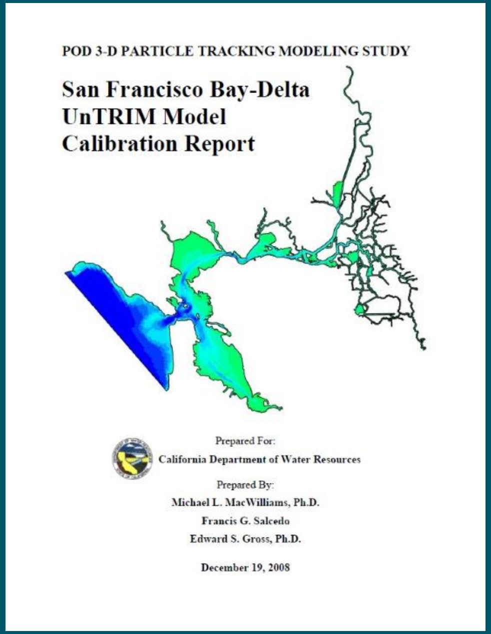
Source: MacWilliams et al. 2007

Twenty Years of Delta Model Advancements

2008–2009

UnTRIM





POD 3-D PARTICLE TRACKING MODELING STUDY

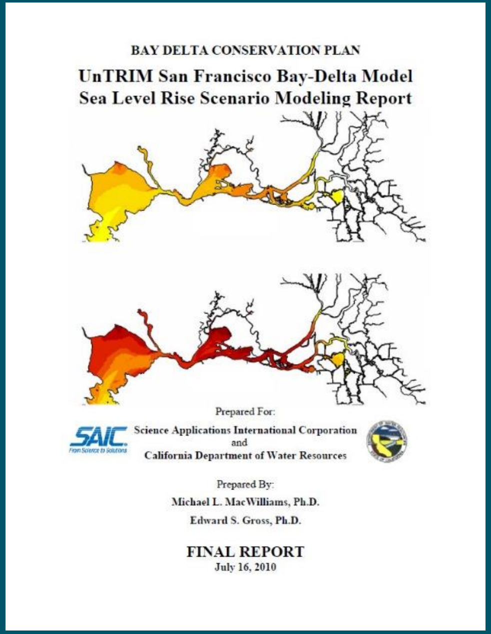
San Francisco Bay-Delta
UnTRIM Model
Calibration Report

Prepared For:
California Department of Water Resources

Prepared By:
Michael L. MacWilliams, Ph.D.
Francis G. Salcedo
Edward S. Gross, Ph.D.

December 19, 2008

Source: MacWilliams et al. 2008



BAY DELTA CONSERVATION PLAN

UnTRIM San Francisco Bay-Delta Model
Sea Level Rise Scenario Modeling Report

Prepared For:
Science Applications International Corporation
and
California Department of Water Resources

Prepared By:
Michael L. MacWilliams, Ph.D.
Edward S. Gross, Ph.D.

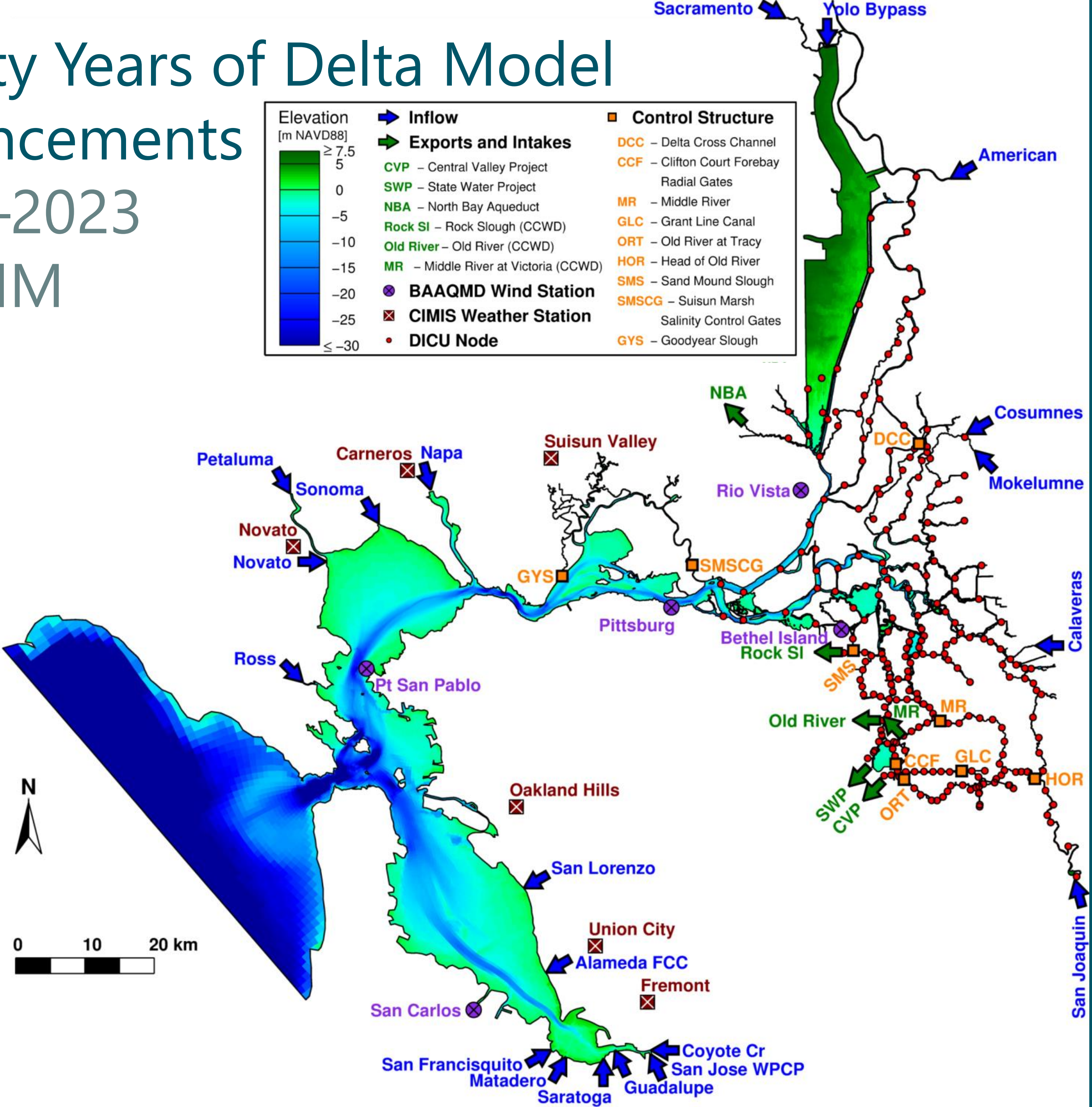
FINAL REPORT
July 16, 2010

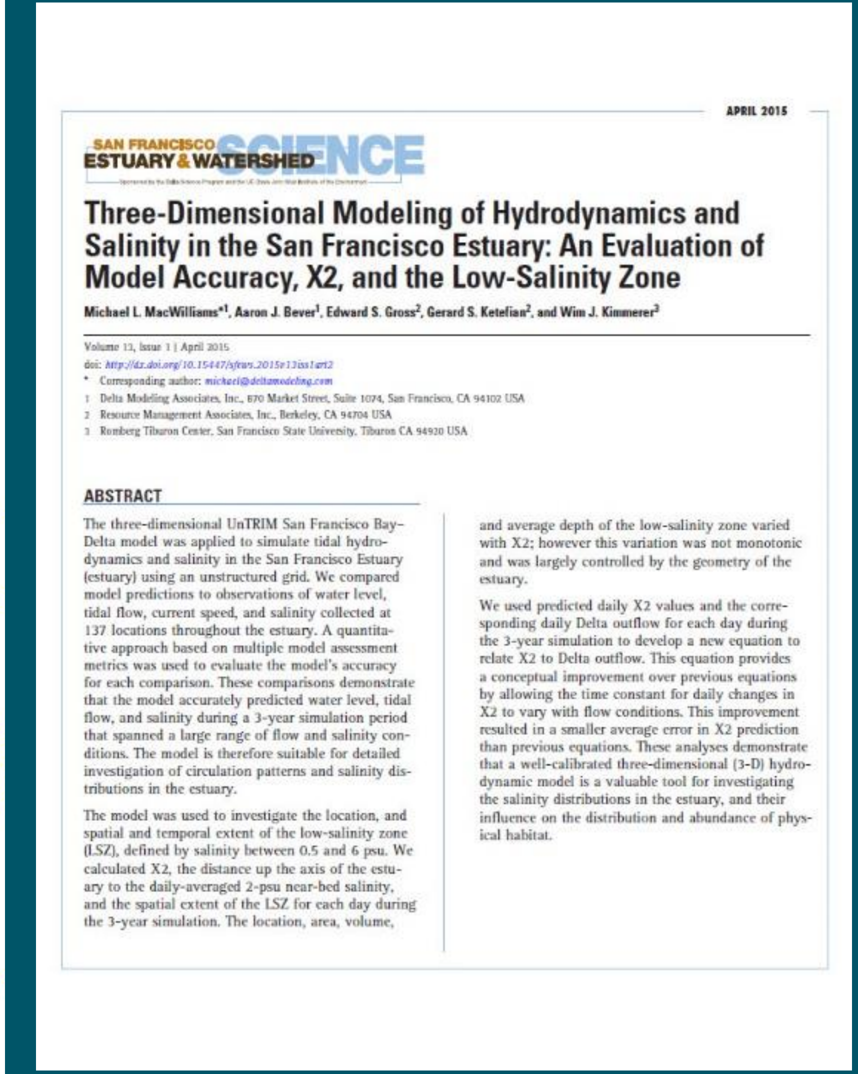
Source: MacWilliams and Gross 2010

Twenty Years of Delta Model Advancements

2010–2023

UnTRIM




APRIL 2015

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

Three-Dimensional Modeling of Hydrodynamics and Salinity in the San Francisco Estuary: An Evaluation of Model Accuracy, X2, and the Low-Salinity Zone

Michael L. MacWilliams*[1], Aaron J. Bever[1], Edward S. Gross[2], Gerard S. Ketefian[2], and Wim J. Kimmerer[3]

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ABSTRACT

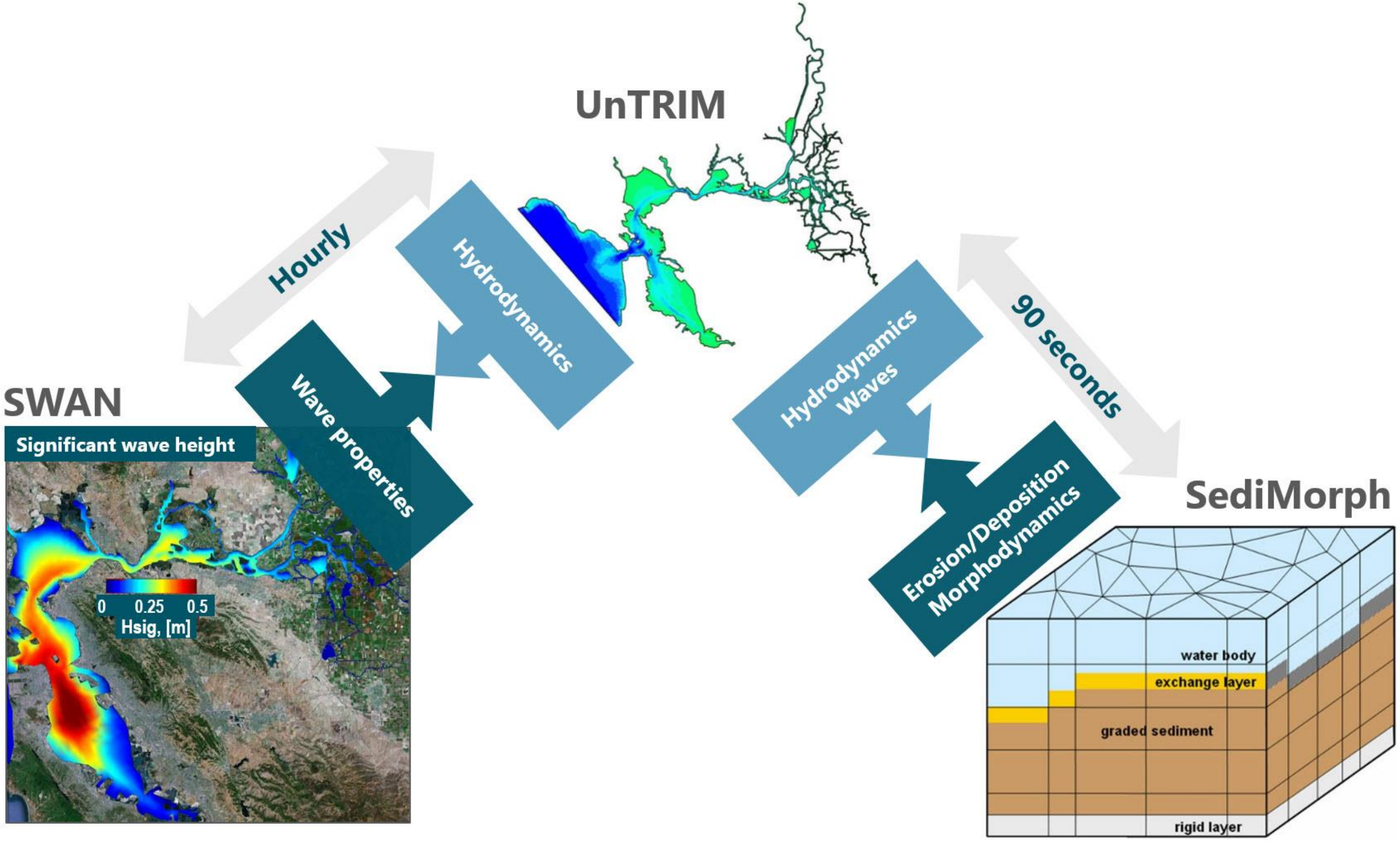
The three-dimensional UnTRIM San Francisco Bay–Delta model was applied to simulate tidal hydrodynamics and salinity in the San Francisco Estuary (estuary) using an unstructured grid. We compared model predictions to observations of water level, tidal flow, current speed, and salinity collected at 137 locations throughout the estuary. A quantitative approach based on multiple model assessment metrics was used to evaluate the model's accuracy for each comparison. These comparisons demonstrate that the model accurately predicted water level, tidal flow, and salinity during a 3-year simulation period that spanned a large range of flow and salinity conditions. The model is therefore suitable for detailed investigation of circulation patterns and salinity distributions in the estuary.

The model was used to investigate the location, and spatial and temporal extent of the low-salinity zone (LSZ), defined by salinity between 0.5 and 6 psu. We calculated X2, the distance up the axis of the estuary to the daily-averaged 2-psu near-bed salinity, and the spatial extent of the LSZ for each day during the 3-year simulation. The location, area, volume, and average depth of the low-salinity zone varied with X2; however this variation was not monotonic and was largely controlled by the geometry of the estuary.

We used predicted daily X2 values and the corresponding daily Delta outflow for each day during the 3-year simulation to develop a new equation to relate X2 to Delta outflow. This equation provides a conceptual improvement over previous equations by allowing the time constant for daily changes in X2 to vary with flow conditions. This improvement resulted in a smaller average error in X2 prediction than previous equations. These analyses demonstrate that a well-calibrated three-dimensional (3-D) hydrodynamic model is a valuable tool for investigating the salinity distributions in the estuary, and their influence on the distribution and abundance of physical habitat.

Source: MacWilliams et al. 2015

Sediment Transport and Morphology




Marine Geology 345 (2013) 235–253

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journal homepage: www.elsevier.com/locate/margeo

Simulating sediment transport processes in San Pablo Bay using coupled hydrodynamic, wave, and sediment transport models

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sediment transport
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channel and shoals
shallow water

ABSTRACT

San Pablo Bay is a tidal sub-embayment of the San Francisco Estuary which is dominated by broad shallow shoals bisected by a deep channel. Under the conceptual model of sediment transport in San Pablo Bay proposed by Krone (1979), sediment typically enters San Pablo Bay during large winter and spring flows and is redistributed during summer conditions through wind wave resuspension and transport by tidal currents. Numerical simulations of sediment resuspension due to wind waves and the subsequent transport of this sediment by tidal currents show that sediment concentrations and fluxes throughout the channel–shoal system result from a complex temporal and spatial interaction of the waves and tides. The three-dimensional UnTRIM San Francisco Bay-Delta Model was coupled with the Simulating WAves Nearshore (SWAN) wave model and the SediMorph morphological model, to develop a three-dimensional (3D) hydrodynamic, wind wave, and sediment transport model of San Francisco Bay and the Sacramento–San Joaquin Delta. The coupled model was validated using water level, velocity, wind waves and suspended sediment data collected in San Pablo Bay, and then used to quantify the spatial and temporal variability of sediment fluxes on the extensive shoals in San Pablo Bay under a range of tidal and wind conditions. The model validation shows this modeling system can accurately predict hydrodynamics, waves, and suspended sediment concentration in San Pablo Bay. The predicted bottom orbital velocities are elevated across the shoals during large wave events regardless of tidal stage, but near low tide orbital velocities are increased even under low to moderate waves. Sediment fluxes between the shoals and the deeper channel are highest during spring tides, and are elevated for up to a week following wave events, even though the greatest influence of the wave event occurs abruptly.

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1. Introduction

Within San Francisco Bay, tidal flats and shallow water areas (less than ~4 m) provide extensive habitat for birds, fish, and crustaceans (Nichols and Pamatmat, 1988; Galbraith et al., 2002) and attenuate waves protecting the shoreline from erosion (Lacy and Hoover, 2011). Traditionally, high winter freshwater flows supplied sediment to San Francisco Bay, where it deposited on these mudflats and shallows (Krone, 1979). Tidal and wave reworking eventually exported the sediment to the Pacific Ocean or moved the sediment to a location of long-term accumulation. Over the last 50 years, however, the sediment supply to San Francisco Bay has decreased due to relict hydraulic mining debris having completely moved through the system (Schoellhamer, 2011). A reduction in sediment supply coupled with 0.2 to 0.5 m of predicted sea level rise over the next 100 years (Bindoff et al., 2007; Cayan et al., 2008) make shallow water areas within the Bay particularly vulnerable to inundation and erosion. As such, a detailed understanding of the processes driving sediment fluxes onto or off of shallow water areas is critical to helping determine how well these areas may keep up with future sea level rise.

Recent observations within San Pablo Bay, a sub-embayment of San Francisco Bay composed of a narrow deep channel and extensive shoals and mudflats, show wind wave induced sediment resuspension and sediment fluxes are intricately tied to the tidal water level and current direction during wave events (Schoellhamer et al., 2008b). Schoellhamer et al. (2008b) also determined that the directions of residual sediment fluxes were different during spring and neap tides at a location on the northern flank of the channel. These data suggest the sediment that fluxes onto and off of the shoals is potentially a complex interaction of not only the tidal currents, wind waves, and sediment bed, but also the timing of the waves in relation to the tidal water level and current direction, all of which may vary spatially within San Pablo Bay.

Although Schoellhamer et al. (2008b) give valuable insight into the processes driving the suspension and transport of sediment, the data only provide information at a few points. A detailed hydrodynamic, sediment transport, and wind wave modeling framework is ideal for investigating the physical processes driving suspended sediment concentrations and fluxes throughout San Pablo Bay. This study uses coupled hydrodynamic, sediment transport, and wave models to

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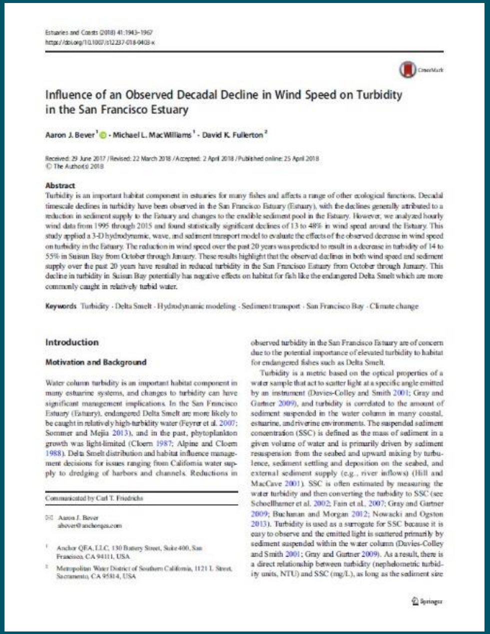
Source: Bever and MacWilliams 2013


Estuaries and Coasts (2018) 41:1943–1967
https://doi.org/10.1007/s12237-018-0403-x

Influence of an Observed Decadal Decline in Wind Speed on Turbidity in the San Francisco Estuary

Aaron J. Bever[1] · Michael L. MacWilliams[1] · David K. Fullerton[2]

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Abstract

Turbidity is an important habitat component in estuaries for many fishes and affects a range of other ecological functions. Decadal timescale declines in turbidity have been observed in the San Francisco Estuary (Estuary), with the declines generally attributed to a reduction in sediment supply to the Estuary and changes to the erodible sediment pool in the Estuary. However, we analyzed hourly wind data from 1995 through 2015 and found statistically significant declines of 13 to 48% in wind speed around the Estuary. This study applied a 3-D hydrodynamic, wave, and sediment transport model to evaluate the effects of the observed decrease in wind speed on turbidity in the Estuary. The reduction in wind speed over the past 20 years was predicted to result in a decrease in turbidity of 14 to 55% in Suisun Bay from October through January. These results highlight that the observed declines in both wind speed and sediment supply over the past 20 years have resulted in reduced turbidity in the San Francisco Estuary from October through January. This decline in turbidity in Suisun Bay potentially has negative effects on habitat for fish like the endangered Delta Smelt which are more commonly caught in relatively turbid water.

Keywords Turbidity · Delta Smelt · Hydrodynamic modeling · Sediment transport · San Francisco Bay · Climate change

Introduction

Motivation and Background

Water column turbidity is an important habitat component in many estuarine systems, and changes to turbidity can have significant management implications. In the San Francisco Estuary (Estuary), endangered Delta Smelt are more likely to be caught in relatively high-turbidity water (Feyrer et al. 2007; Sommer and Mejia 2013), and in the past, phytoplankton growth was light-limited (Cloern 1987; Alpine and Cloern 1988). Delta Smelt distribution and habitat influence management decisions for issues ranging from California water supply to dredging of harbors and channels. Reductions in observed turbidity in the San Francisco Estuary are of concern due to the potential importance of elevated turbidity to habitat for endangered fishes such as Delta Smelt.

Turbidity is a metric based on the optical properties of a water sample that act to scatter light at a specific angle emitted by an instrument (Davies-Colley and Smith 2001; Gray and Gartner 2009), and turbidity is correlated to the amount of sediment suspended in the water column in many coastal, estuarine, and riverine environments. The suspended sediment concentration (SSC) is defined as the mass of sediment in a given volume of water and is primarily driven by sediment resuspension from the seabed and upward mixing by turbulence, sediment settling and deposition on the seabed, and external sediment supply (e.g., river inflows) (Hill and MacCave 2001). SSC is often estimated by measuring the water turbidity and then converting the turbidity to SSC (see Schoellhamer et al. 2002; Fain et al. 2007; Gray and Gartner 2009; Buchanan and Morgan 2012; Nowacki and Ogston 2013). Turbidity is used as a surrogate for SSC because it is easy to observe and the emitted light is scattered primarily by sediment suspended within the water column (Davies-Colley and Smith 2001; Gray and Gartner 2009). As a result, there is a direct relationship between turbidity (nephelometric turbidity units, NTU) and SSC (mg/L), as long as the sediment size

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Communicated by Carl T. Friedrichs

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Springer

Source: Bever et al. 2018

Standards for Assessment of Model Accuracy

<table>
<tr><th colspan="2">Model accuracy</th><th>Water level</th><th>Flow</th><th>Salinity</th><th>Current speed</th></tr>
<tr><td rowspan="3">Skill accuracy</td><td>Accurate</td><td>>0.975</td><td>>0.975</td><td>>0.85</td><td>>0.9</td></tr>
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<tr><td>Poor agreement</td><td><0.95</td><td><0.95</td><td><0.7</td><td><0.8</td></tr>
<tr><td rowspan="4">Target accuracy</td><td>Very accurate</td><td colspan="4">0.0 - 0.25</td></tr>
<tr><td>Accurate</td><td colspan="4">0.25 - 0.5</td></tr>
<tr><td>Acceptable</td><td colspan="4">0.5 - 1.0</td></tr>
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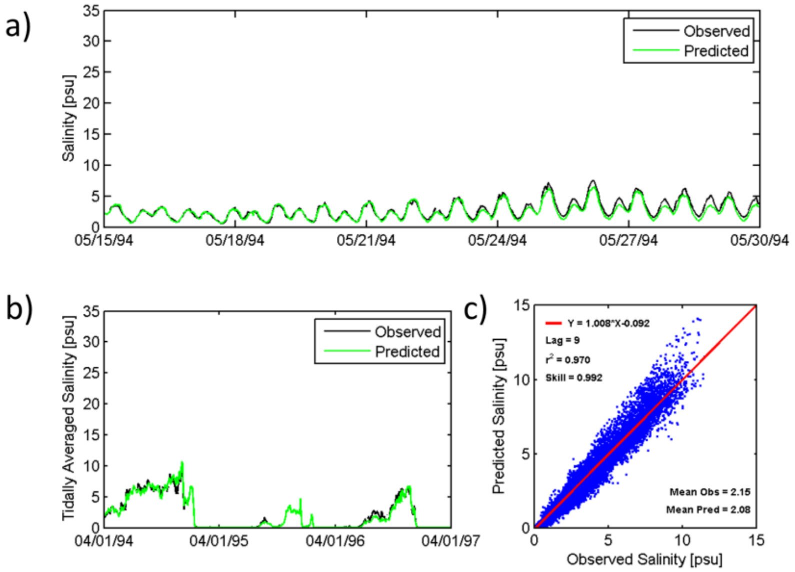

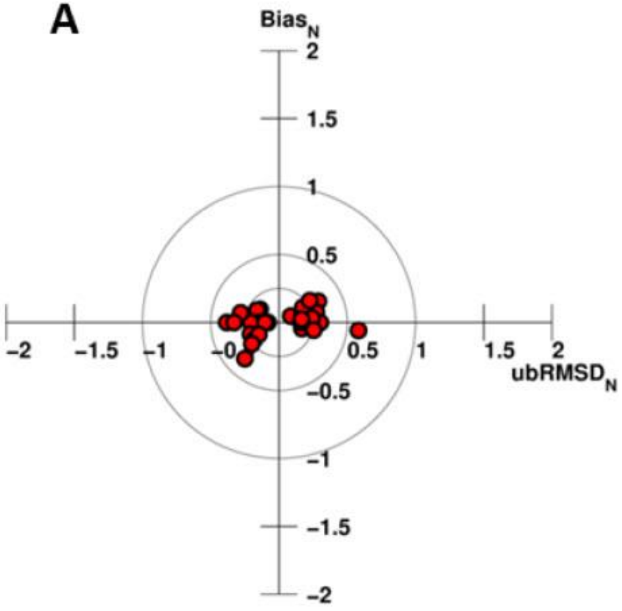

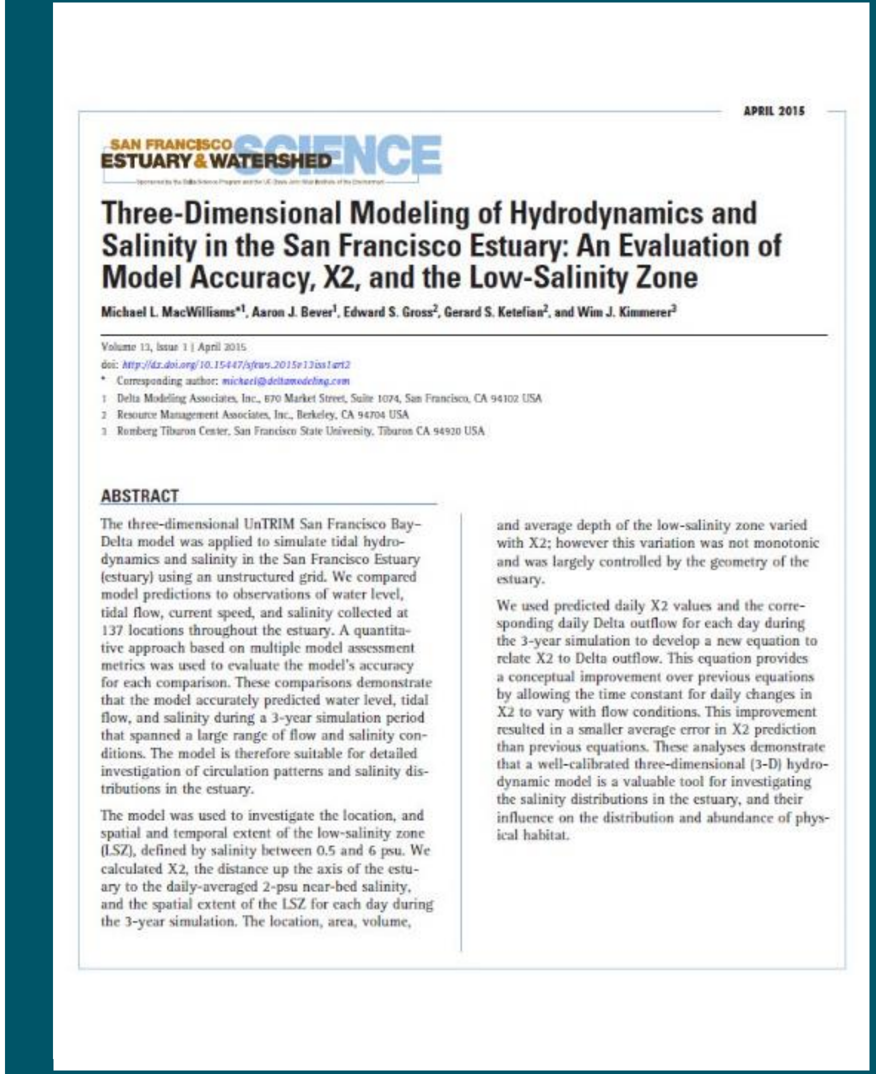

APRIL 2015

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

Three-Dimensional Modeling of Hydrodynamics and Salinity in the San Francisco Estuary: An Evaluation of Model Accuracy, X2, and the Low-Salinity Zone

Michael L. MacWilliams*[1], Aaron J. Bever[1], Edward S. Gross[2], Gerard S. Ketefian[2], and Wim J. Kimmerer[3]

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ABSTRACT

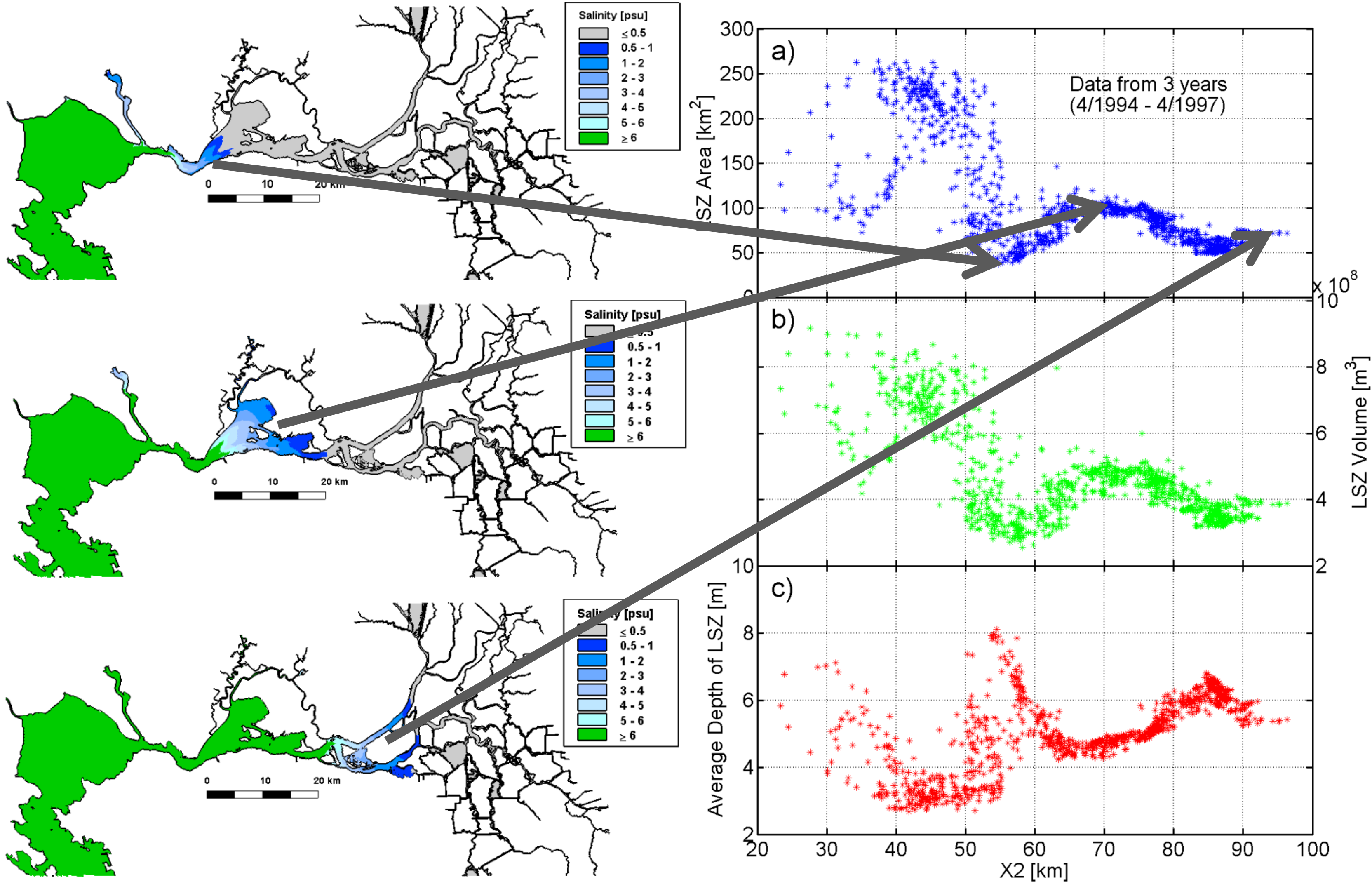
The three-dimensional UnTRIM San Francisco Bay–Delta model was applied to simulate tidal hydrodynamics and salinity in the San Francisco Estuary (estuary) using an unstructured grid. We compared model predictions to observations of water level, tidal flow, current speed, and salinity collected at 137 locations throughout the estuary. A quantitative approach based on multiple model assessment metrics was used to evaluate the model's accuracy for each comparison. These comparisons demonstrate that the model accurately predicted water level, tidal flow, and salinity during a 3-year simulation period that spanned a large range of flow and salinity conditions. The model is therefore suitable for detailed investigation of circulation patterns and salinity distributions in the estuary.

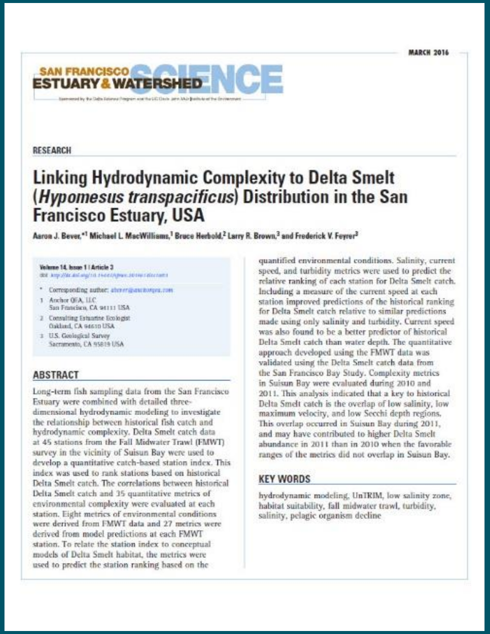
The model was used to investigate the location, and spatial and temporal extent of the low-salinity zone (LSZ), defined by salinity between 0.5 and 6 psu. We calculated X2, the distance up the axis of the estuary to the daily-averaged 2-psu near-bed salinity, and the spatial extent of the LSZ for each day during the 3-year simulation. The location, area, volume, and average depth of the low-salinity zone varied with X2; however this variation was not monotonic and was largely controlled by the geometry of the estuary.

We used predicted daily X2 values and the corresponding daily Delta outflow for each day during the 3-year simulation to develop a new equation to relate X2 to Delta outflow. This equation provides a conceptual improvement over previous equations by allowing the time constant for daily changes in X2 to vary with flow conditions. This improvement resulted in a smaller average error in X2 prediction than previous equations. These analyses demonstrate that a well-calibrated three-dimensional (3-D) hydrodynamic model is a valuable tool for investigating the salinity distributions in the estuary, and their influence on the distribution and abundance of physical habitat.

Source: MacWilliams et al. 2015

X2 and the Low Salinity Zone





MARCH 2016

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

RESEARCH

Linking Hydrodynamic Complexity to Delta Smelt (*Hypomesus transpacificus*) Distribution in the San Francisco Estuary, USA

Aaron J. Bever,*[1] Michael L. MacWilliams,[1] Bruce Herbold,[2] Larry R. Brown,[3] and Frederick V. Feyrer[3]

Volume 14, Issue 1 | Article 3

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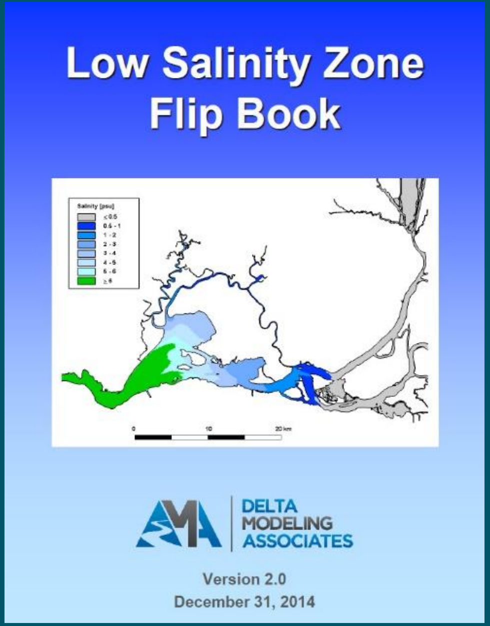
ABSTRACT

Long-term fish sampling data from the San Francisco Estuary were combined with detailed three-dimensional hydrodynamic modeling to investigate the relationship between historical fish catch and hydrodynamic complexity. Delta Smelt catch data at 45 stations from the Fall Midwater Trawl (FMWT) survey in the vicinity of Suisun Bay were used to develop a quantitative catch-based station index. This index was used to rank stations based on historical Delta Smelt catch. The correlations between historical Delta Smelt catch and 35 quantitative metrics of environmental complexity were evaluated at each station. Eight metrics of environmental conditions were derived from FMWT data and 27 metrics were derived from model predictions at each FMWT station. To relate the station index to conceptual models of Delta Smelt habitat, the metrics were used to predict the station ranking based on the quantified environmental conditions. Salinity, current speed, and turbidity metrics were used to predict the relative ranking of each station for Delta Smelt catch. Including a measure of the current speed at each station improved predictions of the historical ranking for Delta Smelt catch relative to similar predictions made using only salinity and turbidity. Current speed was also found to be a better predictor of historical Delta Smelt catch than water depth. The quantitative approach developed using the FMWT data was validated using the Delta Smelt catch data from the San Francisco Bay Study. Complexity metrics in Suisun Bay were evaluated during 2010 and 2011. This analysis indicated that a key to historical Delta Smelt catch is the overlap of low salinity, low maximum velocity, and low Secchi depth regions. This overlap occurred in Suisun Bay during 2011, and may have contributed to higher Delta Smelt abundance in 2011 than in 2010 when the favorable ranges of the metrics did not overlap in Suisun Bay.

KEY WORDS

hydrodynamic modeling, UnTRIM, low salinity zone, habitat suitability, fall midwater trawl, turbidity, salinity, pelagic organism decline

Source: Bever et al. 2016



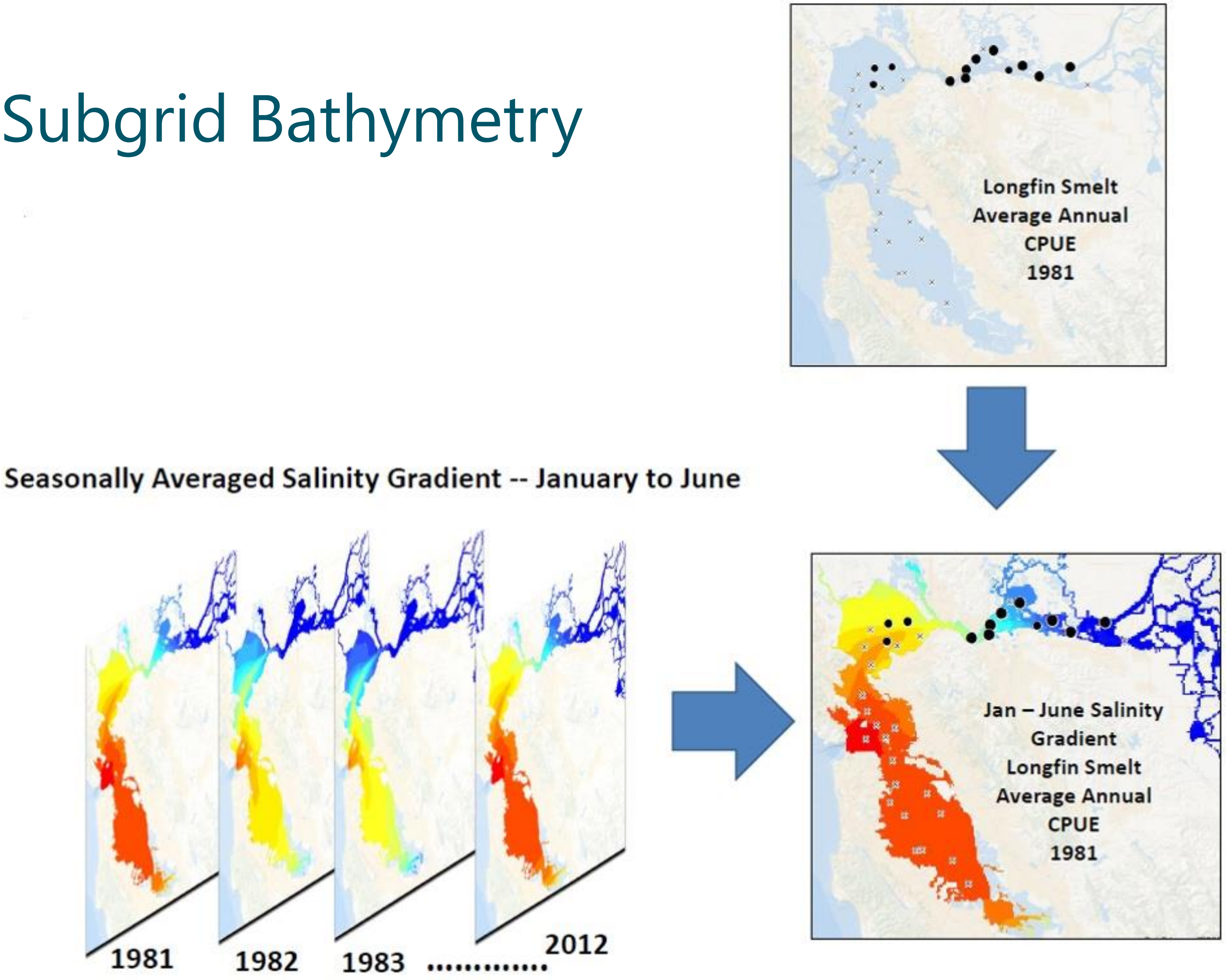
Low Salinity Zone Flip Book

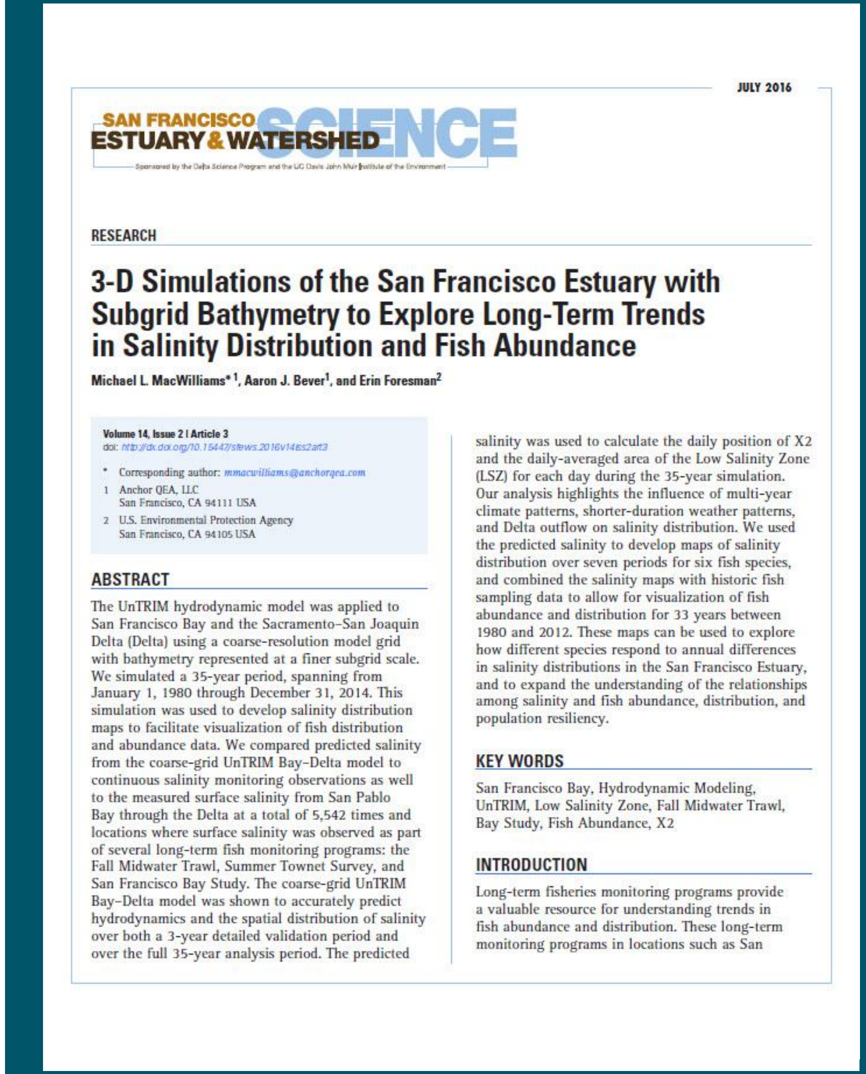
DELTA MODELING ASSOCIATES

Version 2.0
December 31, 2014

Source: Delta Modeling Associates 2014

Subgrid Bathymetry




JULY 2016

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE
Sponsored by the Delta Science Program and the UC Davis John Muir Institute of the Environment

RESEARCH

3-D Simulations of the San Francisco Estuary with Subgrid Bathymetry to Explore Long-Term Trends in Salinity Distribution and Fish Abundance

Michael L. MacWilliams*[1], Aaron J. Bever[1], and Erin Foresman[2]

Volume 14, Issue 2 | Article 3
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ABSTRACT

The UnTRIM hydrodynamic model was applied to San Francisco Bay and the Sacramento–San Joaquin Delta (Delta) using a coarse-resolution model grid with bathymetry represented at a finer subgrid scale. We simulated a 35-year period, spanning from January 1, 1980 through December 31, 2014. This simulation was used to develop salinity distribution maps to facilitate visualization of fish distribution and abundance data. We compared predicted salinity from the coarse-grid UnTRIM Bay–Delta model to continuous salinity monitoring observations as well to the measured surface salinity from San Pablo Bay through the Delta at a total of 5,542 times and locations where surface salinity was observed as part of several long-term fish monitoring programs: the Fall Midwater Trawl, Summer Townet Survey, and San Francisco Bay Study. The coarse-grid UnTRIM Bay–Delta model was shown to accurately predict hydrodynamics and the spatial distribution of salinity over both a 3-year detailed validation period and over the full 35-year analysis period. The predicted salinity was used to calculate the daily position of X2 and the daily-averaged area of the Low Salinity Zone (LSZ) for each day during the 35-year simulation. Our analysis highlights the influence of multi-year climate patterns, shorter-duration weather patterns, and Delta outflow on salinity distribution. We used the predicted salinity to develop maps of salinity distribution over seven periods for six fish species, and combined the salinity maps with historic fish sampling data to allow for visualization of fish abundance and distribution for 33 years between 1980 and 2012. These maps can be used to explore how different species respond to annual differences in salinity distributions in the San Francisco Estuary, and to expand the understanding of the relationships among salinity and fish abundance, distribution, and population resiliency.

KEY WORDS

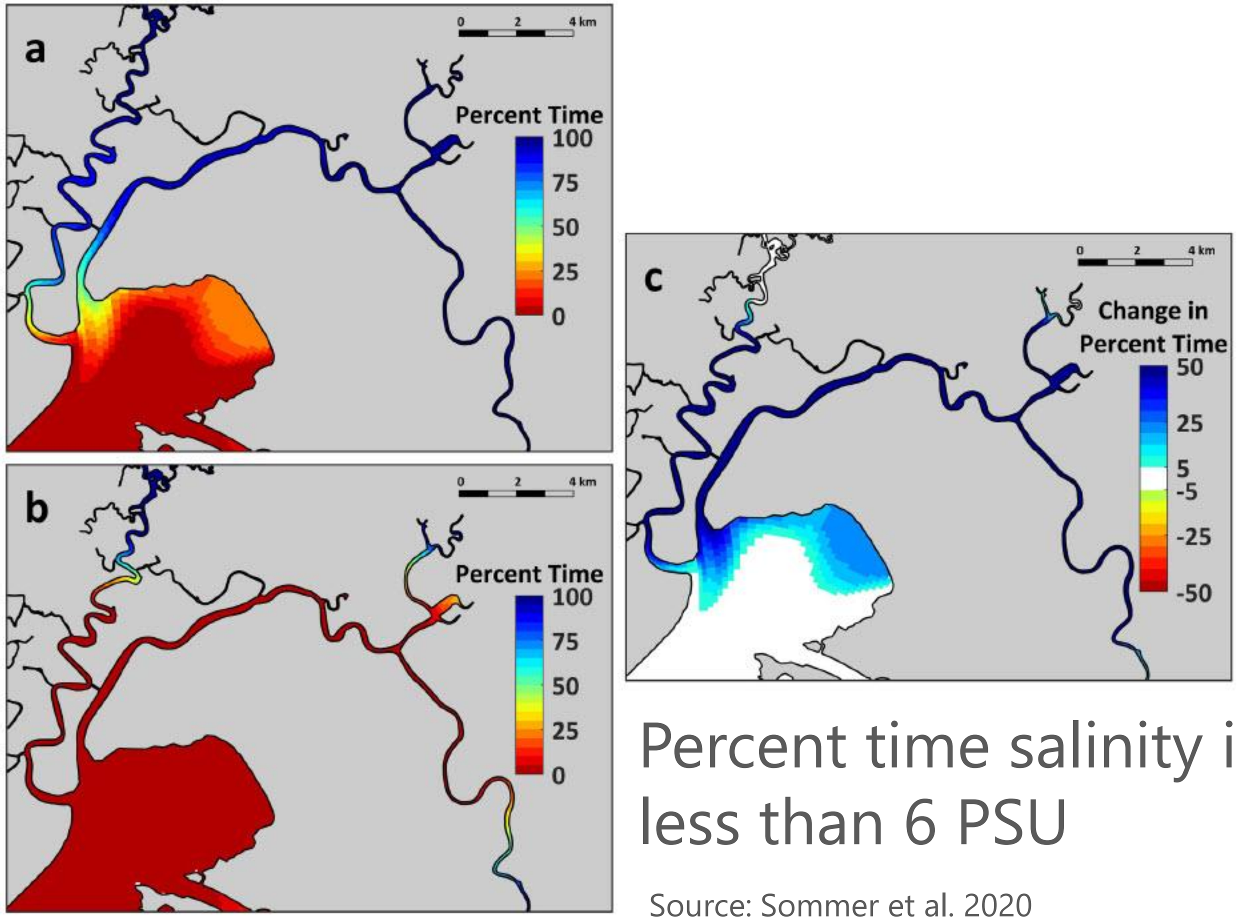
San Francisco Bay, Hydrodynamic Modeling, UnTRIM, Low Salinity Zone, Fall Midwater Trawl, Bay Study, Fish Abundance, X2

INTRODUCTION

Long-term fisheries monitoring programs provide a valuable resource for understanding trends in fish abundance and distribution. These long-term monitoring programs in locations such as San

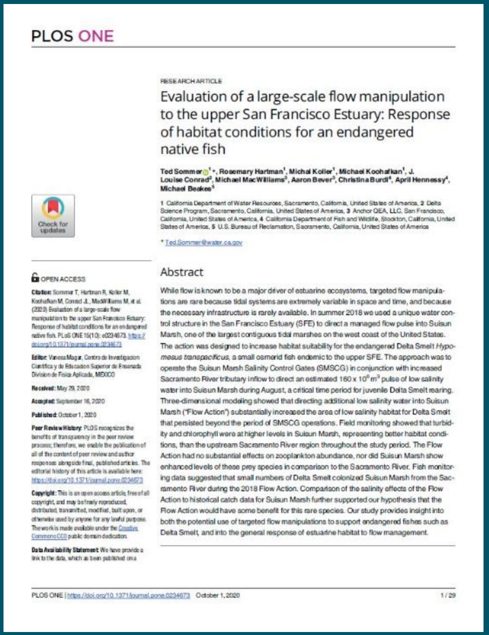
Source: MacWilliams et al. 2016a

Planning Large-Scale Flow Operations for Management of Estuarine Habitat



Percent time salinity is less than 6 PSU

Source: Sommer et al. 2020



PLOS ONE

RESEARCH ARTICLE

Evaluation of a large-scale flow manipulation to the upper San Francisco Estuary: Response of habitat conditions for an endangered native fish

Ted Sommer[1]*, Rosemary Hartman[1], Michal Koller[1], Michael Koohafkan[1], J. Louise Conrad[2], Michael MacWilliams[3], Aaron Bever[3], Christina Burdi[4], April Hennessy[4], Michael Beakes[5]

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OPEN ACCESS

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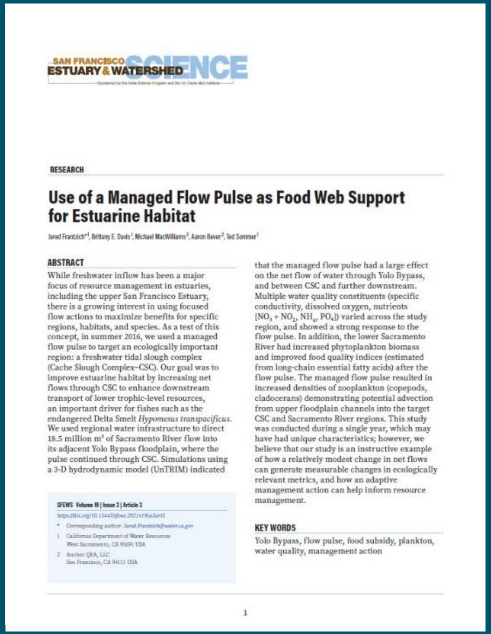
Data Availability Statement: We have provide a link to the data, which as been published on a

Abstract

While flow is known to be a major driver of estuarine ecosystems, targeted flow manipulations are rare because tidal systems are extremely variable in space and time, and because the necessary infrastructure is rarely available. In summer 2018 we used a unique water control structure in the San Francisco Estuary (SFE) to direct a managed flow pulse into Suisun Marsh, one of the largest contiguous tidal marshes on the west coast of the United States. The action was designed to increase habitat suitability for the endangered Delta Smelt *Hypomesus transpacificus*, a small osmerid fish endemic to the upper SFE. The approach was to operate the Suisun Marsh Salinity Control Gates (SMSCG) in conjunction with increased Sacramento River tributary inflow to direct an estimated $160 \times 10^6\ m^3$ pulse of low salinity water into Suisun Marsh during August, a critical time period for juvenile Delta Smelt rearing. Three-dimensional modeling showed that directing additional low salinity water into Suisun Marsh ("Flow Action") substantially increased the area of low salinity habitat for Delta Smelt that persisted beyond the period of SMSCG operations. Field monitoring showed that turbidity and chlorophyll were at higher levels in Suisun Marsh, representing better habitat conditions, than the upstream Sacramento River region throughout the study period. The Flow Action had no substantial effects on zooplankton abundance, nor did Suisun Marsh show enhanced levels of these prey species in comparison to the Sacramento River. Fish monitoring data suggested that small numbers of Delta Smelt colonized Suisun Marsh from the Sacramento River during the 2018 Flow Action. Comparison of the salinity effects of the Flow Action to historical catch data for Suisun Marsh further supported our hypothesis that the Flow Action would have some benefit for this rare species. Our study provides insight into both the potential use of targeted flow manipulations to support endangered fishes such as Delta Smelt, and into the general response of estuarine habitat to flow management.

PLOS ONE | https://doi.org/10.1371/journal.pone.0234673 October 1, 2020 1 / 29

Source: Sommer et al. 2020



SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

RESEARCH

Use of a Managed Flow Pulse as Food Web Support for Estuarine Habitat

Jared Frantzich*[1], Brittany E. Davis[1], Michael MacWilliams[2], Aaron Bever[2], Ted Sommer[1]

ABSTRACT

While freshwater inflow has been a major focus of resource management in estuaries, including the upper San Francisco Estuary, there is a growing interest in using focused flow actions to maximize benefits for specific regions, habitats, and species. As a test of this concept, in summer 2016, we used a managed flow pulse to target an ecologically important region: a freshwater tidal slough complex (Cache Slough Complex–CSC). Our goal was to improve estuarine habitat by increasing net flows through CSC to enhance downstream transport of lower trophic-level resources, an important driver for fishes such as the endangered Delta Smelt *Hypomesus transpacificus*. We used regional water infrastructure to direct 18.5 million m^3 of Sacramento River flow into its adjacent Yolo Bypass floodplain, where the pulse continued through CSC. Simulations using a 3-D hydrodynamic model (UnTRIM) indicated that the managed flow pulse had a large effect on the net flow of water through Yolo Bypass, and between CSC and further downstream. Multiple water quality constituents (specific conductivity, dissolved oxygen, nutrients [$NO_3 + NO_2$, NH_4, PO_4]) varied across the study region, and showed a strong response to the flow pulse. In addition, the lower Sacramento River had increased phytoplankton biomass and improved food quality indices (estimated from long-chain essential fatty acids) after the flow pulse. The managed flow pulse resulted in increased densities of zooplankton (copepods, cladocerans) demonstrating potential advection from upper floodplain channels into the target CSC and Sacramento River regions. This study was conducted during a single year, which may have had unique characteristics; however, we believe that our study is an instructive example of how a relatively modest change in net flows can generate measurable changes in ecologically relevant metrics, and how an adaptive management action can help inform resource management.

SFEWS Volume 19 | Issue 3 | Article 3

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KEY WORDS

Yolo Bypass, flow pulse, food subsidy, plankton, water quality, management action

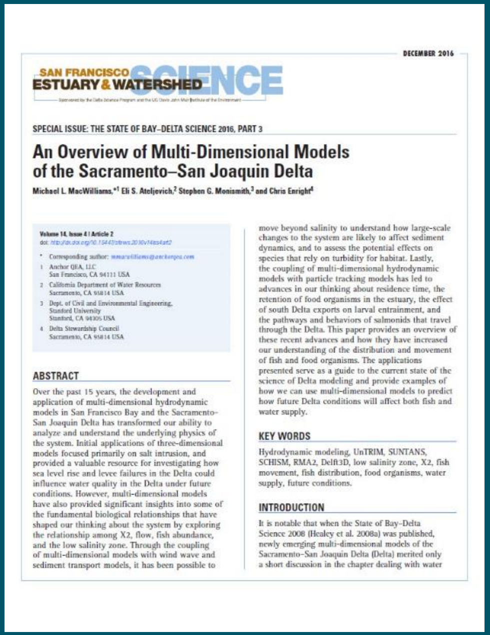
1

Source: Frantzich et al. 2021

Closing Thoughts

> “The challenge for the multi-dimensional modeler then becomes to take the enormous amount of information generated by the model and present it in a way that can be used to increase understanding of the system, without averaging out all of the important details.”

MacWilliams et al. 2016b (*State of Bay-Delta Science*)



DECEMBER 2016

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

Sponsored by the Delta Science Program and the UC Davis John Muir Institute of the Environment

SPECIAL ISSUE: THE STATE OF BAY–DELTA SCIENCE 2016, PART 3

An Overview of Multi-Dimensional Models of the Sacramento–San Joaquin Delta

Michael L. MacWilliams,*[1] Eli S. Ateljevich,[2] Stephen G. Monismith,[3] and Chris Enright[4]

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doi: http://dx.doi.org/10.15447/sfews.2016v14iss4art2

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ABSTRACT

Over the past 15 years, the development and application of multi-dimensional hydrodynamic models in San Francisco Bay and the Sacramento-San Joaquin Delta has transformed our ability to analyze and understand the underlying physics of the system. Initial applications of three-dimensional models focused primarily on salt intrusion, and provided a valuable resource for investigating how sea level rise and levee failures in the Delta could influence water quality in the Delta under future conditions. However, multi-dimensional models have also provided significant insights into some of the fundamental biological relationships that have shaped our thinking about the system by exploring the relationship among X2, flow, fish abundance, and the low salinity zone. Through the coupling of multi-dimensional models with wind wave and sediment transport models, it has been possible to move beyond salinity to understand how large-scale changes to the system are likely to affect sediment dynamics, and to assess the potential effects on species that rely on turbidity for habitat. Lastly, the coupling of multi-dimensional hydrodynamic models with particle tracking models has led to advances in our thinking about residence time, the retention of food organisms in the estuary, the effect of south Delta exports on larval entrainment, and the pathways and behaviors of salmonids that travel through the Delta. This paper provides an overview of these recent advances and how they have increased our understanding of the distribution and movement of fish and food organisms. The applications presented serve as a guide to the current state of the science of Delta modeling and provide examples of how we can use multi-dimensional models to predict how future Delta conditions will affect both fish and water supply.

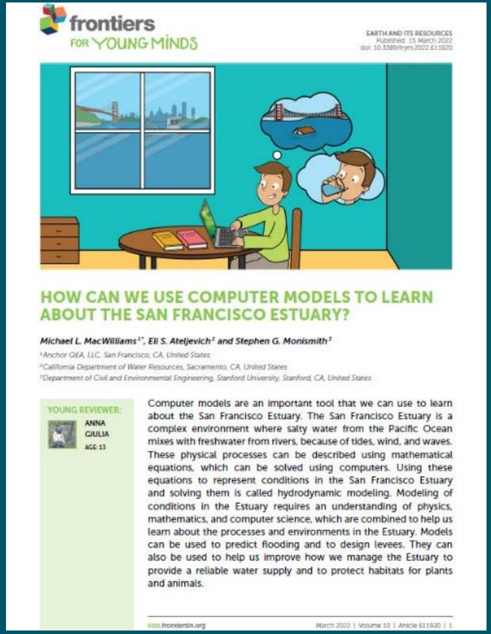
KEY WORDS

Hydrodynamic modeling, UnTRIM, SUNTANS, SCHISM, RMA2, Delft3D, low salinity zone, X2, fish movement, fish distribution, food organisms, water supply, future conditions.

INTRODUCTION

It is notable that when the State of Bay–Delta Science 2008 (Healey et al. 2008a) was published, newly emerging multi-dimensional models of the Sacramento–San Joaquin Delta (Delta) merited only a short discussion in the chapter dealing with water

Source: MacWilliams et al. 2016b



frontiers FOR YOUNG MINDS

EARTH AND ITS RESOURCES
Published: 15 March 2022
doi: 10.3389/frym.2022.611920

HOW CAN WE USE COMPUTER MODELS TO LEARN ABOUT THE SAN FRANCISCO ESTUARY?

Michael L. MacWilliams[1], Eli S. Ateljevich[2] and Stephen G. Monismith[3]*

[1]Anchor QEA, LLC, San Francisco, CA, United States
[2]California Department of Water Resources, Sacramento, CA, United States
[3]Department of Civil and Environmental Engineering, Stanford University, Stanford, CA, United States

YOUNG REVIEWER:
ANNA GIULIA
AGE: 13

Computer models are an important tool that we can use to learn about the San Francisco Estuary. The San Francisco Estuary is a complex environment where salty water from the Pacific Ocean mixes with freshwater from rivers, because of tides, wind, and waves. These physical processes can be described using mathematical equations, which can be solved using computers. Using these equations to represent conditions in the San Francisco Estuary and solving them is called hydrodynamic modeling. Modeling of conditions in the Estuary requires an understanding of physics, mathematics, and computer science, which are combined to help us learn about the processes and environments in the Estuary. Models can be used to predict flooding and to design levees. They can also be used to help us improve how we manage the Estuary to provide a reliable water supply and to protect habitats for plants and animals.

kids.frontiersin.org March 2022 | Volume 10 | Article 611920 | 1

Source: MacWilliams et al. 2022

Thank you!

Source: MacWilliams et al. 2022

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