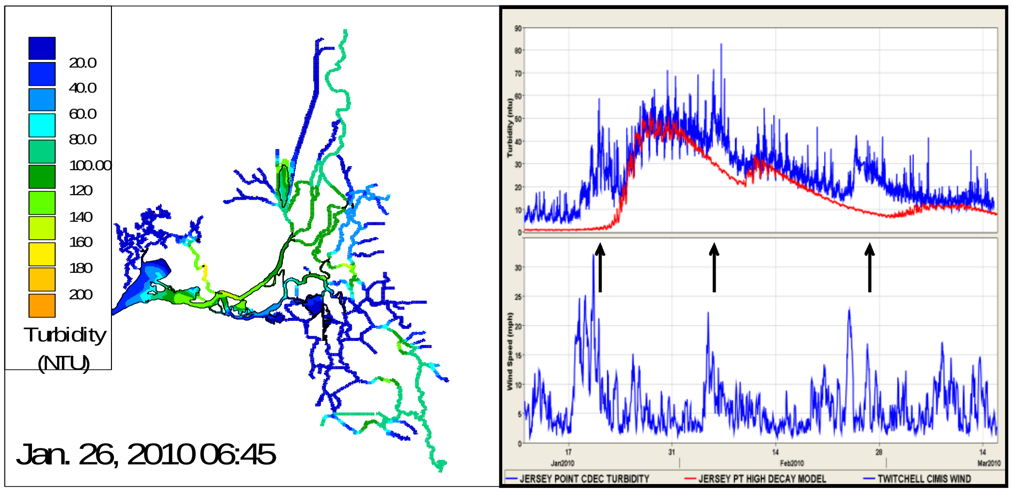
Turbidity and Adult Delta Smelt Modeling with RMA 2-D Models: November 2011 – February 2012



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1 Executive Summary

Metropolitan Water District of Southern California (MWD) has directed RMA to conduct weekly real-time modeling of the turbidity and Delta Smelt movement in the Sacramento-San Joaquin Delta using the RMA Bay-Delta Model and the Delta Smelt particle tracking model for Water Year 2012. This effort has produced weekly forecast information on turbidity and smelt movement in the Delta. RMA is tasked to improve the model accuracy and to streamline the forecast process, so that the forecast information will be shared in a timely manner to water/environmental communities, to enable improved water Projects operation, therefore, it will potentially reduce the Delta smelt salvage, and improve the export water supply.

As part of the 2-Gate project, MWD funded the development and application of a transport model simulating the distribution of turbidity in the Delta and a particle tracking model simulating a habitat-seeking behavior for adult delta smelt (RMA 2008, 2009a, 2009b, 2010a, 2010b, 2011). The particle tracking model uses EC and turbidity gradients as well as hydrodynamics to drive delta smelt movement, simulating their hypothesized turbidity-seeking behavior and their potential to become "salvage" in the State Water Project (SWP) and Central Valley Project (CVP) export locations.

This document describes technical improvements and the modeling results in Water Year 2012 (WY2012) for simulating flow, turbidity, EC and delta smelt behavior using RMA models for forecasting simulations and for the hindcast simulation. Previous documentation (RMA, 2010b) covered the calibration efforts for the turbidity model. As mentioned in this previous documentation (RMA, 2010b), turbidity modeling does not incorporate the in-Delta storage and release of sediments, for example due to changes in channel velocity or wind-driven effects, so RMA's turbidity model cannot capture these sinks and sources of turbidity. Also, the turbidity model calibration was optimized to perform best under high flow, high turbidity conditions.

WY2012 marks the third year this combination of models has been used to forecast turbidity and adult delta smelt movement in the Delta. Forecasting runs were infrequent in Water Year (WY) 2010 as the methodology was just being developed. The process used in WY2011 became very time consuming as it introduced the potential use of WARMF model turbidity boundary conditions into the forecast process. Because the WARMF sediment model was undergoing development during the forecasting season, WARMF turbidity forecast results were not reliable enough to use effectively for weekly forecasts.

For WY2012, MWD directed RMA to produce a series of weekly forecasts during the period December 05, 2011 – March 02, 2012, and to streamline the forecasting process. The weather was unusually dry during this period and, as a consequence, the utility of forecasting runs in supplying information on monitoring or controlling turbidity was limited. The one rain event that did occur produced very little turbidity on the tributaries and thus only a minor rise in Delta turbidity. Turbidity data was unusually noisy this forecasting season, and difficult to "clean" (*i.e.*, it was difficult to remove suspect data) as measured turbidities in the Delta were very low. However, this uneventful water year allowed RMA to improve our forecasting strategy and methodology in a coordinated manner and to develop and test several utility programs. RMA also worked closely with 34North to post RMA forecasting results and documentation on the Bay Delta Live website.

In a separate document, we illustrate the substantial improvements made in WARMF turbidity modeling developed during a joint RMA/Systech subtask this year, WY2012. Under this subtask, RMA incorporated the results of updates to the WARMF hindcast model as RMA model boundary conditions to determine the downstream (in-Delta) consequences of WARMF's model output. After each run, RMA would analyze the results of new WY2010 and WY2011 hindcasts, send result plots comparing RMA model output to turbidity data, and recommend turbidity and/or flow boundaries that needed to be improved in the WARMF model. As illustrated in that document, this was a successful collaboration with Yolo, Cosumnes, Mokelumne and Calaveras River locations showing substantial improvement. The Sacramento and San Joaquin River boundaries still require some improvement as indicated by the hindcast simulations.

A utility program was developed to improve the speed and accuracy of RMA model forecast boundary conditions. As a consequence, the ease of boundary condition development has improved considerably. More importantly, the QA/QC process has improved greatly and a naming convention has been standardized for use in the utility program during boundary condition development. A scenario utility program was developed to automate the production of SWP exports boundary conditions under alternate forecast scenarios – note that RMA and MWD staff agreed that alternative scenarios were restricted to changes in export volume and timing. RMA did not have the opportunity to test the utility program developed for use in scenarios, as the hydrologic conditions this year did not necessitate alternate scenarios. However, the methodology was tested using the WY2011 scenario.

RMA also developed a methodology to forecast salinity boundary conditions at Martinez, and was able to forecast salinity conditions in the Delta by the end of the forecast period. The unusual nature of this water year highlighted a need to update the salinity model calibration and just upstream of the western model boundary at Martinez.

Hindcast model results are documented in Section 5. The single significant turbidity event in late January was captured well by the model, and resulted in a brief period of elevated central Delta turbidities which quickly dissipated. A turbidity bridge never formed in the south/central Delta regions during the hindcast, and the adult delta smelt behavioral model showed few particles reaching the export locations. This was in general agreement with the salvage data.

The following are suggestions on ways to improve the forecast modeling and the presentation of results:

- Develop an RMA11 sediment model. As indicated in the companion document (RMA, 2012) illustrating the interaction between RMA and WARMF turbidity results, the ability of WARMF to simulate turbidity as RMA model boundaries has improved dramatically. As WARMF actually models suspended sediment, the movement to a sediment model using improved WARMF model output is a natural next step that would increase acceptance of the modeling results in the scientific community.

- Continue the collaboration between Systech and RMA to further improve the WARMF Sacramento and San Joaquin hindcast results for turbidity.
- Test the ability of the adult delta smelt model results to estimate the location of adult smelt by comparison with Spring Kodiak Trawl data. This would be accomplished by having Systech hindcast turbidity boundary conditions in years when the delta smelt populations were higher and the salvage numbers of the pumps indicate the potential for turbidity-influenced movement in the Delta.
- Include a mechanism of wind-driven re-suspension in the turbidity model.

2 Objectives

The objectives of the project are: to conduct weekly flow, EC and turbidity forecast in the work documented in this report were to: produce at least seven and up to eleven turbidity, salinity, flow and adult delta smelt model forecasts for the wet season of WY2012; streamline the methodology for producing weekly forecasts; develop an improved forecast boundary condition methodology for the RMA11 salinity model; develop a methodology for producing boundary conditions for scenarios altering export flows in anticipation of the need to control the movement of turbidity into the central and south Delta; and, to work with 34North to post RMA forecast results on the Bay-Delta Live website.

3 Background

The work discussed in this document builds on previous work funded by MWD to develop methodologies to model and forecast turbidity (RMA 2008, 2009a, 2009b, 2010a, 2010b, 2011) and to simulate the movement of adult delta smelt. Smelt movements are simulated during periods of high Delta inflow based on simulated distributions of salinity (represented as electrical conductivity, EC) and turbidity, using a particle tracking behavior model (RMA, 2008). Because turbidity is hypothesized as an important driver for the distribution of adult delta smelt, the ability to minimize adult entrainment is assumed to be dependent on monitoring and potentially controlling the progress of turbidity plumes from the Sacramento and San Joaquin Rivers (or other boundary inflows) into the central Delta.

The reader is referred to the documentation cited above for background on the RMA models, and the development of the turbidity and adult delta smelt applications.

4 Forecasting for WY2012

This section provides brief summaries of the individual forecasts produced for WY2012, as well as some developments and issues encountered this forecasting season. This section only includes brief descriptions of the technical work – the majority of the documentation is included as appendices, and the work is referenced as such in the text. The methodology for assembling the necessary boundary conditions and data files for each weekly forecast did not change substantially from WY2011, and is described in detail in the WY2011 hindcast documentation (RMA, 2011).

4.1 Weekly forecast summaries

Model boundary conditions for the forecast models were developed using several sources for historical and forecast conditions including: CNRFC flow data and predictions, CDEC and USGS data, and DWR-supplied model inputs and results from their flow and salinity forecasts. Boundary conditions were prepared using these data sources and using professional judgment where necessary to resolve data discrepancies and to piece the data together for reasonable BC. In addition, WARMF model boundary conditions were used during the forecast period at several locations.

4.2 WARMF model boundary conditions[1]

In forecast mode, WARMF simulations require real-time and forecast time series data to drive the simulation. There are five types of time series data used as inputs to the WARMF model: meteorology, air and rain chemistry, point sources, reservoir releases, and diversions. Data up to real-time is collected for those model inputs for which it is available—reservoir releases and many meteorology stations. All remaining time series inputs except meteorology are filled in by extrapolation using average values for each day of the year based on the historical record.

There are seven meteorology parameters used by WARMF: precipitation, minimum temperature, maximum temperature, cloud cover, dewpoint temperature, air pressure, and wind speed. The 6-day forecast meteorology is collected from the National Weather Service and entered into the WARMF database. Missing past and future meteorology data is filled in by comparing stations with missing data to nearby stations which have more complete data. Meteorology beyond the 6-day forecast window is filled in by extrapolation. All but precipitation are extrapolated by calculating the average value for each day of the year from historical data and then applying that average in the extrapolation. Extrapolated precipitation is defaulted to zero.

Forecast reservoir releases are acquired from the California Data Exchange Center and entered into the WARMF time series database. Reservoir releases beyond the scheduled period are extrapolated by continuing the last scheduled release flow through the forecast period. WARMF is first run for at least one year prior to the forecast time period to establish good initial conditions for the forecast. Then the forecast is run using the updated time series inputs.

4.3 Internal boundary conditions

The turbidity model calibration was optimized to perform best under high flow, high turbidity conditions. Under the low flow, low turbidity conditions this season, the difference between model results and data was apparent. In order to improve the in-Delta modeled turbidity, a standard approach for forecast models was adopted – the use of Internal Boundary Conditions (IBCs). The IBCs were applied at several in-Delta data locations during the historical period – the IBCs were turned off during the forecast period.

The technical detail and comparisons of the model with- and without-IBC are given in Section 10 (Internal Boundary Condition Appendix).

[1] The text in this section was supplied by Systech. Small changes to the text were made to simplify wording.

4.4 Salinity Model Update – Martinez Boundary Condition, Salinity Calibration and DICU Issues

As mentioned in previous forecast documentation (RMA 2010a, 2011), the standard methodology for developing a salinity boundary condition at Martinez for the RMA11 uncoupled water quality model is to average top and bottom salinity measurements at Martinez. For DSM2 modeling which uses top salinity, DWR has used a utility developed several years ago to forecast Martinez top salinity. For WY2012, RMA modified and tested the DWR utility for use in forecasting bottom salinity.

When RMA applied this revised boundary condition in November 2011 to January 2012, it was observed that the model underestimated salinity in the western Delta. As we analyzed this problem, it was apparent that there were potentially three contributing factors:

1. The flow conditions this fall were very unusual – after a very wet winter, the high spring and summer flows on the Sacramento River kept salinity out the Delta. By fall, flows decreased very rapidly leading to a rapid increase in salinity intrusion in the Delta.
2. The dispersion coefficients in the western Delta were too low.
3. The DICU model (monthly flows and salinity) supplied by DWR for this forecast season was probably overestimating late fall and early winter agricultural return flows during this unusually dry period. Additionally, the salinity in these return flows was also suspect.

Each of these issues is discussed in detail in Section 11 (Salinity Appendix).

4.5 Forecast summary for WY2012

The hydrologic conditions of this forecast year proved uneventful as an extraordinarily dry period extended through the end of February. As a consequence, turbidity was low throughout the Delta, with conditions outside of the optimal range of the turbidity model calibration. RMA instituted an IBC methodology to optimize the modeled conditions in the Delta before each forecast. Although the dry period prompted the need for utilizing the IBC, the methodology has proven useful in a broader sense to improve pre-forecast estimates on turbidity in the Delta.

Although RMA received 2 weeks and 5 days of forecast flow and salinity boundary conditions from DWR's DSM2 forecasts, the forecast period presented in the weekly documentation was shortened to two weeks for several reasons (although the RMA models were run for 2 weeks and 5 days of forecast period). WARMF model boundary conditions relay on NOAA forecast data and reservoir release forecasts that extend for a five-day period in the future – past that time the forecast boundary conditions default to constants, averages or zero (see Section 4.2). Given travel time (during higher flow periods), this translates to approximately 10 days of good forecast conditions reaching the central Delta. As shown in Figure 11-1 and Figure 11-2, the period in which the salinity boundary condition forecast at Martinez looks reasonable extends about 5 to 6 days into the future. Given these considerations, it was decided that for documentation and posting on the Bay-Delta Live website, RMA would only present 2 weeks of the forecast period as representing the time during which forecast conditions represented the best official estimates of future flow and meteorological conditions.

5 RMA Model Hindcast for WY2012

The turbidity hindcast covers the period November 01, 2011 through March 01, 2012.

5.1 Boundary Condition Development

5.1.1 RMA2

The RMA2 boundary conditions were developed for the hindcast using the boundary conditions from the final forecast simulation of WY2012. Additional time series of flow and export data and gate operations supplied by DWR were appended to the final forecast of this season (February 16, 2012) to create the final hindcast input files. Figure 5-1 and Figure 5-3 illustrate the flow boundary conditions for the Sacramento River at Freeport and the San Joaquin River at Vernalis. Time series of flow entering the Delta from smaller tributaries are plotted in Figure 5-6, and daily averaged exports for the SWP and CVP are shown in Figure 5-7. Table 5-1 lists the flow boundary condition data sources for the hindcast, along with any modifications that were made to these data. Shifts in the CDEC downloaded flow record were seen in the San Joaquin at Vernalis time series in December (see Figure 5-3) and at the Calaveras River in November. These shifts were identified and corrected based on a comparison to the flow data reported on the USGS web site.

5.1.2 RMA11

Similarly to the RMA2 boundary condition development, RMA11 EC and turbidity boundary conditions were developed by appending observed data to time series developed during the last forecast period. CDEC reported EC and turbidity data were used for the Yolo Bypass (Cache-Ryer CDEC station), Cosumnes and Mokelumne Rivers (South Mokelumne CDEC station), and the Calaveras River (Rough and Ready Island CDEC station). Table 5-2 and Table 5-3 list the EC and turbidity boundary locations and the data sources used in the hindcast. The turbidity on the Sacramento River at Freeport is shown in Figure 5-2. A storm system bringing precipitation to the northern Sacramento River basin in mid-late January resulted in a turbidity peak of approximately 90 NTU on January 24, 2012. The San Joaquin at Vernalis turbidity boundary condition is shown in Figure 5-4, and Figure 5-5 presents the Martinez boundary turbidity.

5.2 Hindcast Results

5.2.1 Flow

Figure 5-17 through Figure 5-19 present hindcast flow simulation results in comparison with CDEC data at the corresponding locations. The top subplot of each figure shows 15 minute data, and the lower plot shows the tidally-averaged results. The comparison locations were chosen to represent important points along the known pathways for suspended sediment transport from north to south through the Delta. With the exception of the South Mokelumne River channel, where modeled results are still within 200-300 cfs of measured data, the modeled and observed data matched well.

5.2.2 Turbidity

Modeled turbidity results are compared against observed USGS data at the three compliance locations, Prisoner's Point, Victoria Canal, and Holland Cut, in Figure 5-20. Modeled turbidity at Prisoner's Point shows a good fit with observed data; turbidity values were predicted to increase to just above the compliance value (12 NTU) during the late January turbidity event. Measured values also increased significantly during this time, but peaked at just under compliance. Turbidity at Holland Cut was never significantly affected by turbidity from the Sacramento during the hindcast period and was instead dominated by resuspension from wind events. Since wind-induced resuspension is not explicitly accounted for in the turbidity model, these events were not captured by the model. Large wind events on December 1st and 22nd, January 7th and 22nd, and smaller wind events on February 15th and 23rd combined with elevated background turbidities, pushed observed turbidities levels above compliance. Figure 5-21 shows wind power, estimated as the wind speed cubed, for three CIMIS stations in the central Delta. The correspondence between large increases in wind power and turbidity at Holland Cut can clearly be seen, and is most likely due to transport of sediment suspended in the adjacent open water area of Franks Tract towards Holland Cut. Modeled turbidity at the Victoria Canal site was generally lower than observed. This was most likely due to generally low flow throughout the south Delta during the hindcast period and the omission of resuspension as a mechanism of turbidity increase. However, modeled Victoria Canal turbidities were still within a very small difference (2–5 NTU) of observed.

Figure 5-22 shows the comparison of turbidity at the SWP export location and turbidity measured inside Clifton Court Forebay (CCFB). Because of differences in flow conditions between the two sites, comparisons between these two locations should be made with caution. A general, low-turbidity trend is seen throughout the hindcast period at both locations, although wind resuspension in CCFB causes relatively higher turbidity values.

Figure 5-23 and Figure 5-24 show the progression and decay of the Sacramento and San Joaquin boundary turbidity traveling downstream through each river. Figure 5-25 through Figure 5-31 show comparisons of observed and modeled turbidities at seven locations throughout the Delta. Model agreement is very good during the high flow and turbidity pulses for which the model was originally calibrated, but produces turbidities on the low side of observed at southern sites where flows remained low throughout the hindcast.

5.2.3 Adult delta smelt behavioral model

Figure 5-32 through Figure 5-49 present weekly turbidity contour plots and particle tracking model results for the hindcast simulation starting November 1, 2011. Particles were inserted into Suisun Bay on November 1st and tracked for the remainder of the hindcast. From Suisun Bay, the particles quickly moved east to the Sacramento–San Joaquin confluence area and remained there until small increases in turbidity drew them up the Sacramento and San Joaquin rivers in early December. The turbidity event in late January caused movement into the Yolo Bypass region. Following that, particles remained in pockets near the Cache Slough–Sacramento confluence, the San Joaquin–Mokelumne confluence, the Yolo Bypass, and the Sacramento–San Joaquin confluence. This spatial distribution matched the general pattern observed by the CA Department of Fish and Game Spring Kodiak Trawl survey of delta smelt (Figure 5-50 and Figure 5-51). A very small percentage of modeled particles were predicted to reach the export locations, which was in general agreement with the small numbers of delta smelt salvage recorded at the pumps (Figure 5-52).

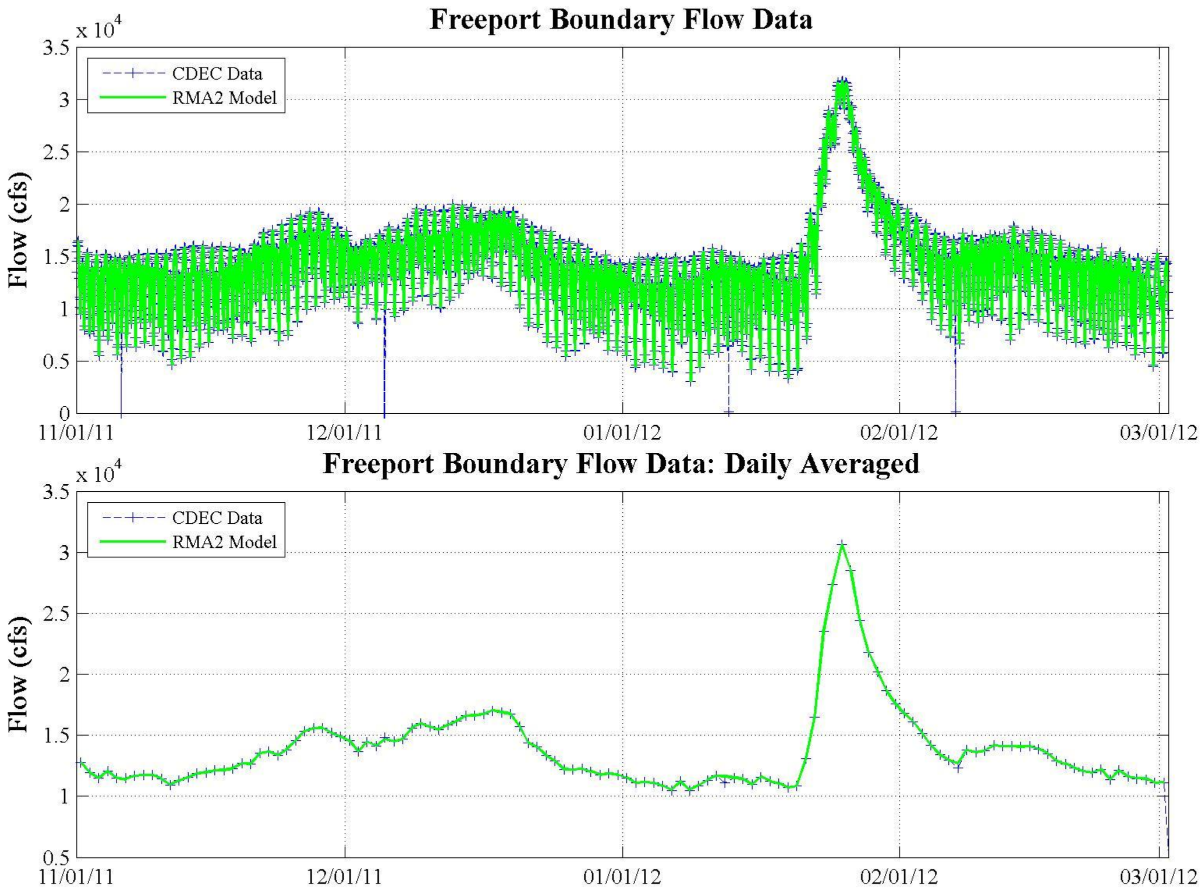

Figure 5-1 Sacramento River at Freeport flow boundary condition for hindcast, compiled using cleaned FPT CDEC data. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown. Note y-axis unit is cfs*10,000.

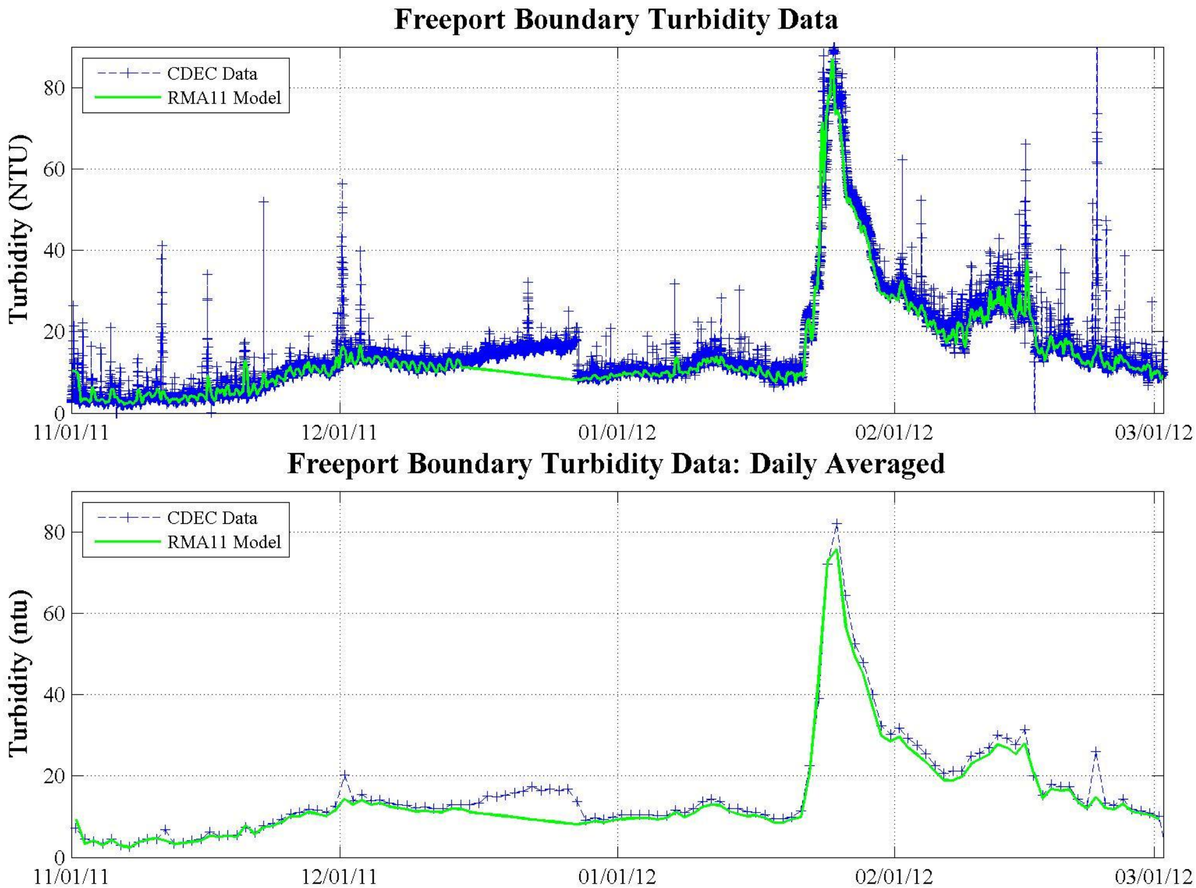

Figure 5-2 Sacramento River at Freeport turbidity boundary condition for hindcast, compiled using cleaned FPT CDEC data. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

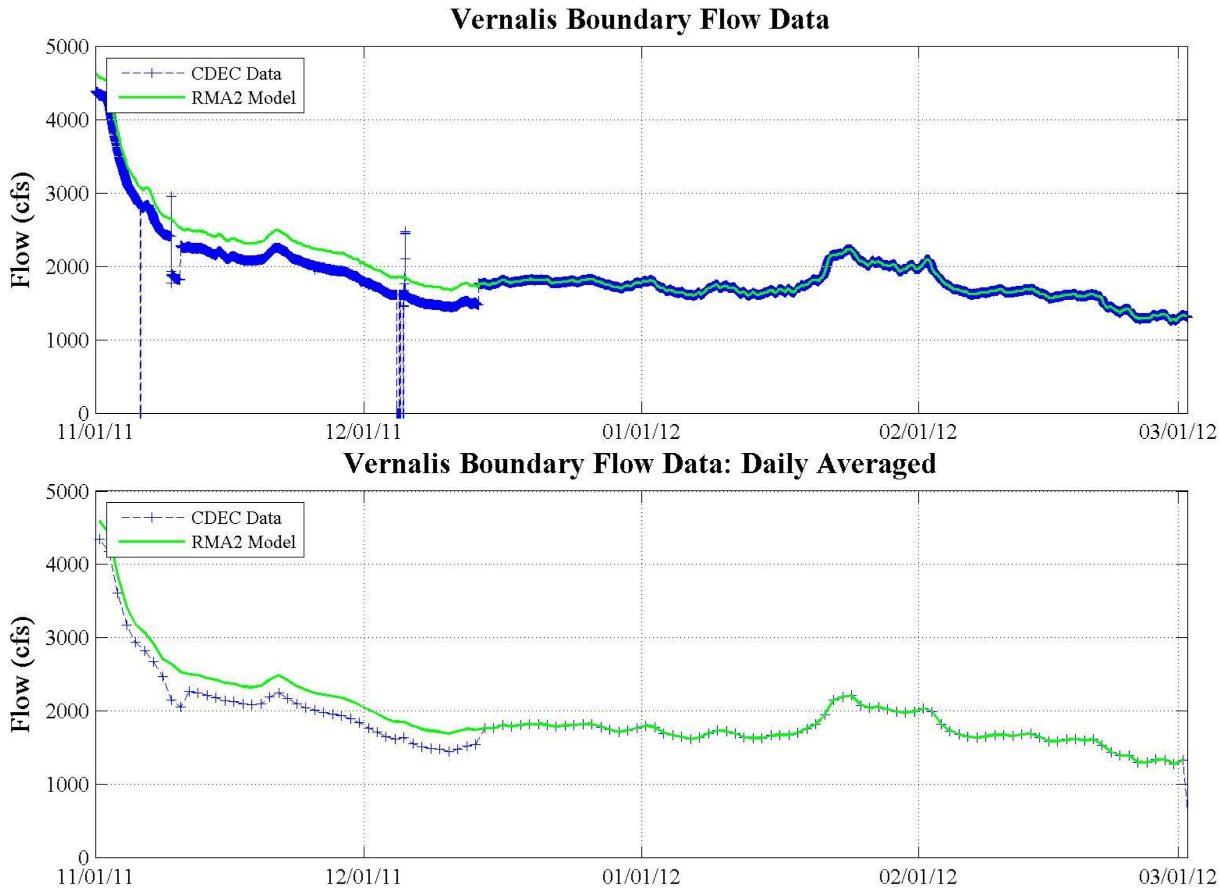

Figure 5-3 San Joaquin River at Vernalis flow boundary condition for hindcast, compiled using cleaned VNS CDEC data. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

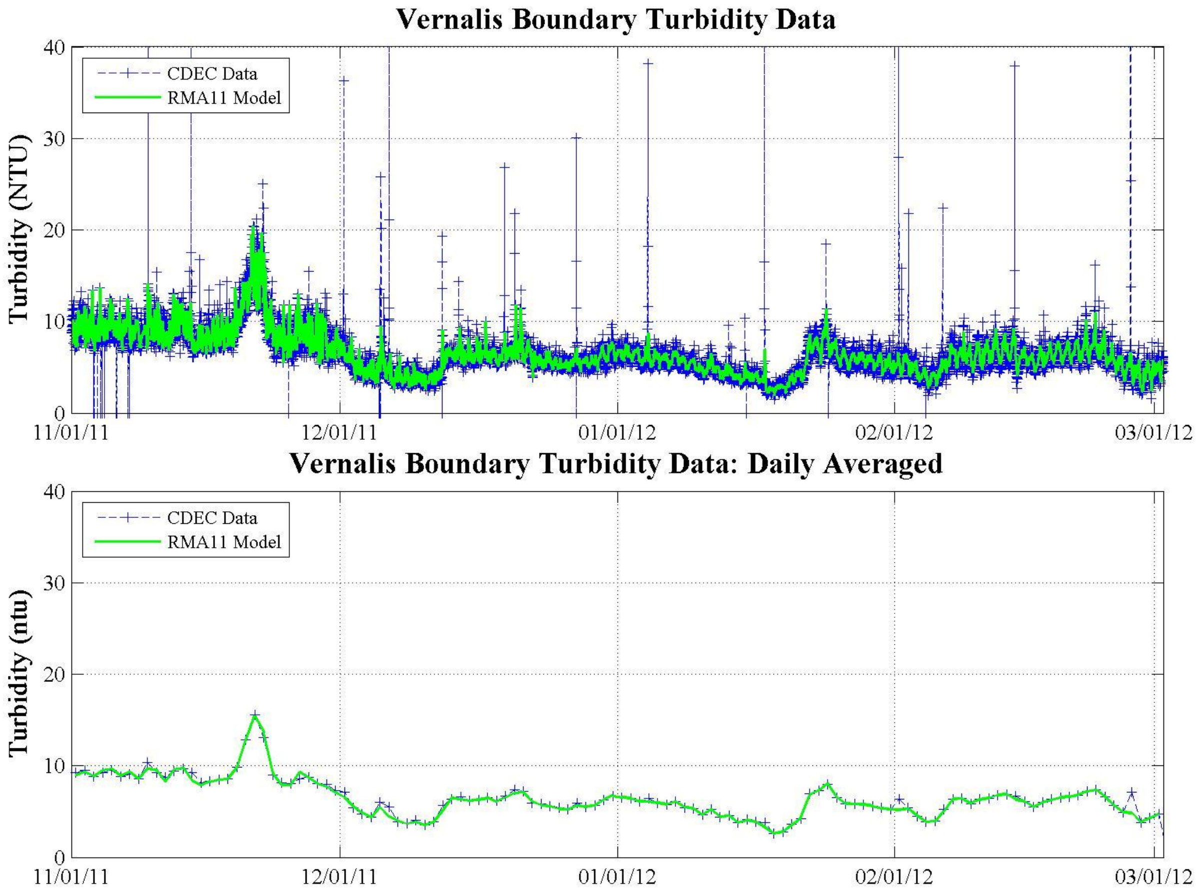

Figure 5-4 San Joaquin River at Vernalis turbidity boundary condition for hindcast, compiled using cleaned SJR CDEC data. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

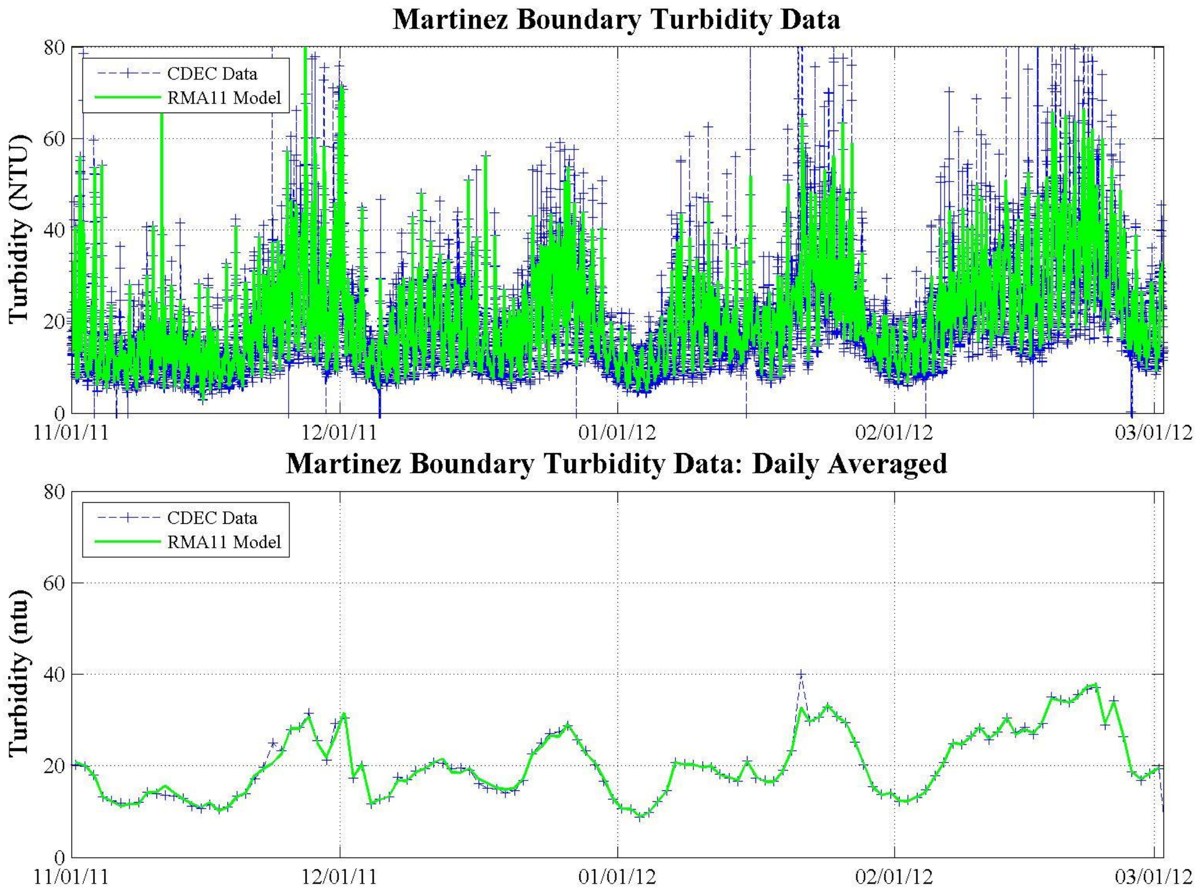

Figure 5-5 Martinez turbidity boundary condition for hindcast, compiled using cleaned MRZ CDEC data. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

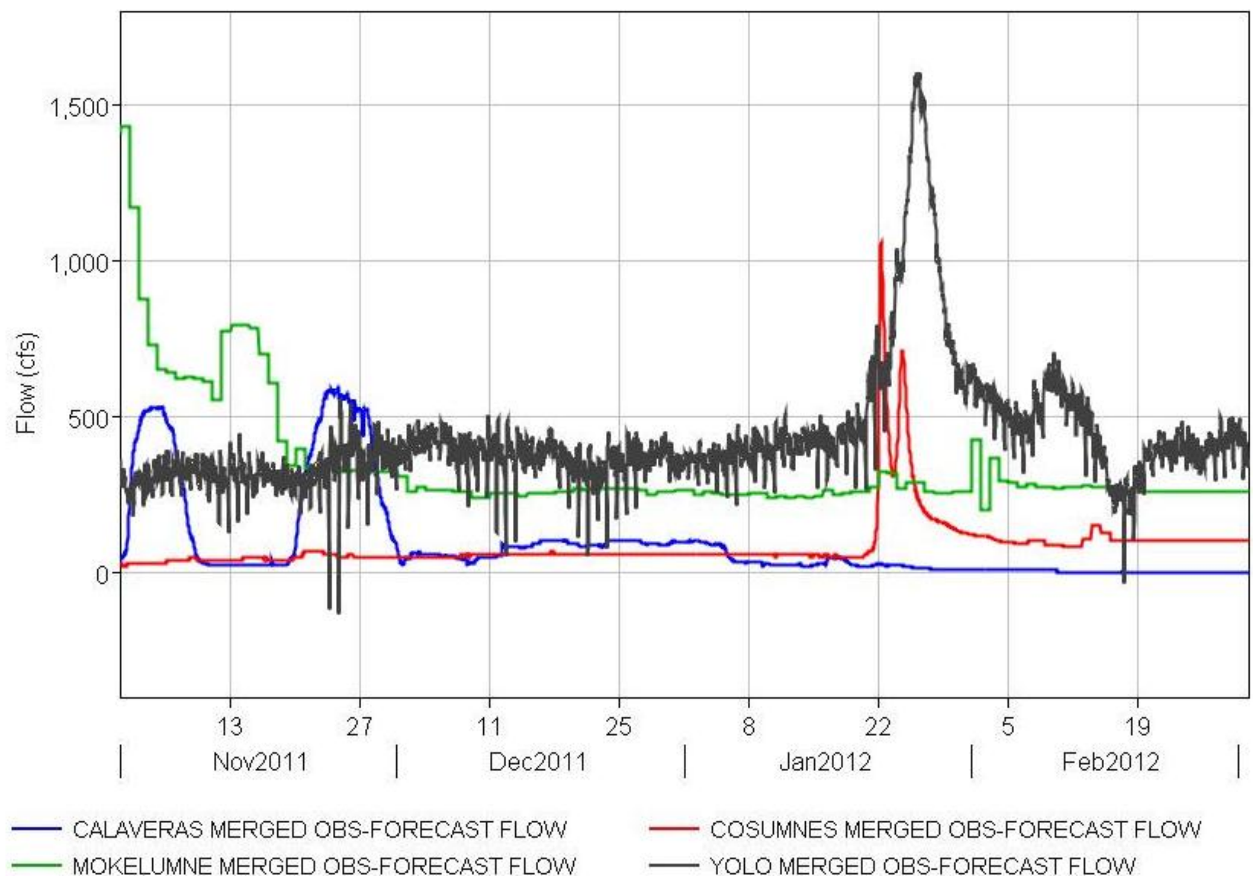

Figure 5-6 Yolo Bypass and Calaveras, Cosumnes, and Mokelumne River hindcast boundary flows.

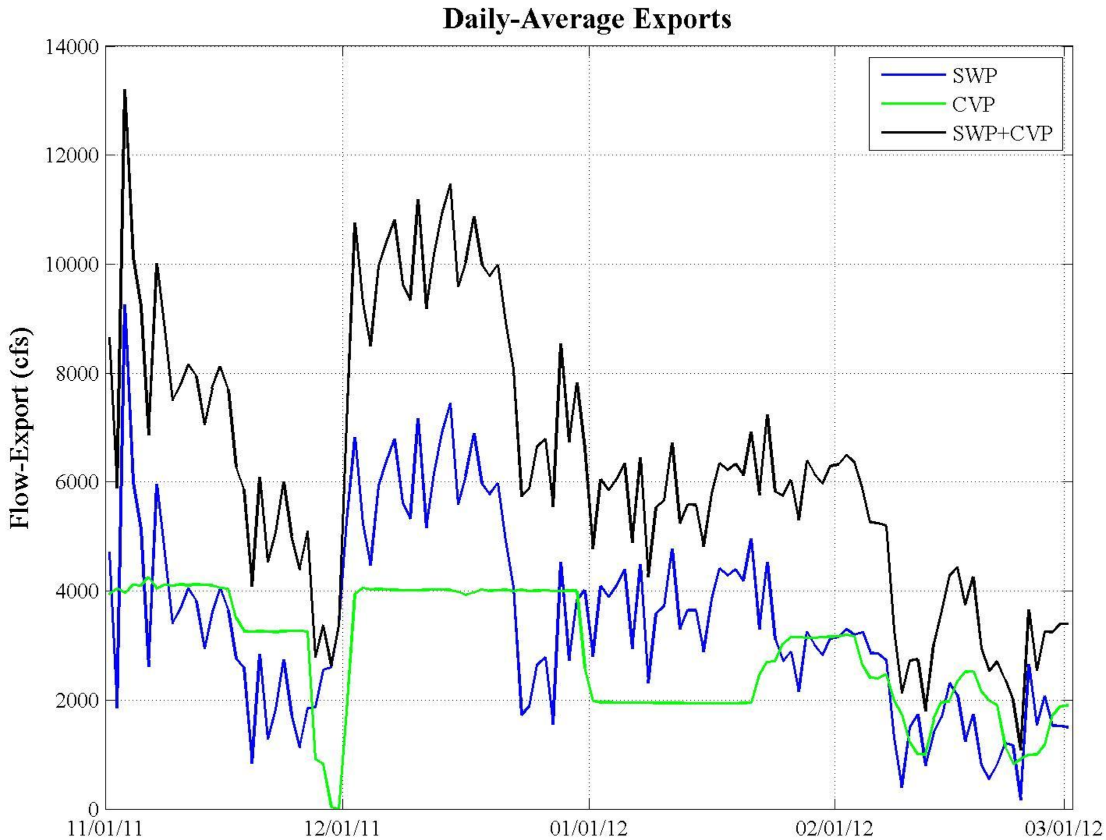

Figure 5-7 DWR-reported, daily-averaged exports at the SWP and CVP export locations, and the combined SWP+CVP exports during the hindcast time period.

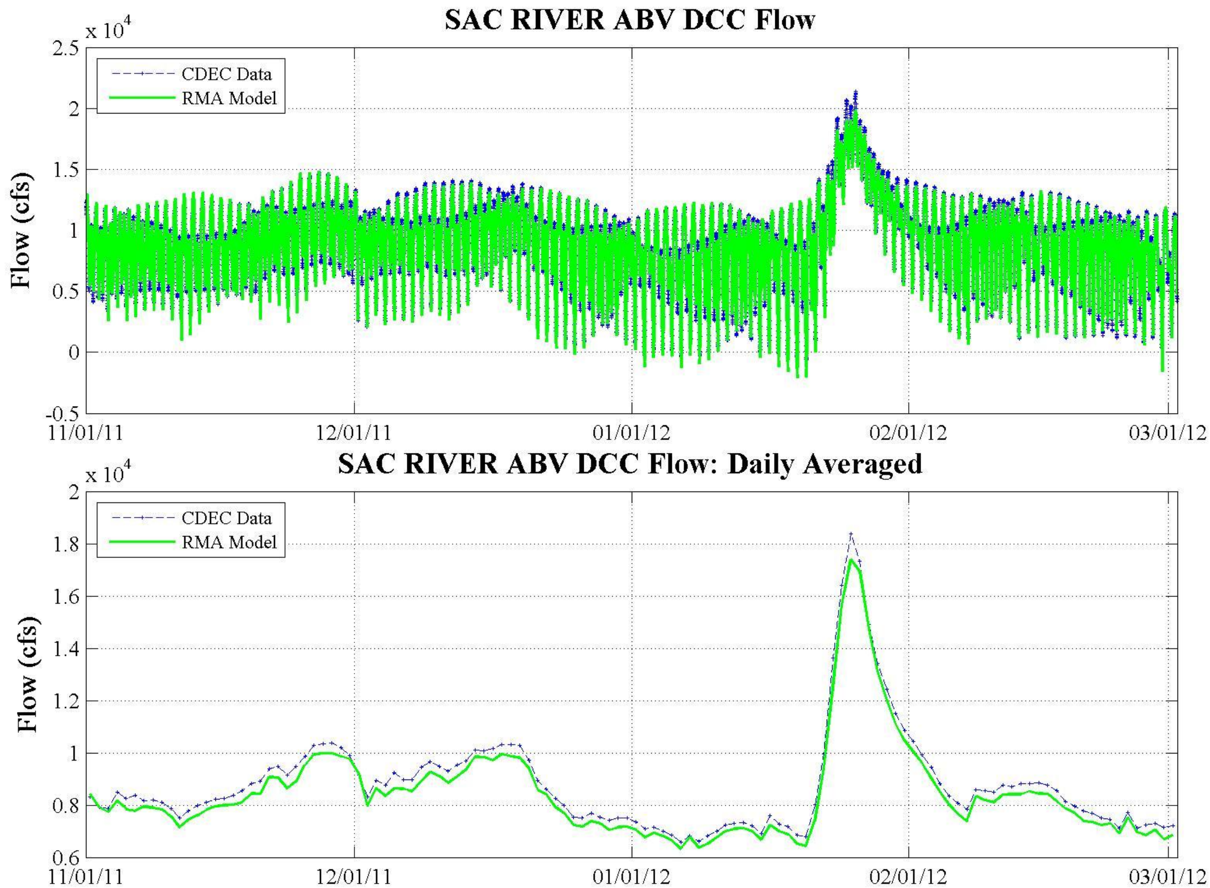

Figure 5-8 Modeled flow and SDC CDEC data at Sacramento River above Delta Cross Channel location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

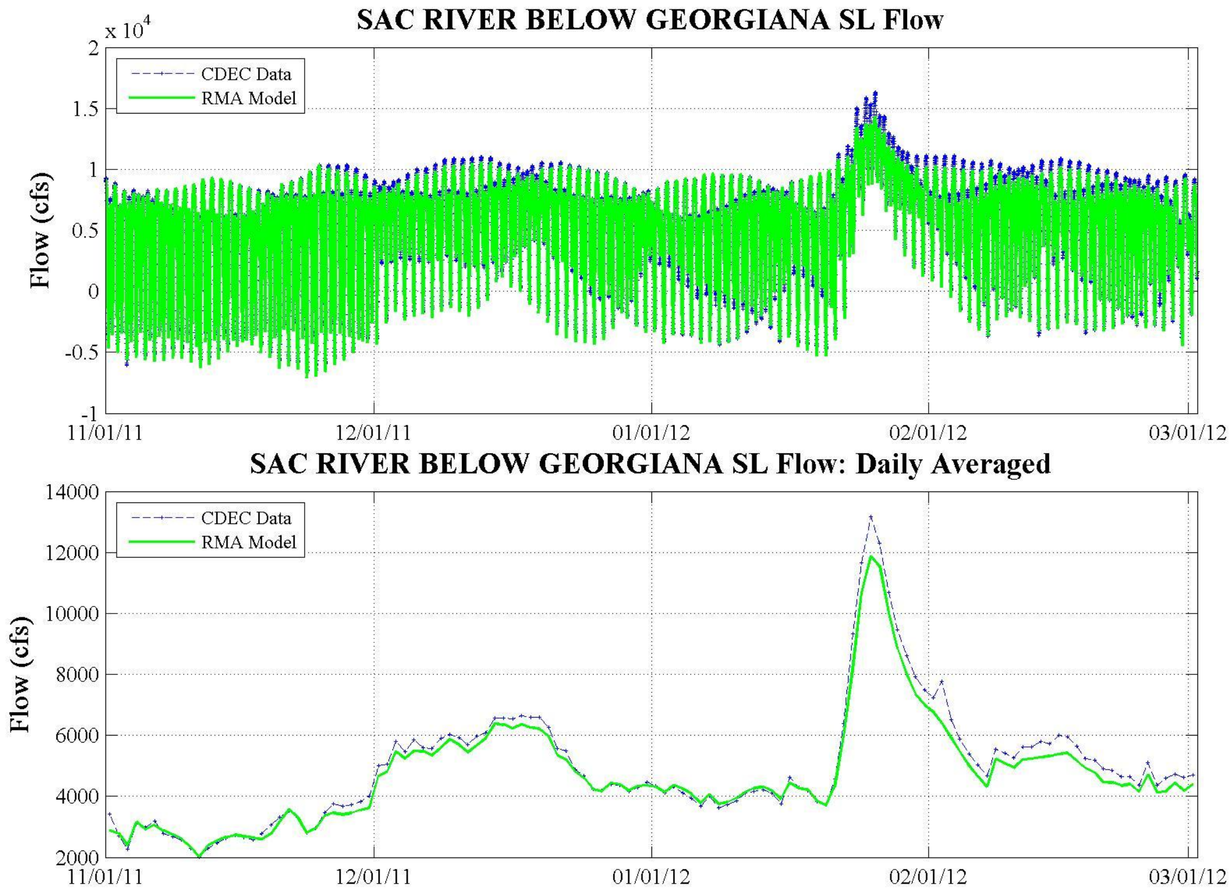

Figure 5-9 Modeled flow and GES CDEC data at Sacramento River below Georgiana Slough location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

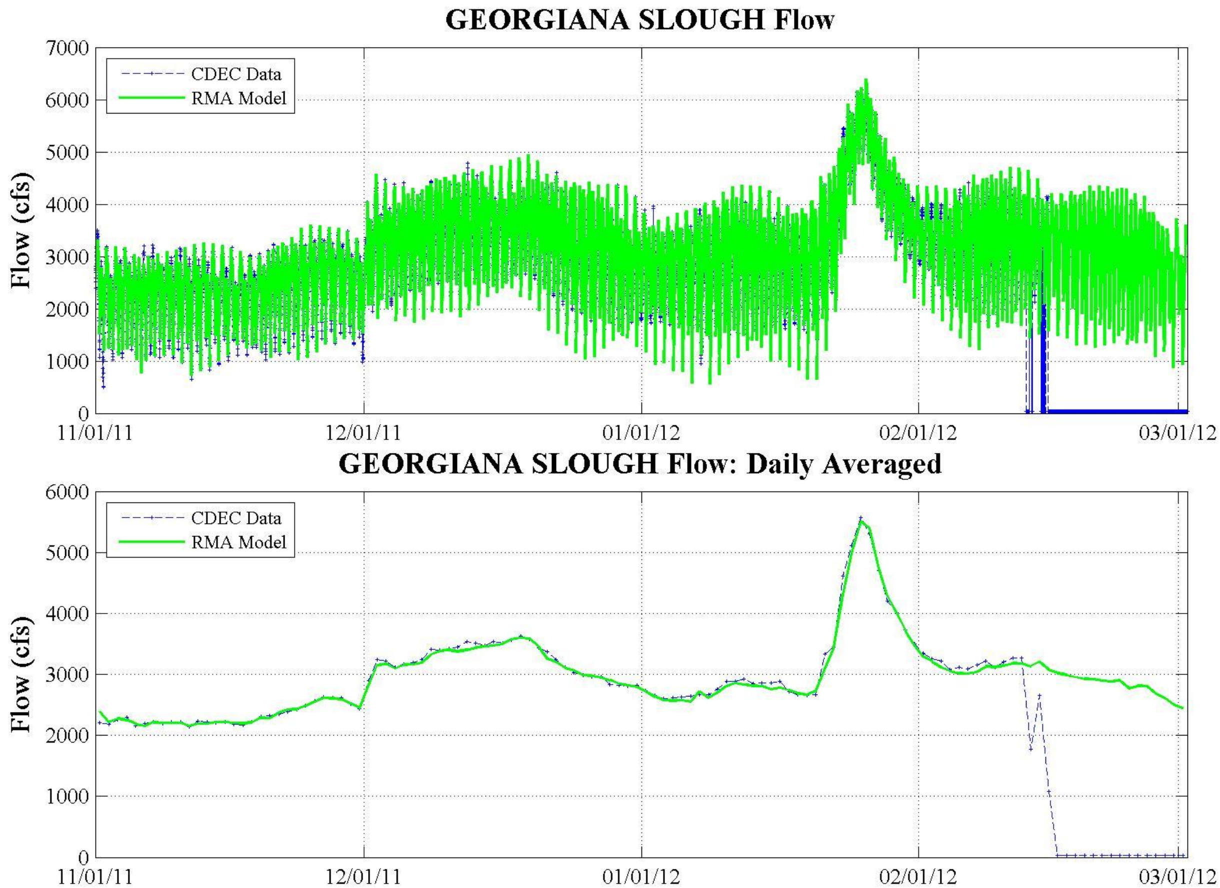

Figure 5-10 Modeled flow and GSS CDEC data at Georgiana Slough location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

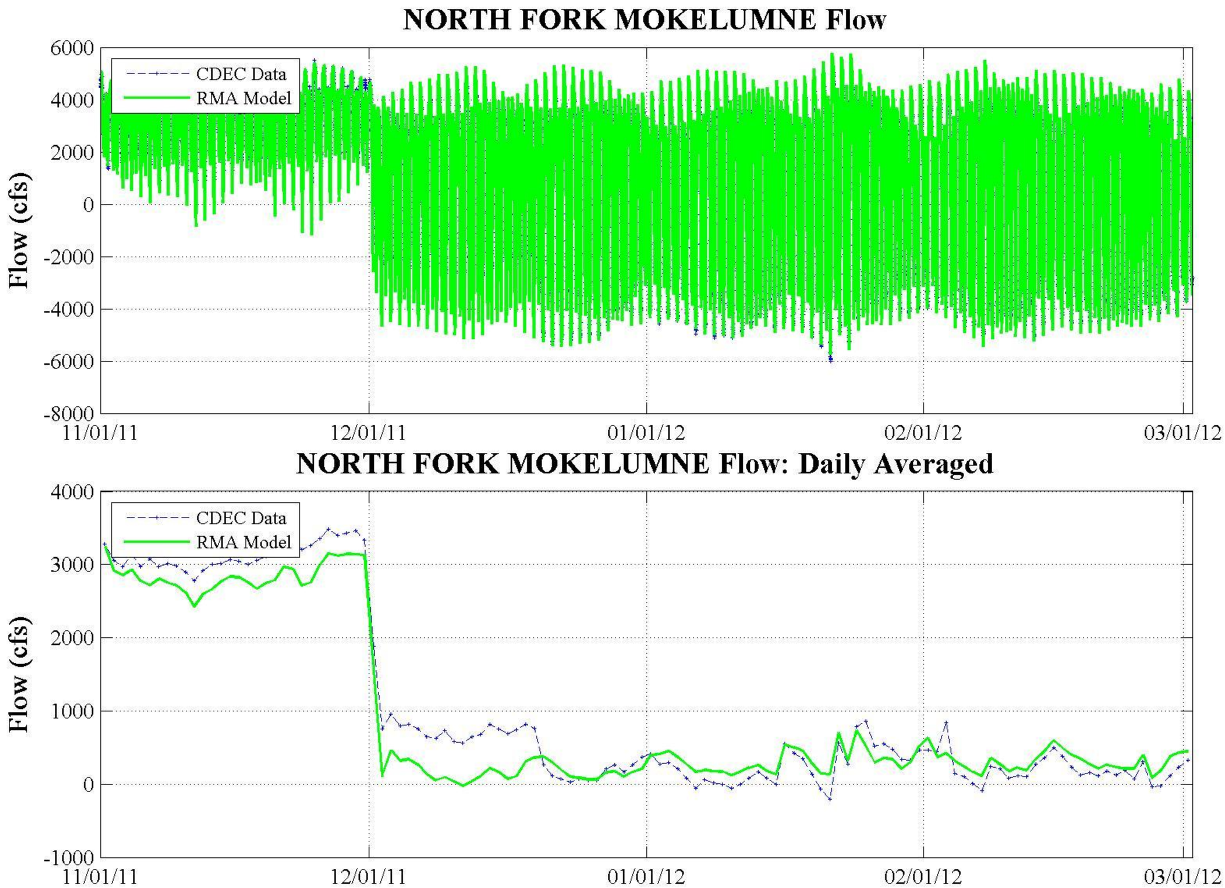

Figure 5-11 Modeled flow and NMR CDEC data at North Fork Mokelumne River location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

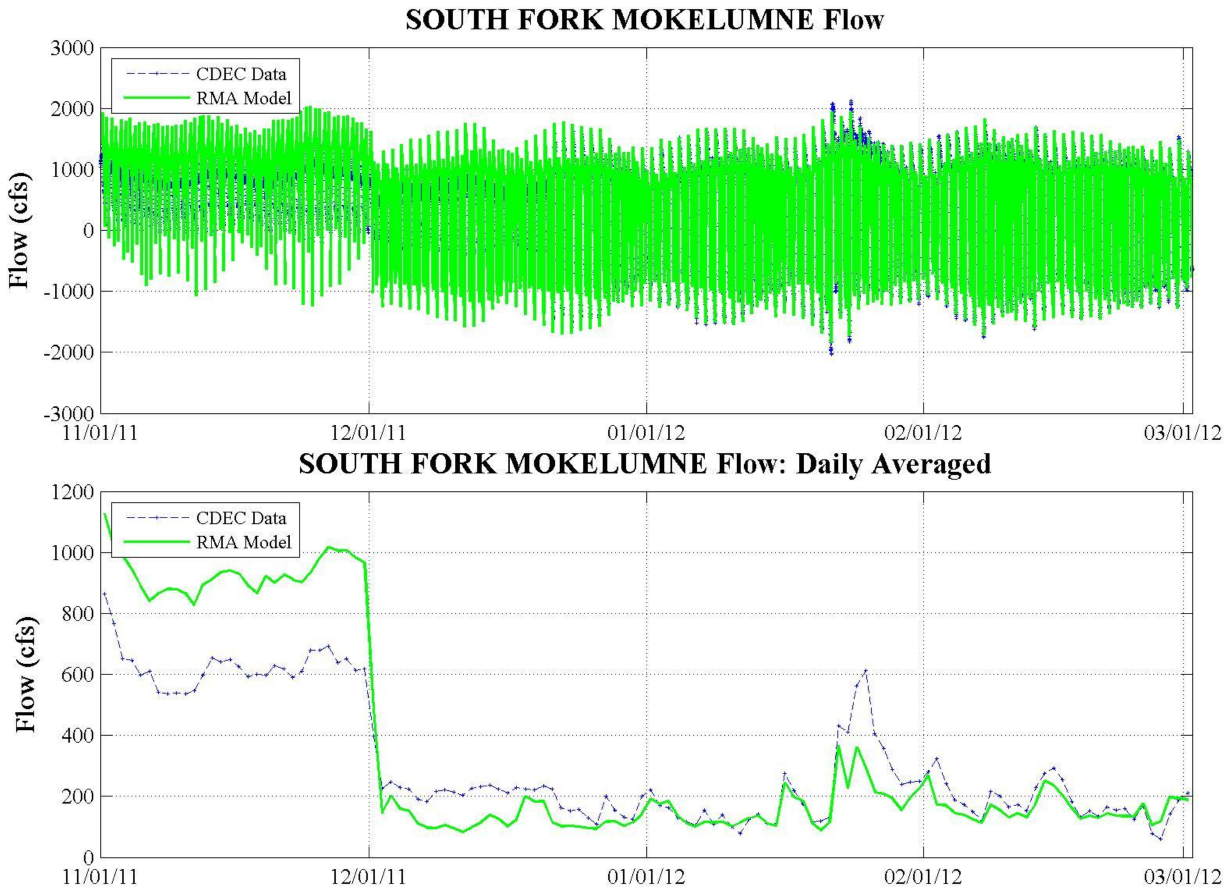

Figure 5-12 Modeled flow and SMR CDEC data at South Fork Mokelumne River location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

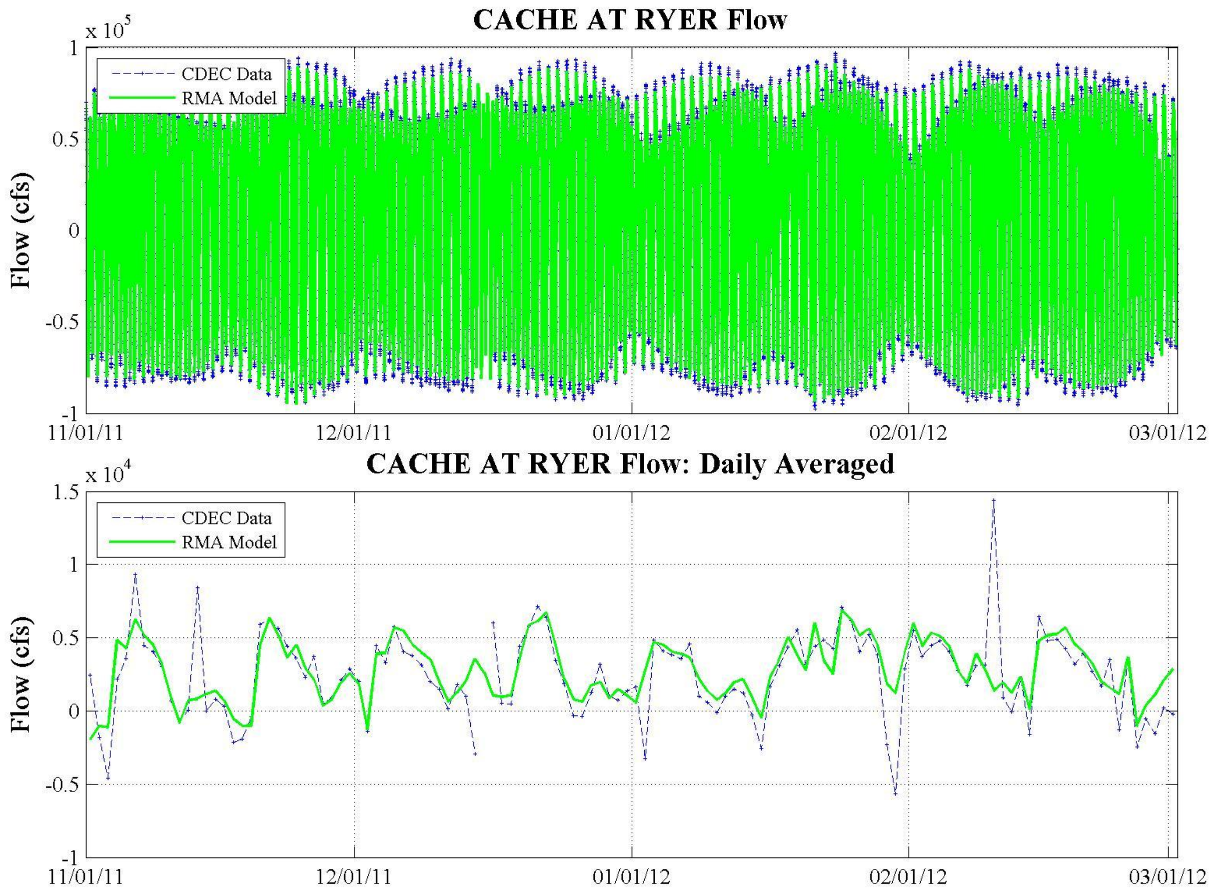

Figure 5-13 Modeled flow and RYI CDEC data at Cache Slough at Ryer Island location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

Figure 5-14 Modeled flow and LPS CDEC data at Little Potato Slough at Terminous Tract location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

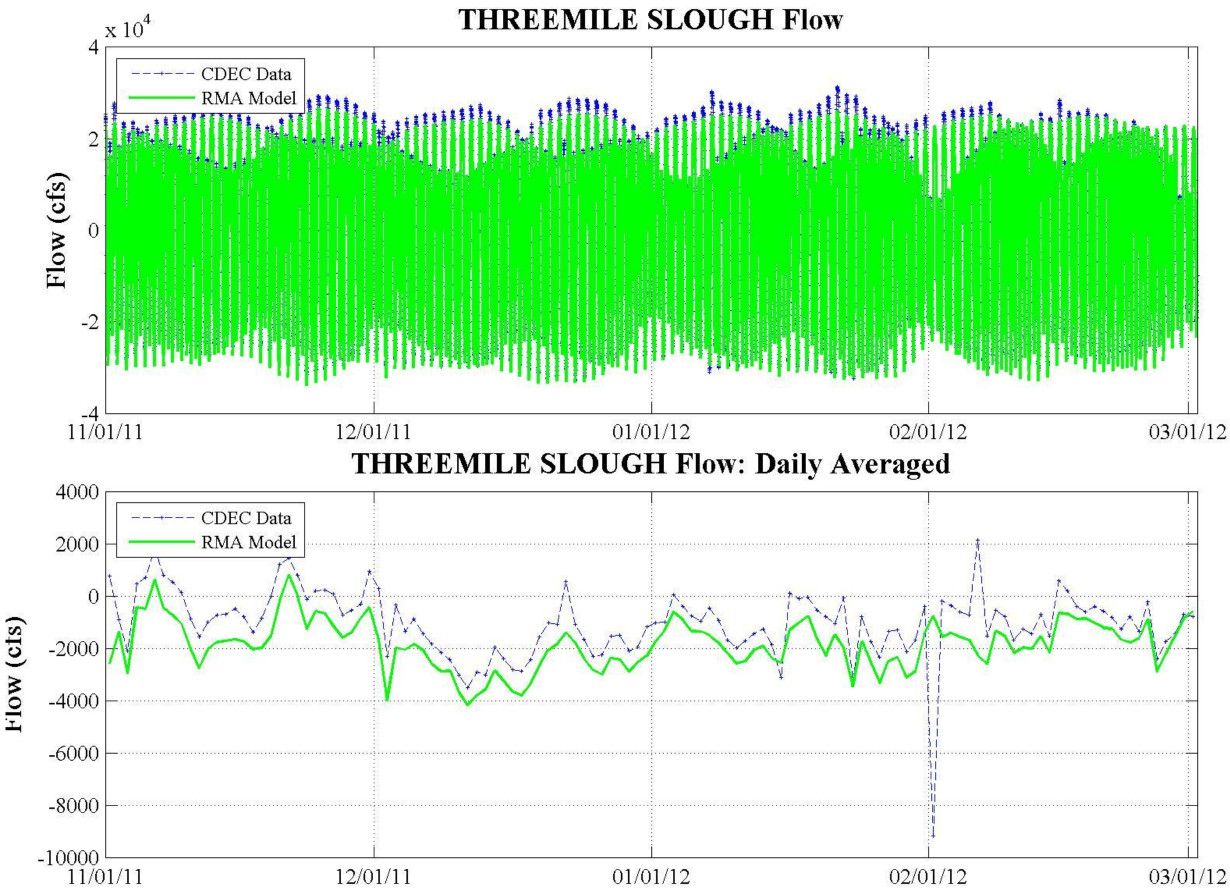

Figure 5-15 Modeled flow and TSL CDEC data at Threemile Slough location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

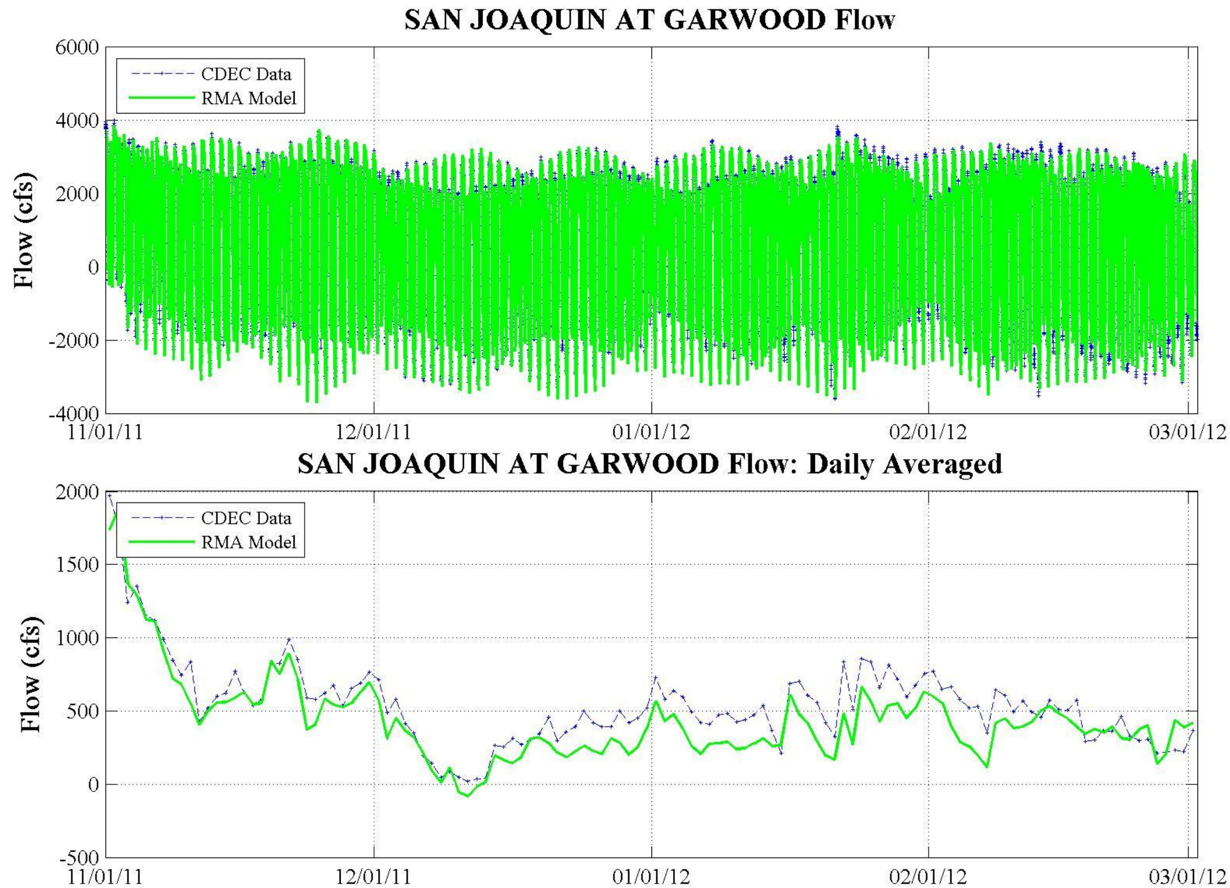

Figure 5-16 Modeled flow and SJG CDEC data at San Joaquin River at Garwood location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

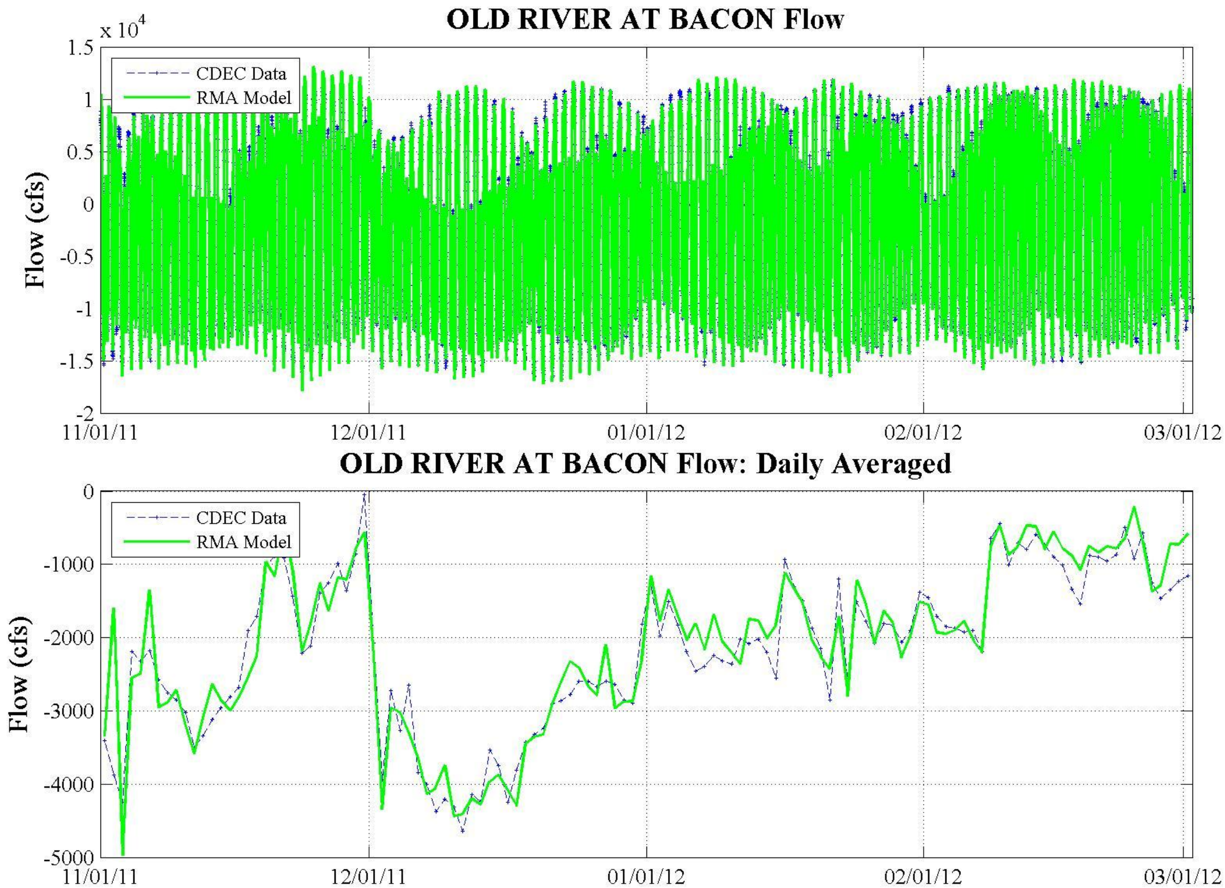

Figure 5-17 Modeled flow and OBI CDEC data at Old River at Bacon (ROLD024) location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

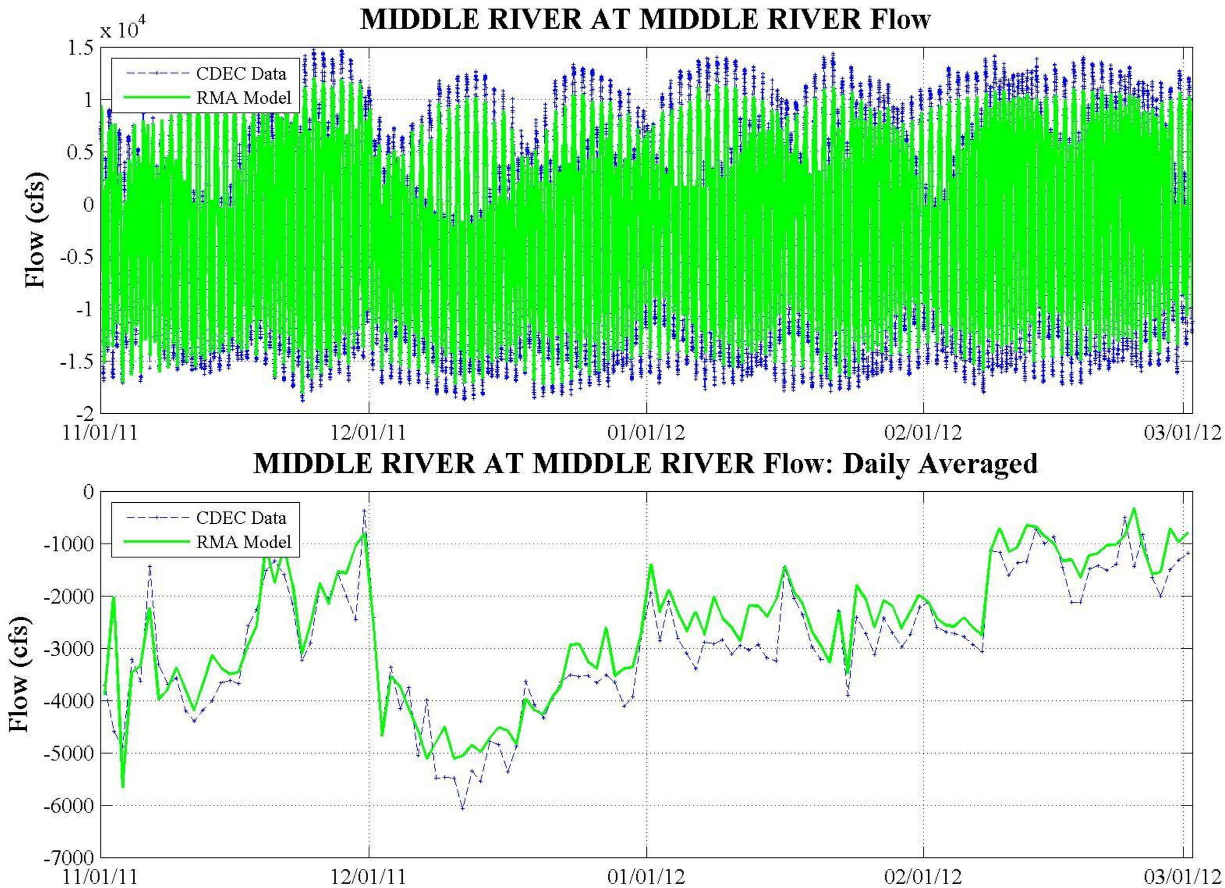

Figure 5-18 Modeled flow and MDM CDEC data at Middle River at Middle River (RMID015) location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

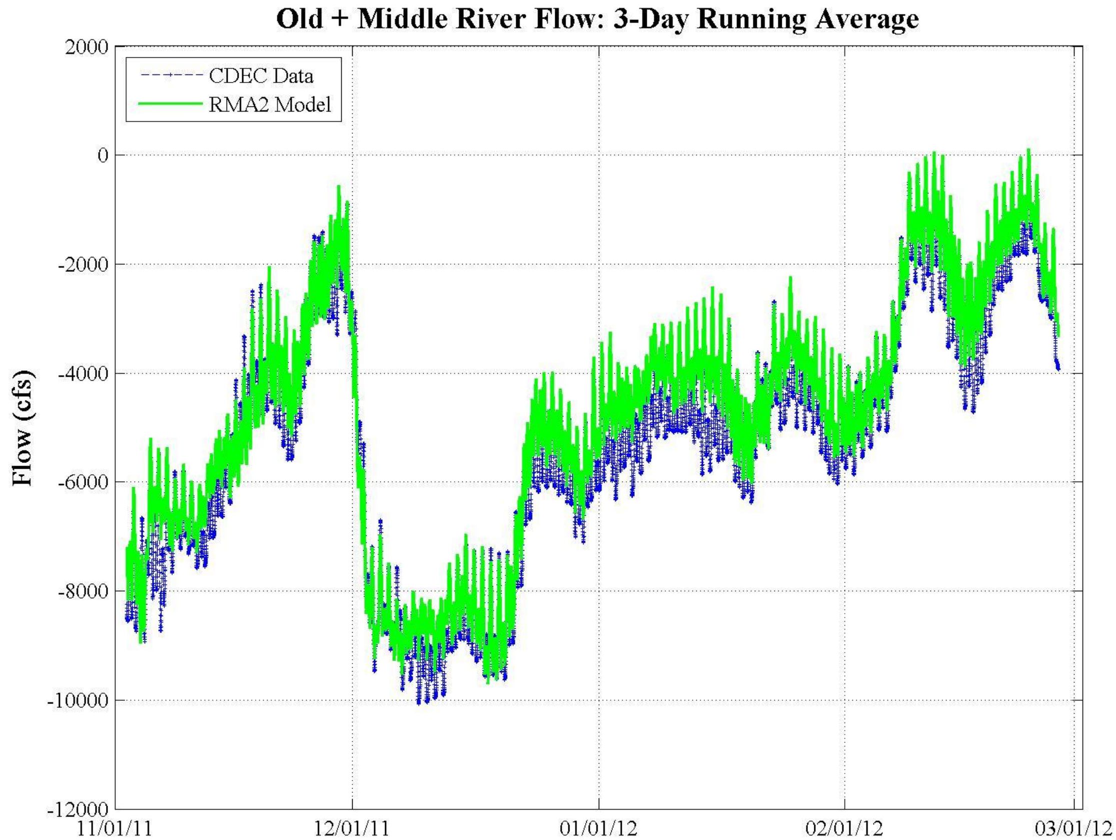

Figure 5-19 Modeled flow and CDEC data comparison for the Old and Middle River flow criterion, three day running average.

Table 5-1 Flow boundary condition sources and development for WY2012 hindcast modeling run.

Boundary Condition Location	Data Source	Comment
Sacramento River at Freeport	Hourly CDEC FPT, cleaned+filled	
San Joaquin River at Vernalis	Hourly CDEC VNS, cleaned+filled	CDEC data shifted 240 cfs prior to Dec 13 to match USGS site data
Cosumnes River	Hourly CNRFC Cosumnes-McConnell observed data, cleaned+filled	
Mokelumne River	Daily DSM2 RMOK070 observed data	
Yolo Bypass	Hourly CDEC LIS, cleaned+filled	
Calaveras River	Hourly CDEC MRS, cleaned+filled	Shifted CDEC data 28Nov-12Dec +37cfs to account for jump in data record
Martinez (stage)	15min CDEC Martinez stage, cleaned+filled, and shifted -2.38 ft.	Shift to account for vertical datum change and salinity modeling

Table 5-2 EC boundary condition sources and development for WY2012 hindcast modeling run.

Boundary Condition Location	Data Source
Sacramento River at Freeport	15min CDEC FPT, cleaned+filled, hourly averaged
San Joaquin River at Vernalis	15min CDEC SJR, cleaned+filled, hourly averaged
Cosumnes River	15min CDEC SMR, cleaned+filled, filtered to remove tidal spikes in EC from the Sac River, daily averaged then converted to hourly
Mokelumne River	15min CDEC SMR, cleaned+filled, filtered to remove tidal spikes in EC from the Sac River, daily averaged then converted to hourly
Yolo Bypass	15min CDEC RYI, cleaned+filled, hourly averaged
Calaveras River	15min CDEC RRI, cleaned+filled, hourly averaged
Martinez	15min CDEC MRZ, cleaned+filled, hourly averaged

Table 5-3 Turbidity boundary condition sources and development for WY2012 hindcast modeling run.

Boundary Condition Location	Data Source
Sacramento River at Freeport	15min CDEC FPT, cleaned+filled, hourly averaged then shifted -15hrs to account for travel time from upstream boundary
San Joaquin River at Vernalis	15min CDEC SJR, cleaned+filled, hourly averaged
Cosumnes River	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly
Mokelumne River	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly
Yolo Bypass	15min CDEC RYI, cleaned+filled, hourly averaged
Calaveras River	15min CDEC RRI, cleaned+filled, hourly averaged
Martinez	15min CDEC MRZ, cleaned+filled, hourly averaged

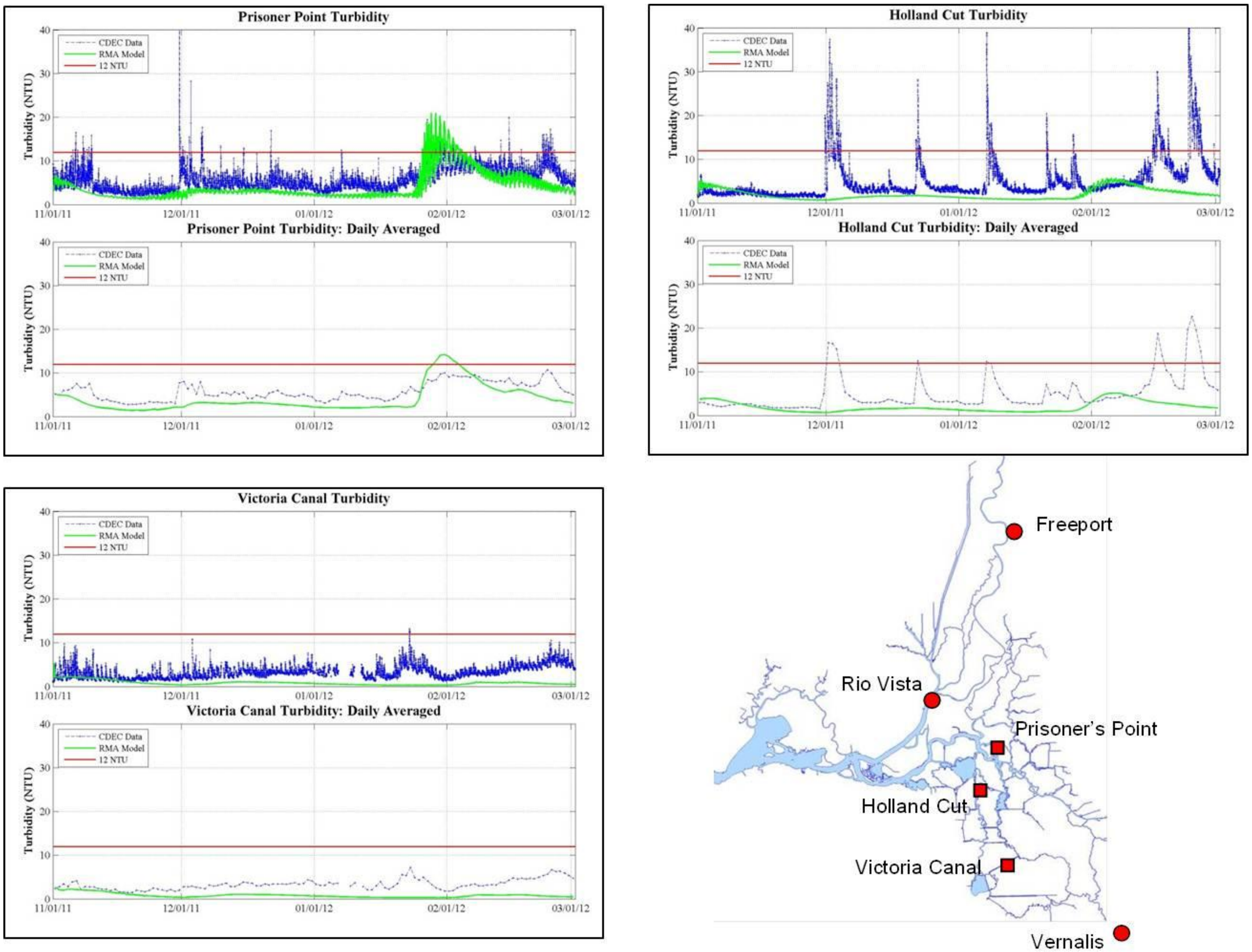

Figure 5-20 Modeled turbidity and cleaned CDEC data at the three compliance locations (Prisoner's Point, Holland Cut, and Victoria Canal). Red line denotes the compliance turbidity value (12NTU). Both 15-min (upper plots) and daily-averaged (lower plots) data are shown.

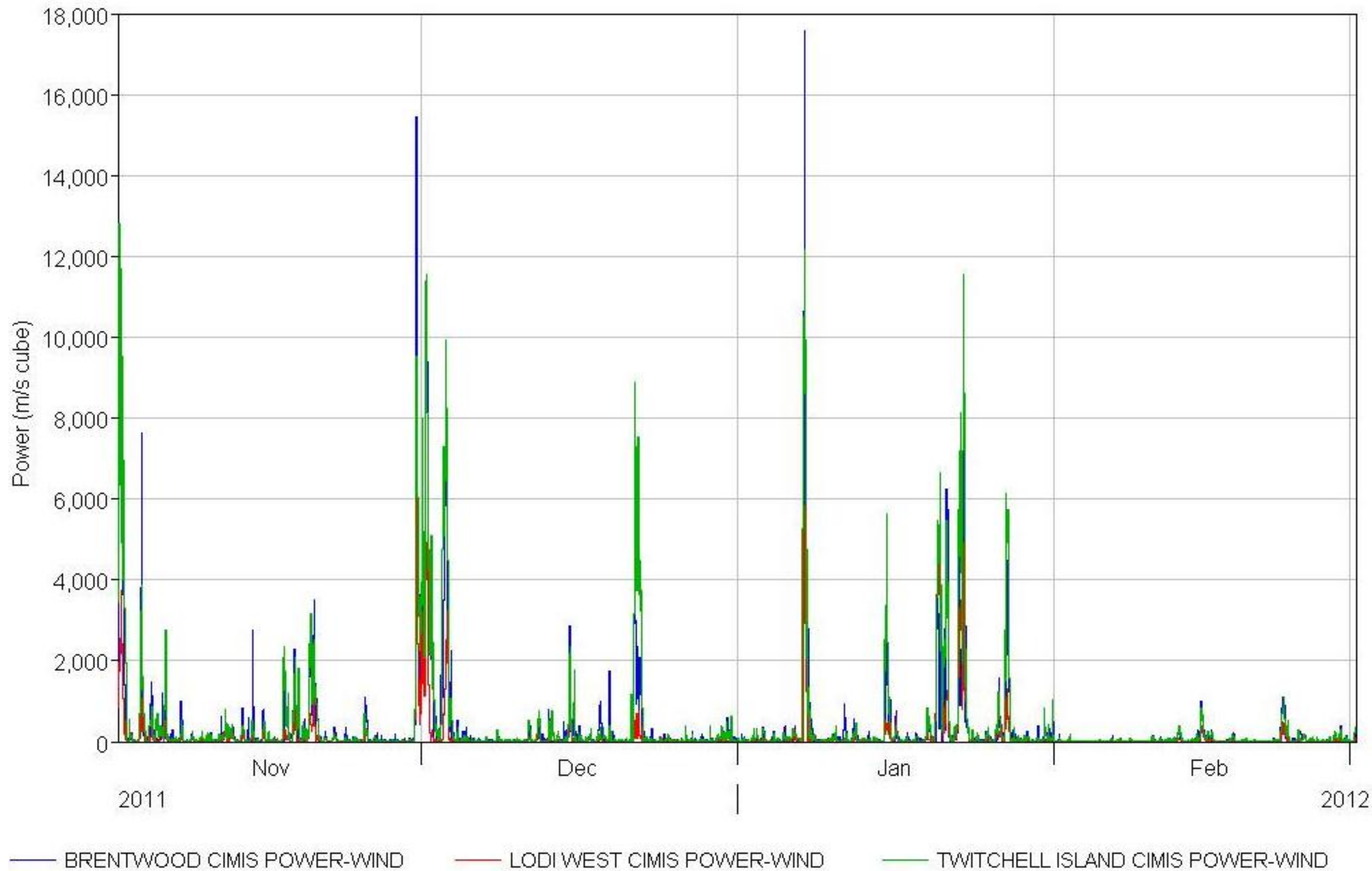

Figure 5-21 CIMIS wind power, computed as the cube of wind speed in m/s, for 3 closest CIMIS stations to the Central Delta (Brentwood, Lodi West, Twitchell Island).

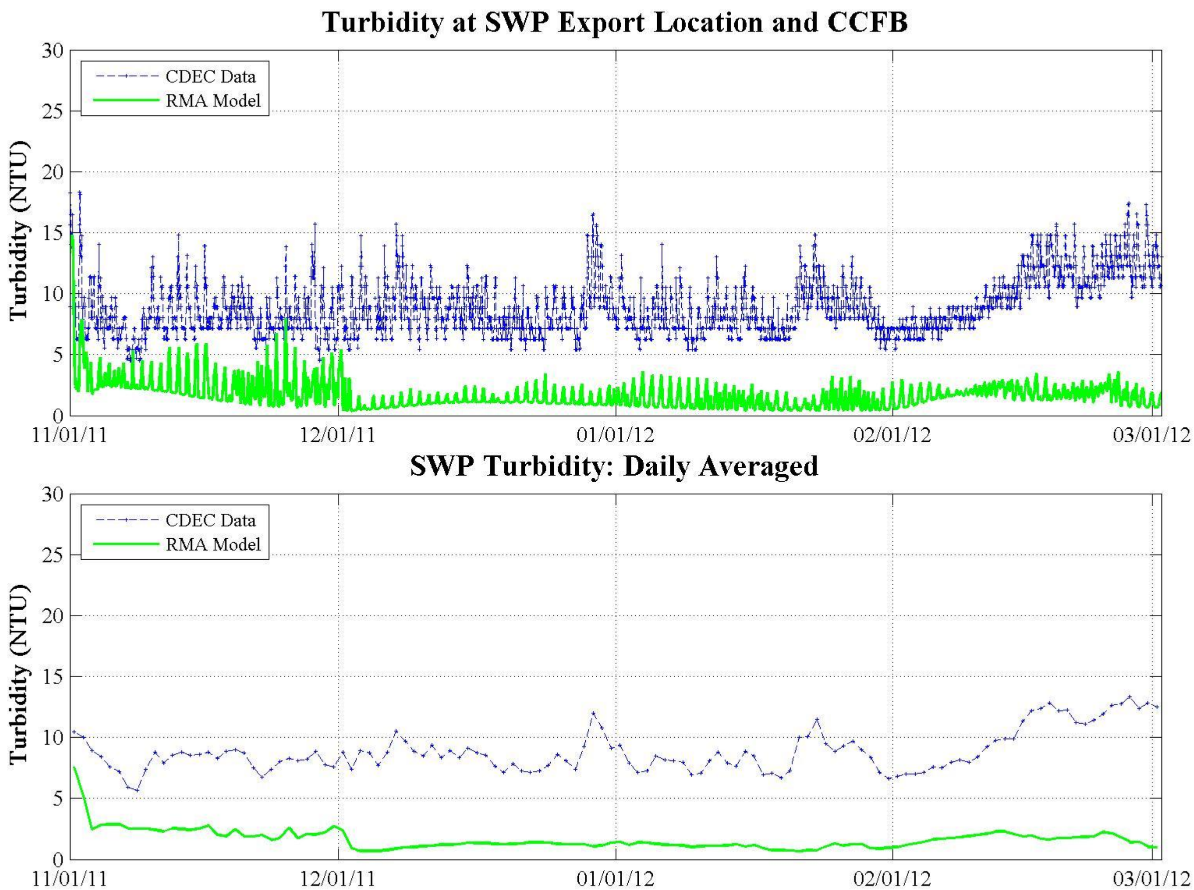

Figure 5-22 Plots compare RMA model output at the SWP export location with data gathered inside Clifton Court Forebay. Note that because of differences in flow conditions between the two sites, turbidity data is not directly comparable. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

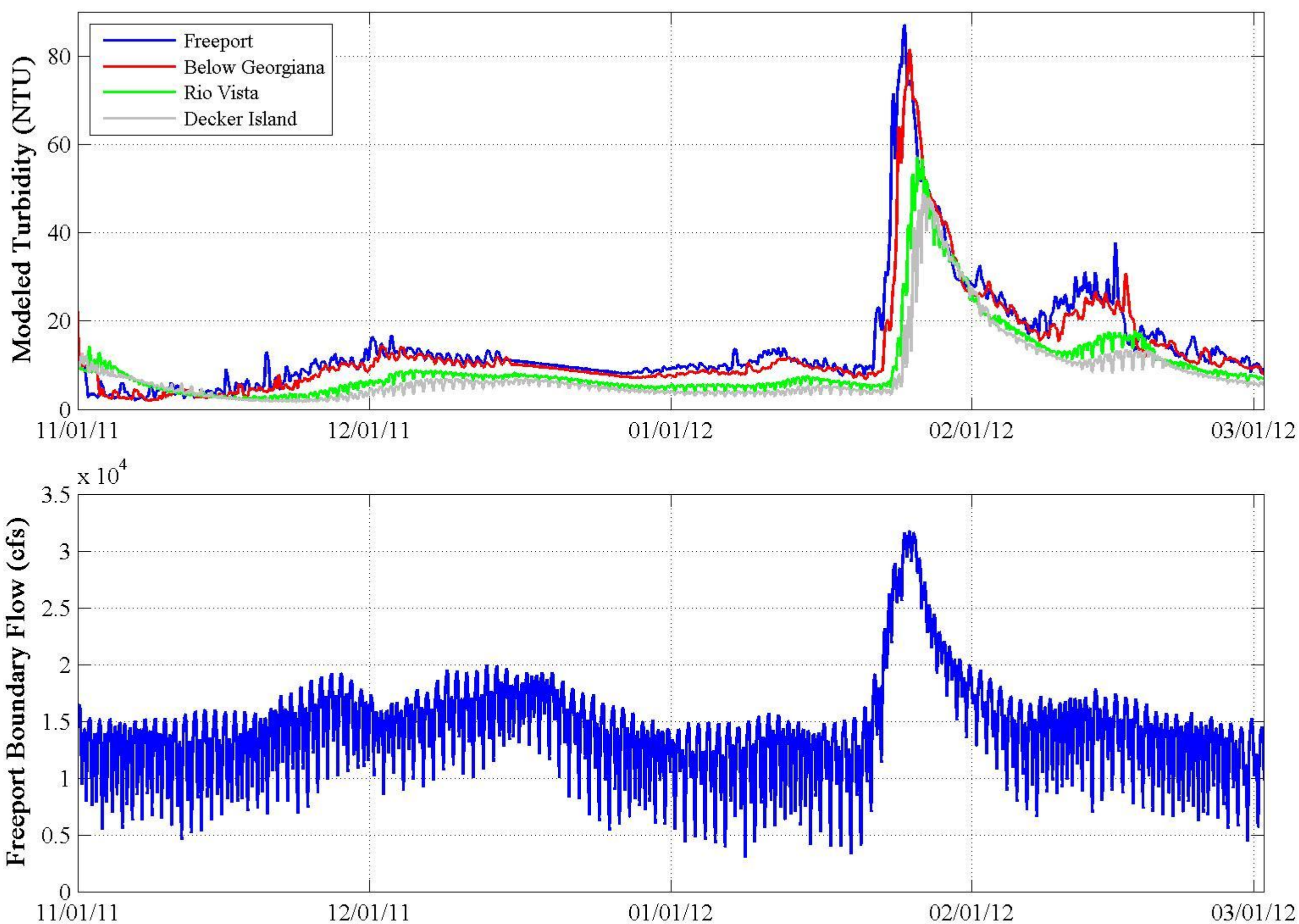

Figure 5-23 Freeport turbidity boundary condition progression down the Sacramento River (upper plot). Lower plot shows magnitude of boundary flow at Freeport.

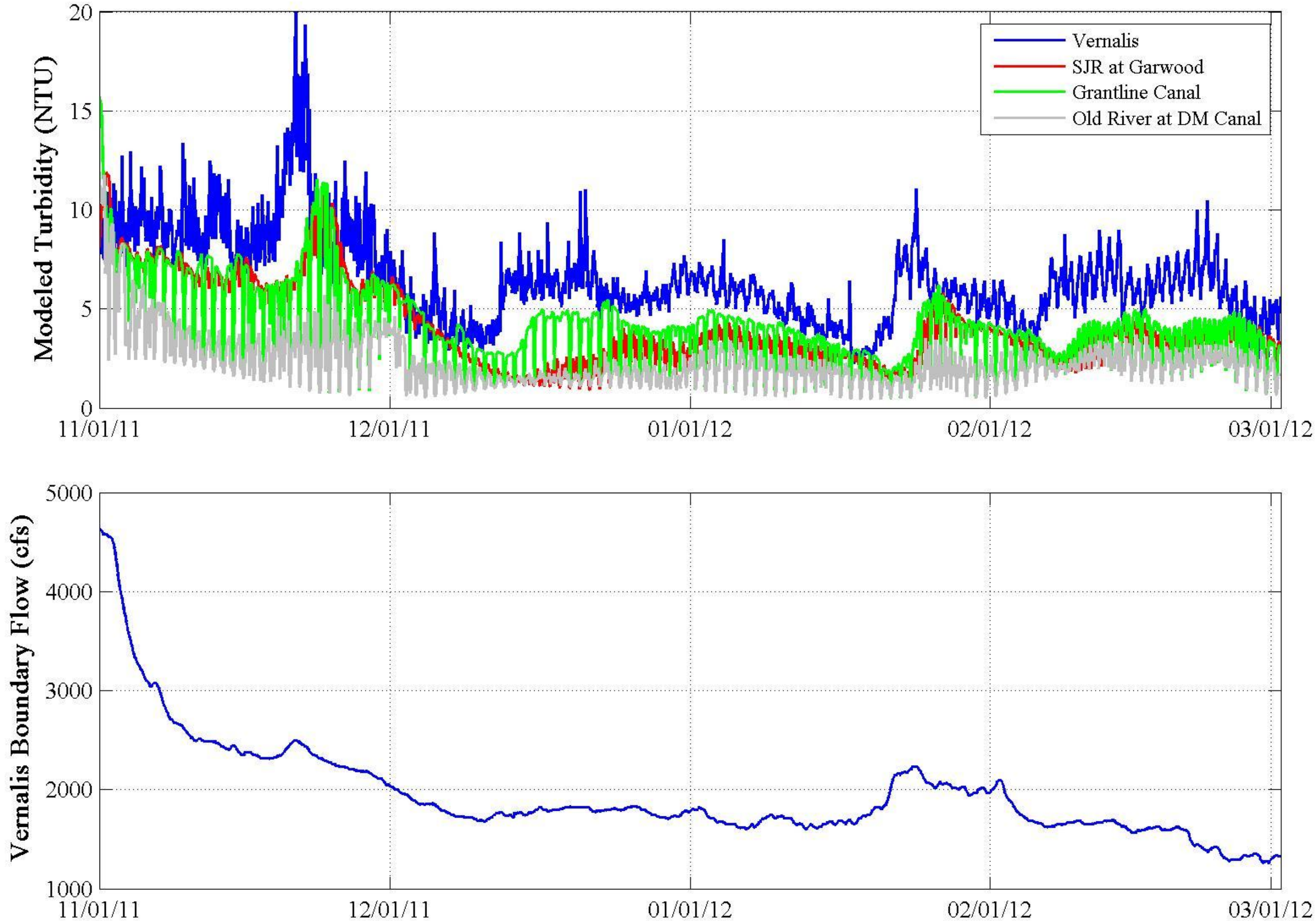

Figure 5-24 Vernalis turbidity boundary condition progression down the San Joaquin River (upper plot). Lower plot shows magnitude of boundary flow at Vernalis.

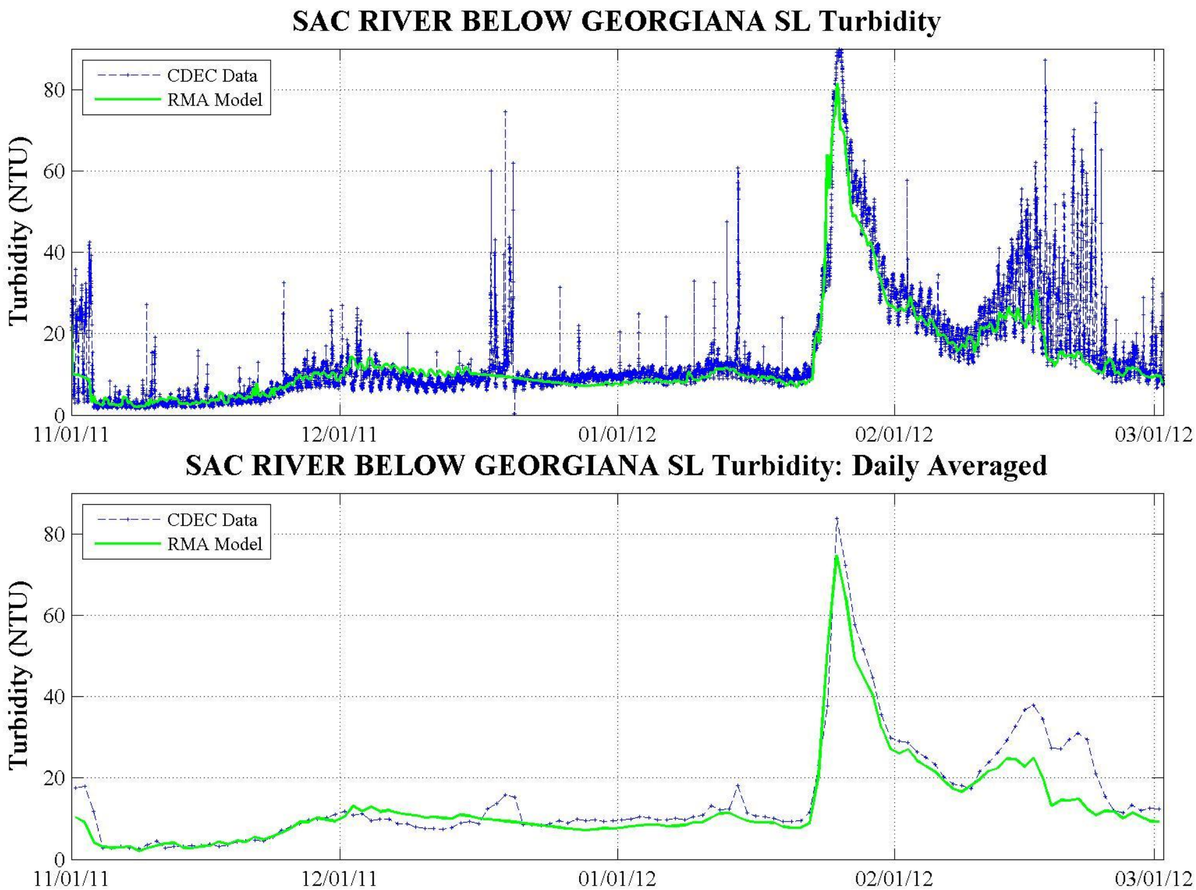

Figure 5-25 Model results and raw GES CDEC data at Sacramento River Below Georgiana Slough location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

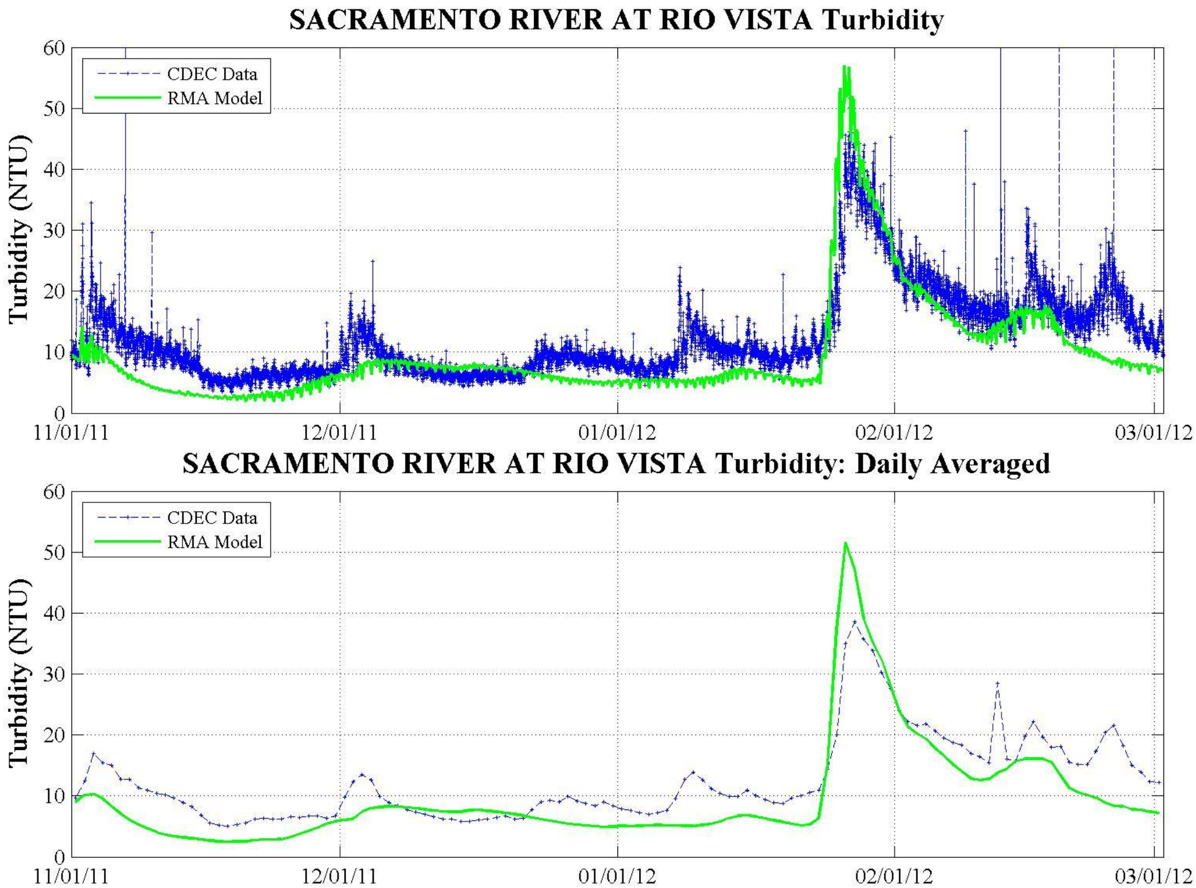

Figure 5-26 Model results and raw RVB CDEC data at Sacramento River at Rio Vista Bridge location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

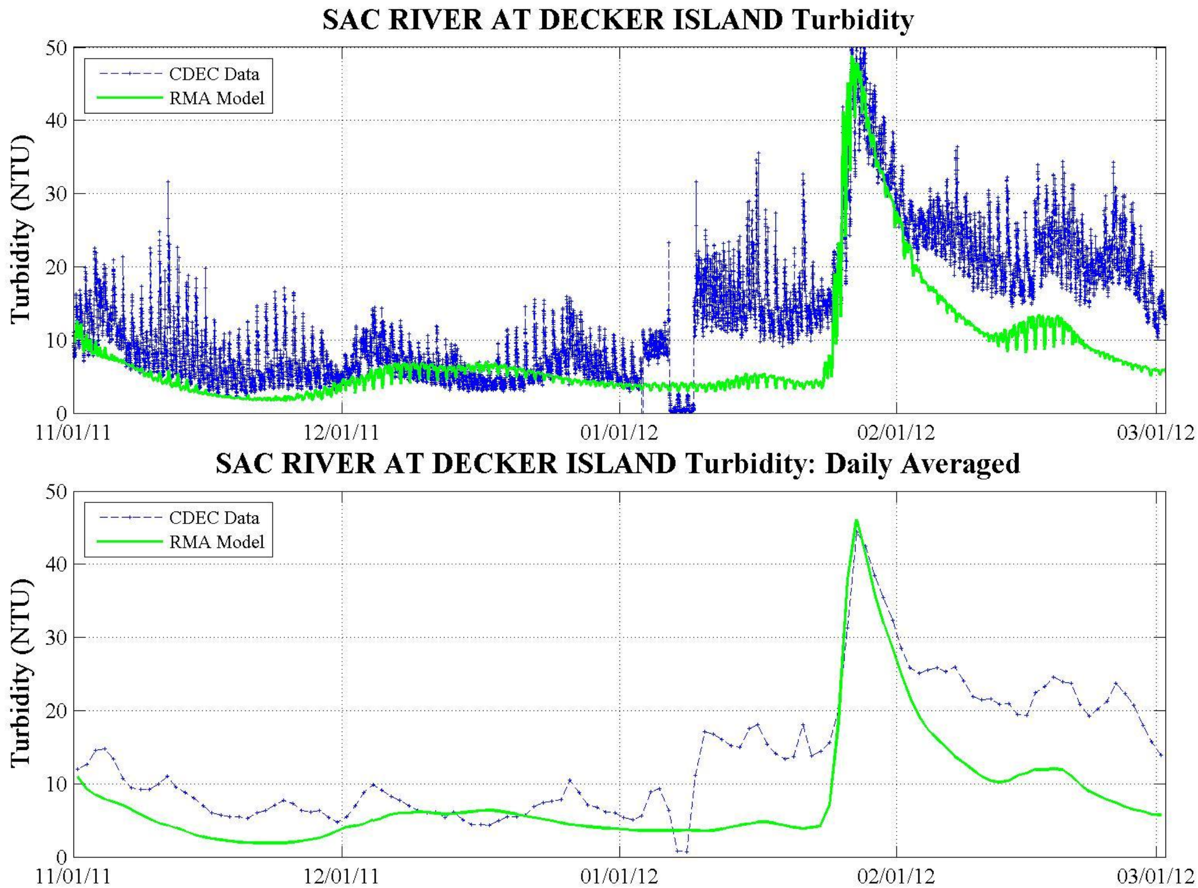

Figure 5-27 Model results and raw SDI CDEC data at Sacramento River at Decker Island location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

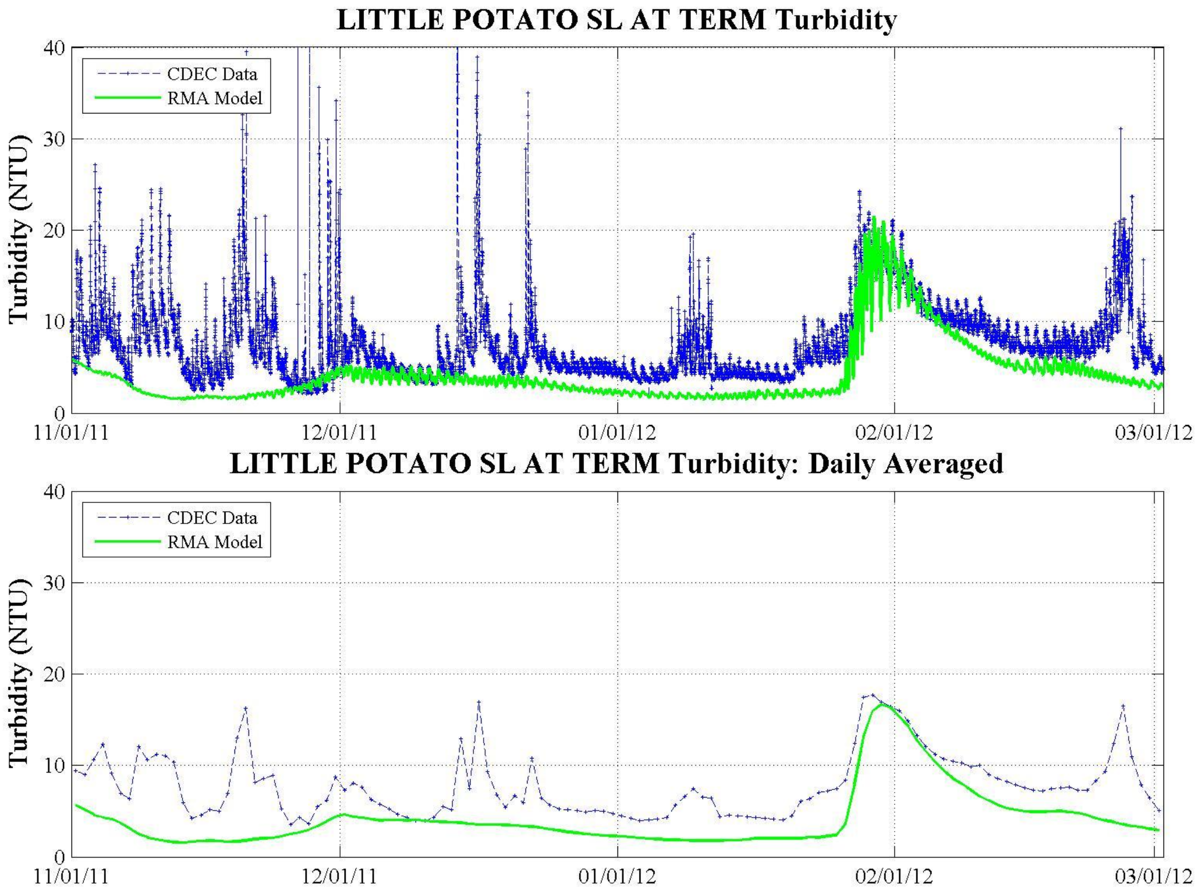

Figure 5-28 Model results and raw LPS CDEC data at Little Potato Slough at Terminous location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

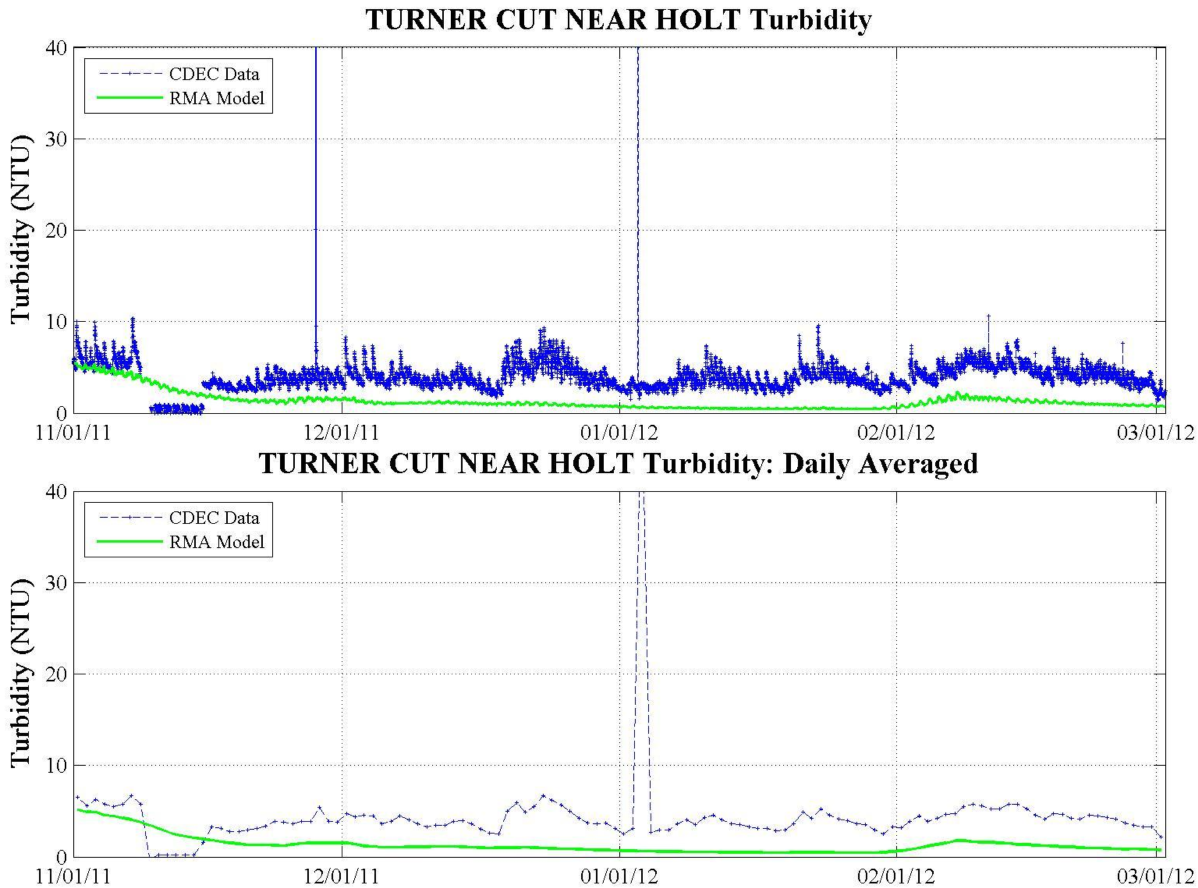

Figure 5-29 Model results and raw TRN CDEC data at Turner Cut Near Holt location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

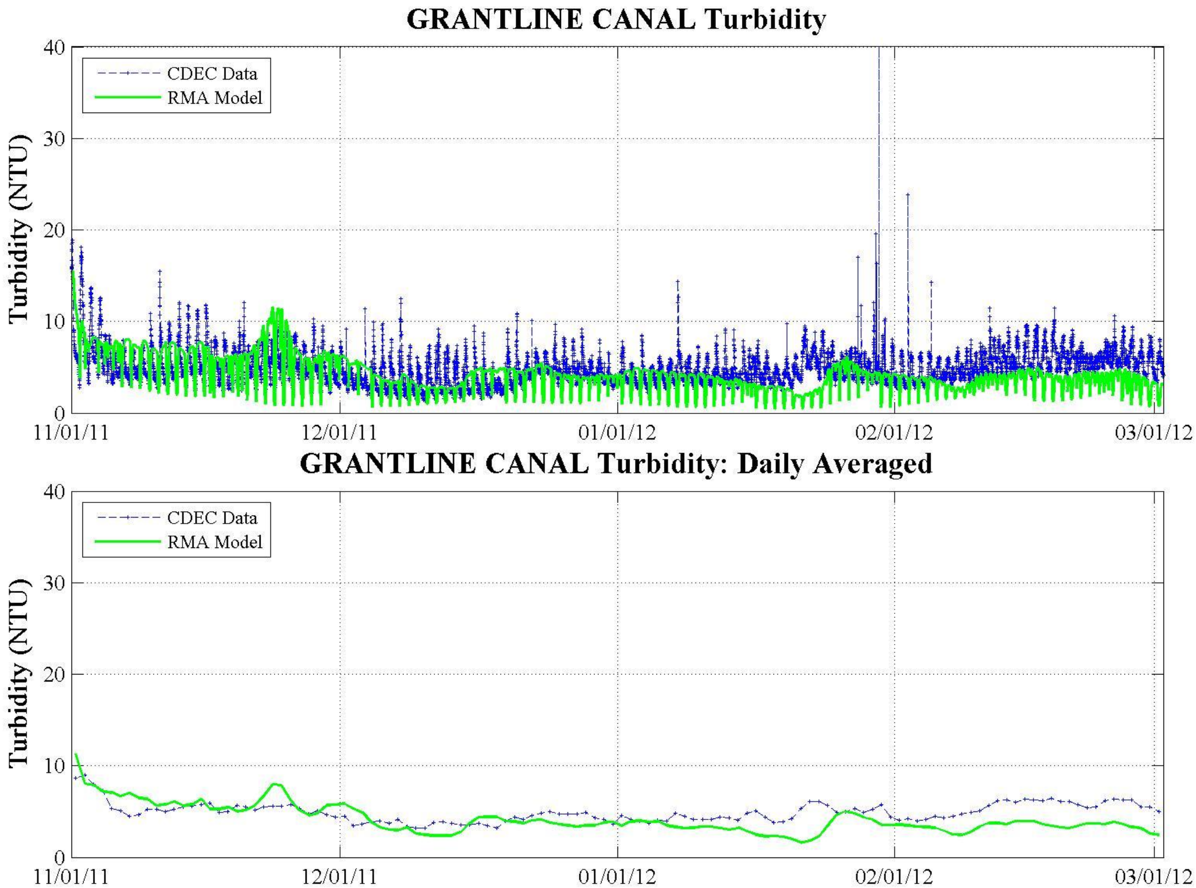

Figure 5-30 Model results and raw GLC CDEC data at Grant Line Canal location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

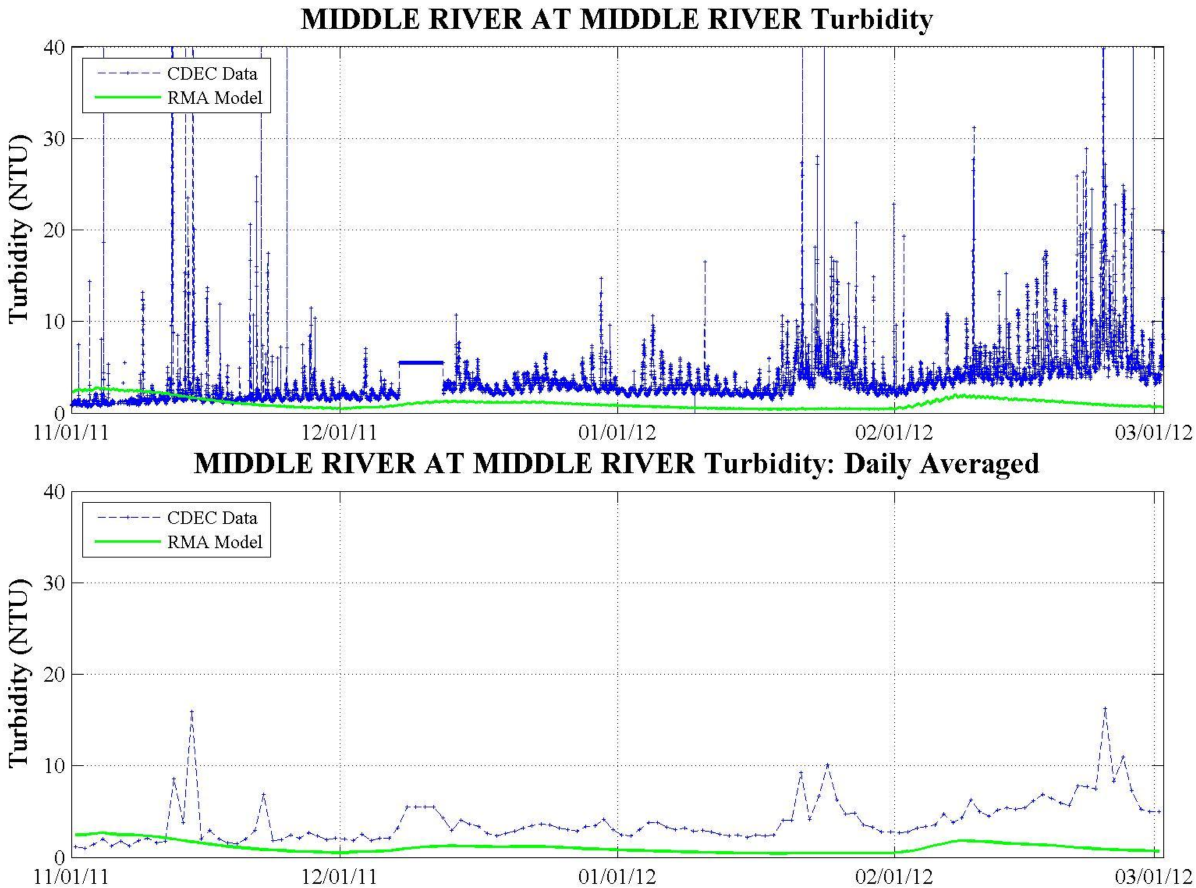

Figure 5-31 Model results and raw MDM CDEC data at Middle River at Middle River location. Both 15-min (upper plot) and daily-averaged (lower plot) data are shown.

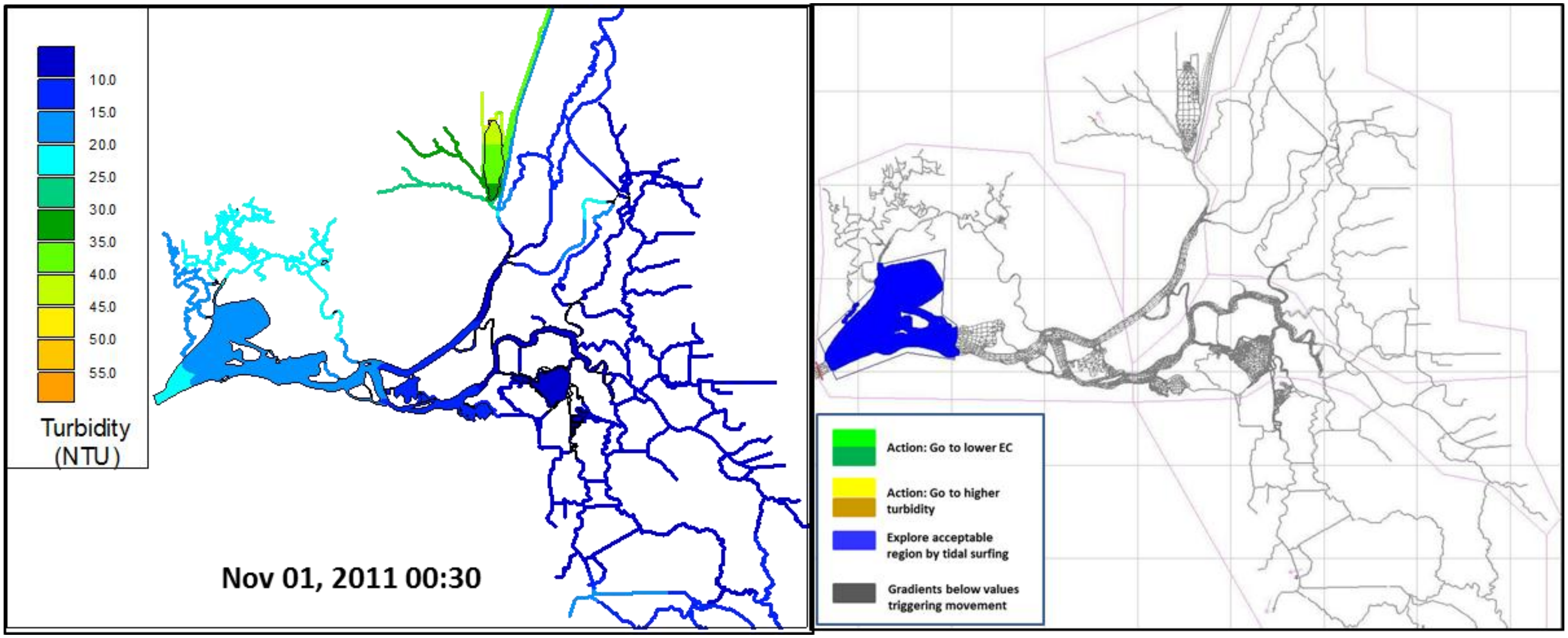

Figure 5-32 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on November 01, 2011. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

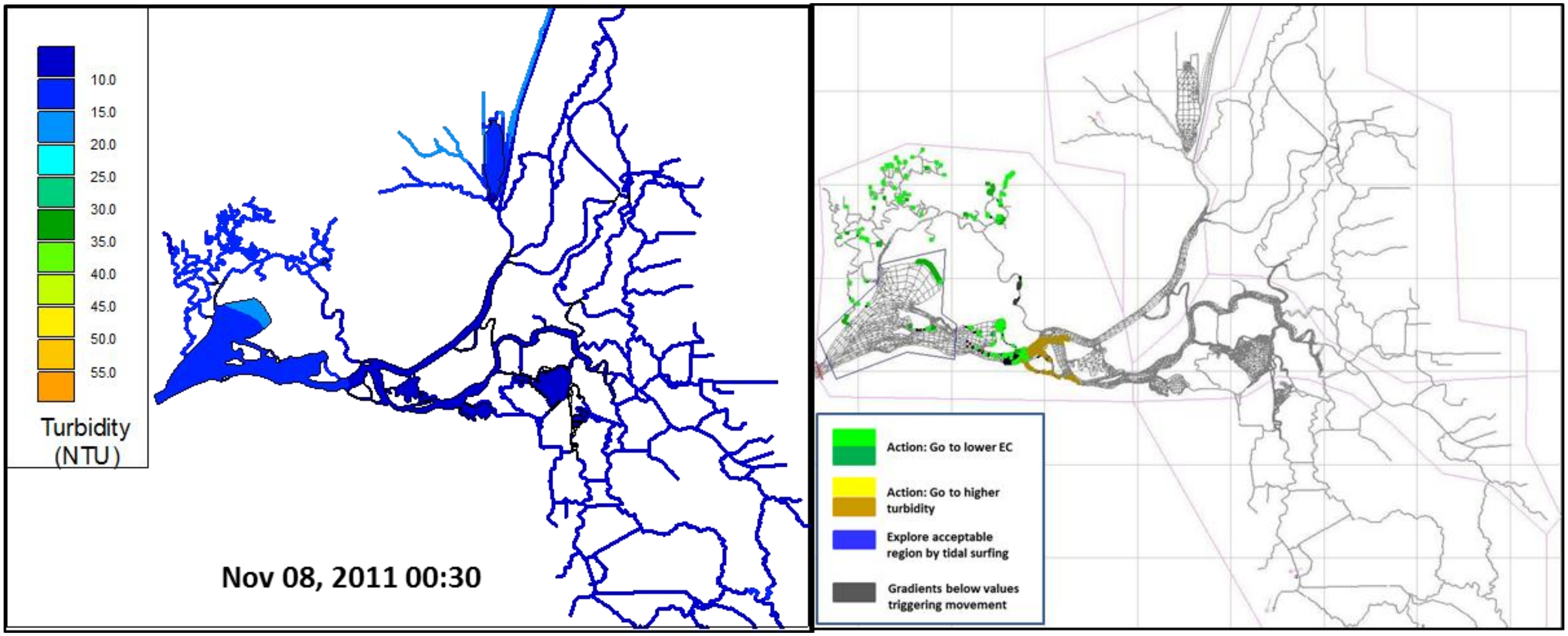

Figure 5-33 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on November 08, 2011. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

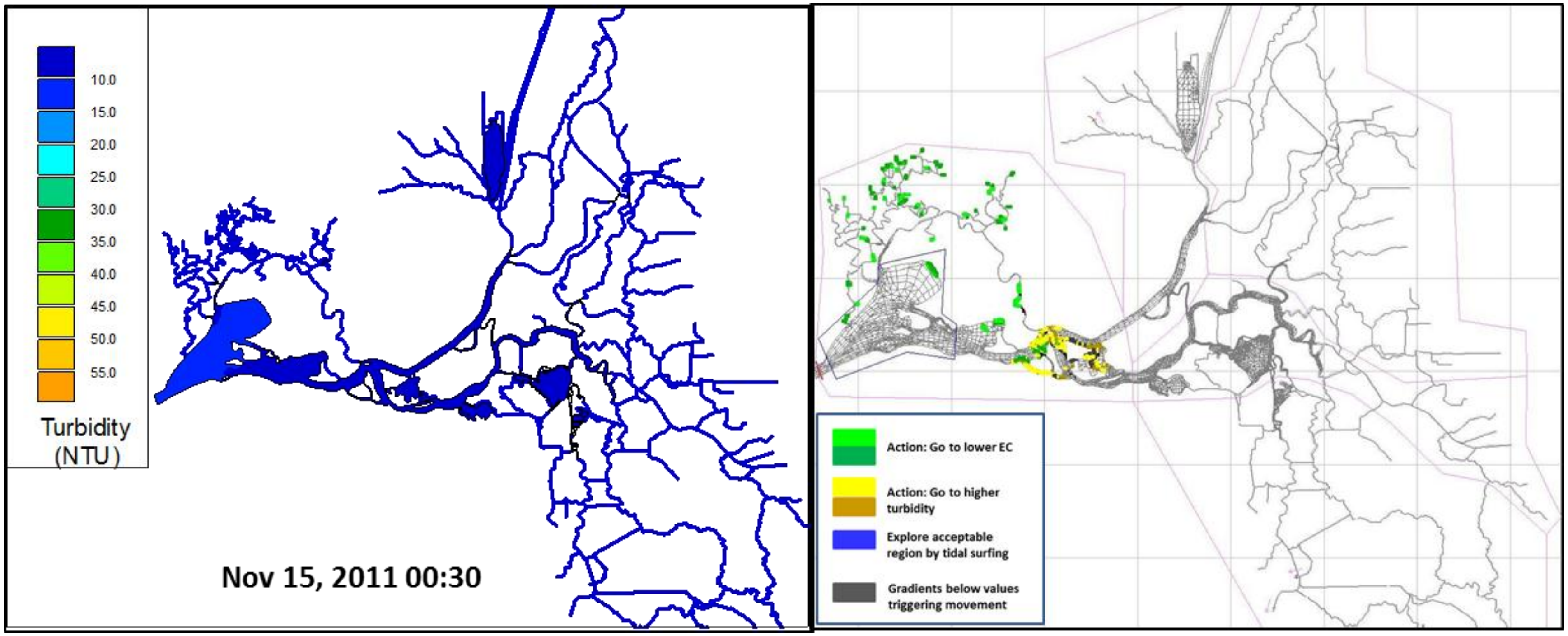

Figure 5-34 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on November 15, 2011. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

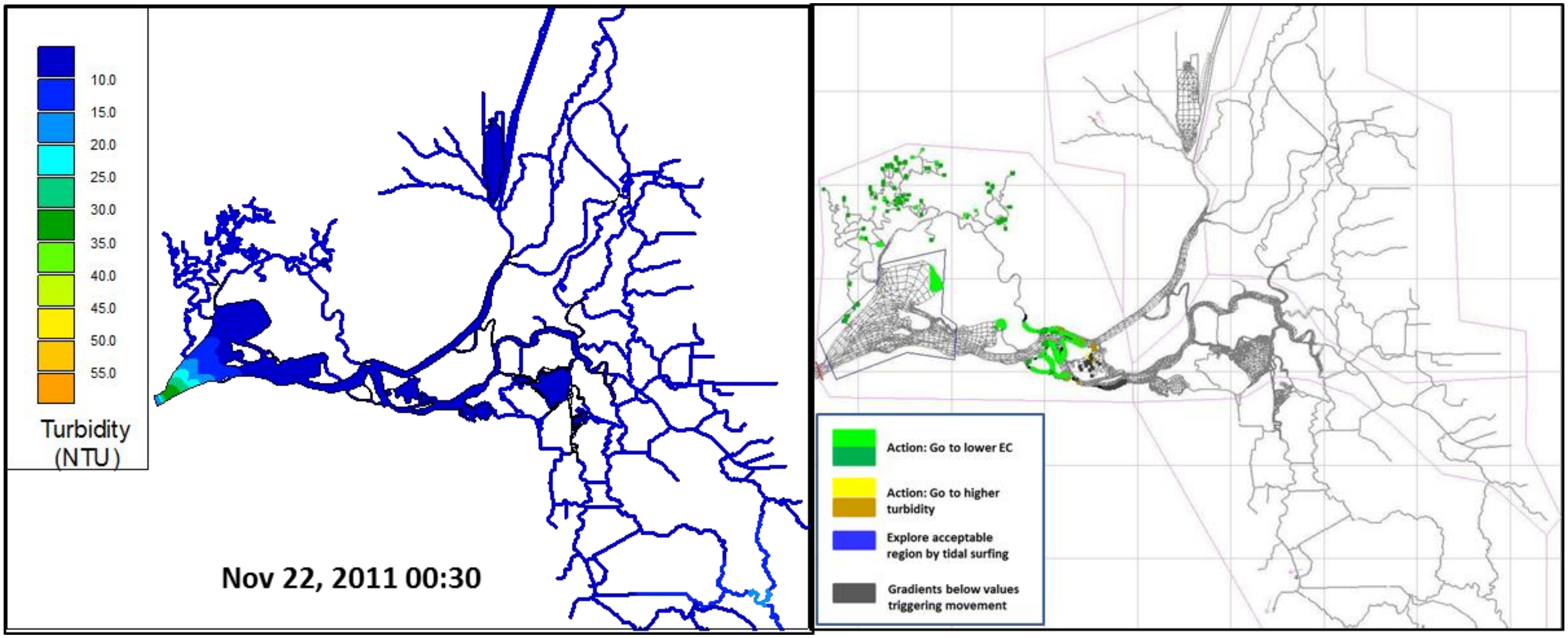

Figure 5-35 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on November 22, 2011. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

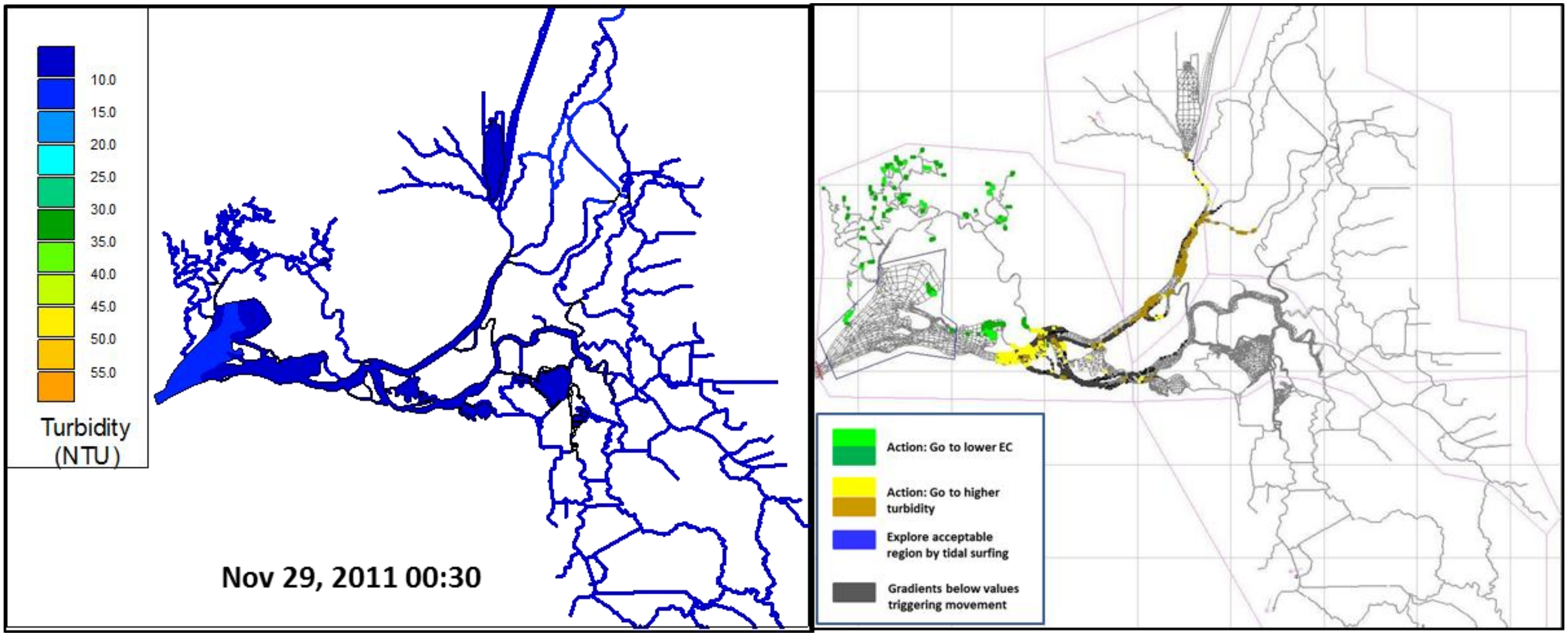

Figure 5-36 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on November 29, 2011. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

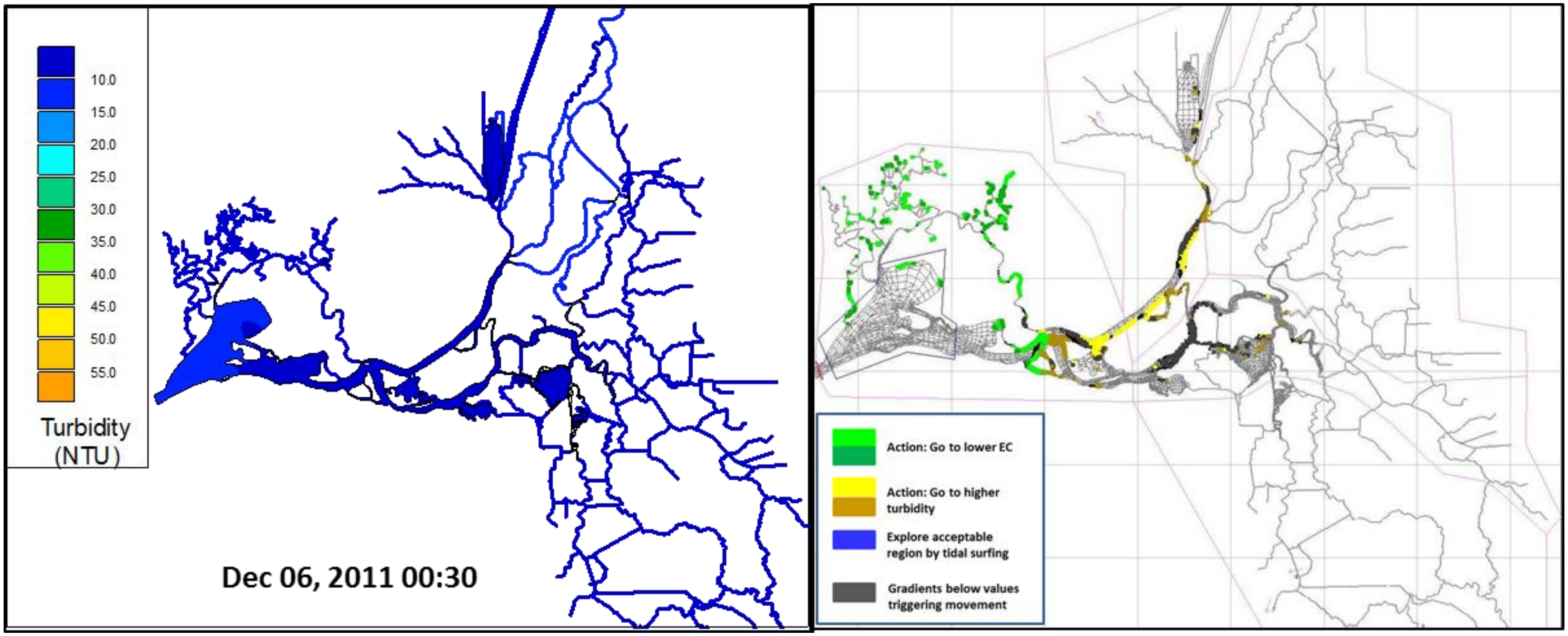

Figure 5-37 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on December 06, 2011. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

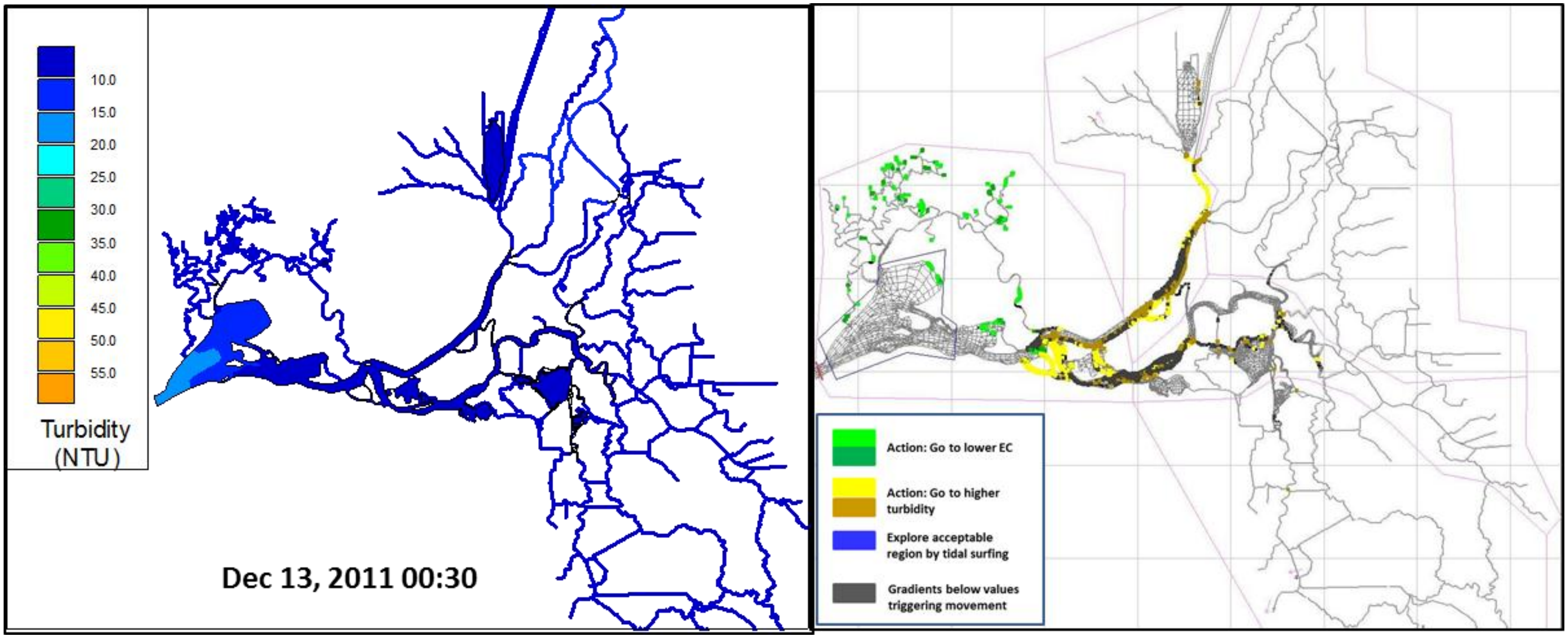

Figure 5-38 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on December 13, 2011. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

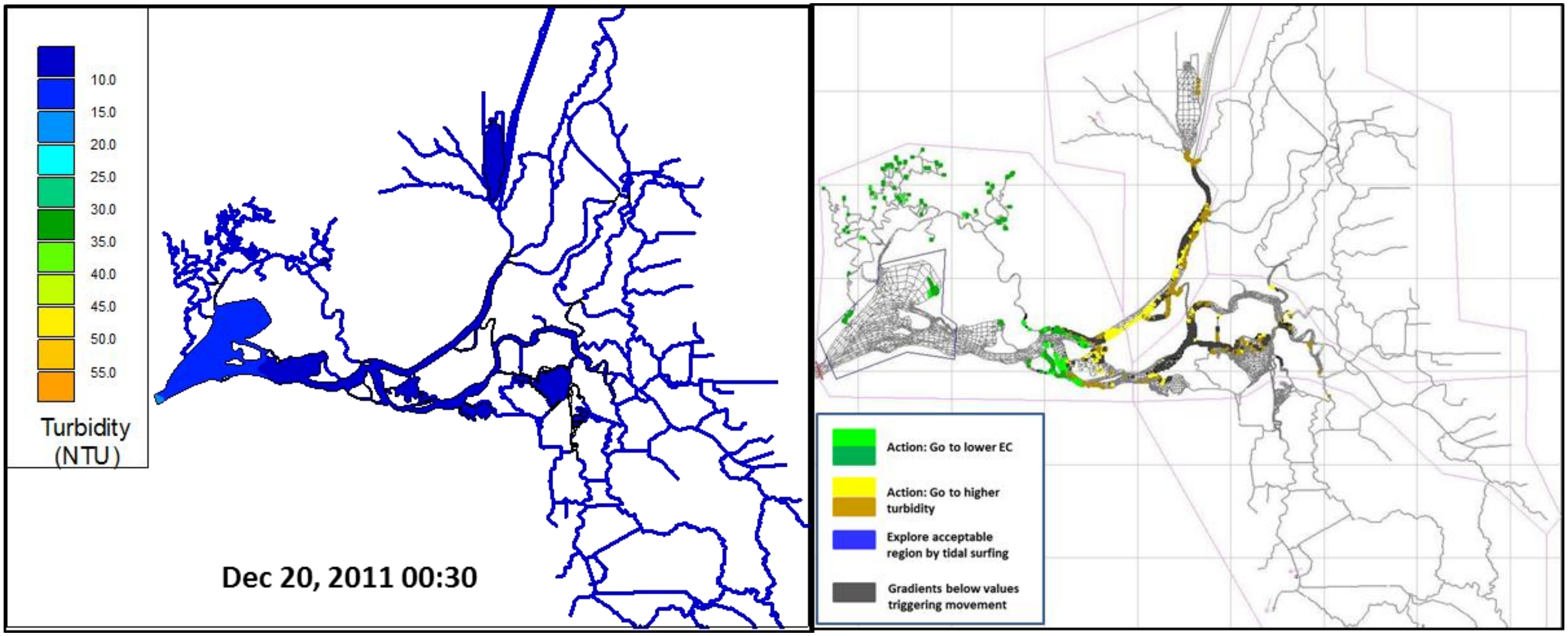

Figure 5-39 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on December 20, 2011. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

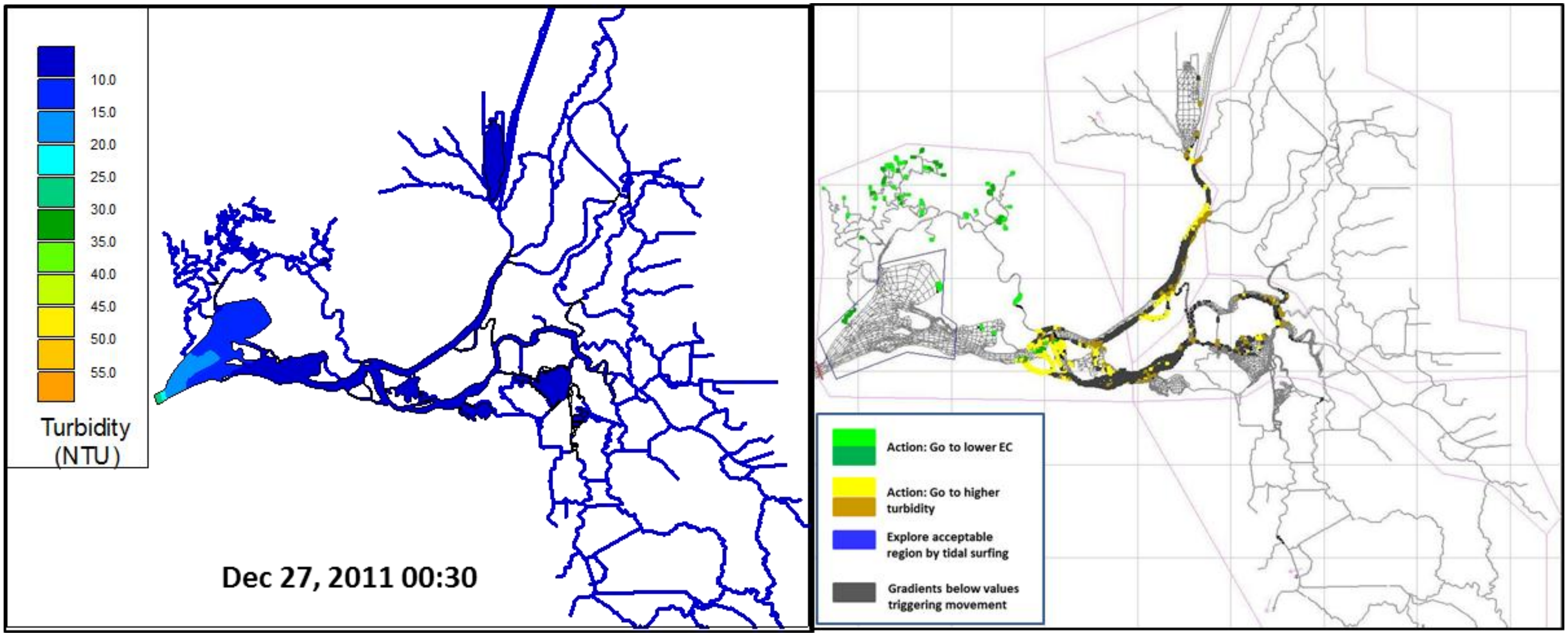

Figure 5-40 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on December 27, 2011. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

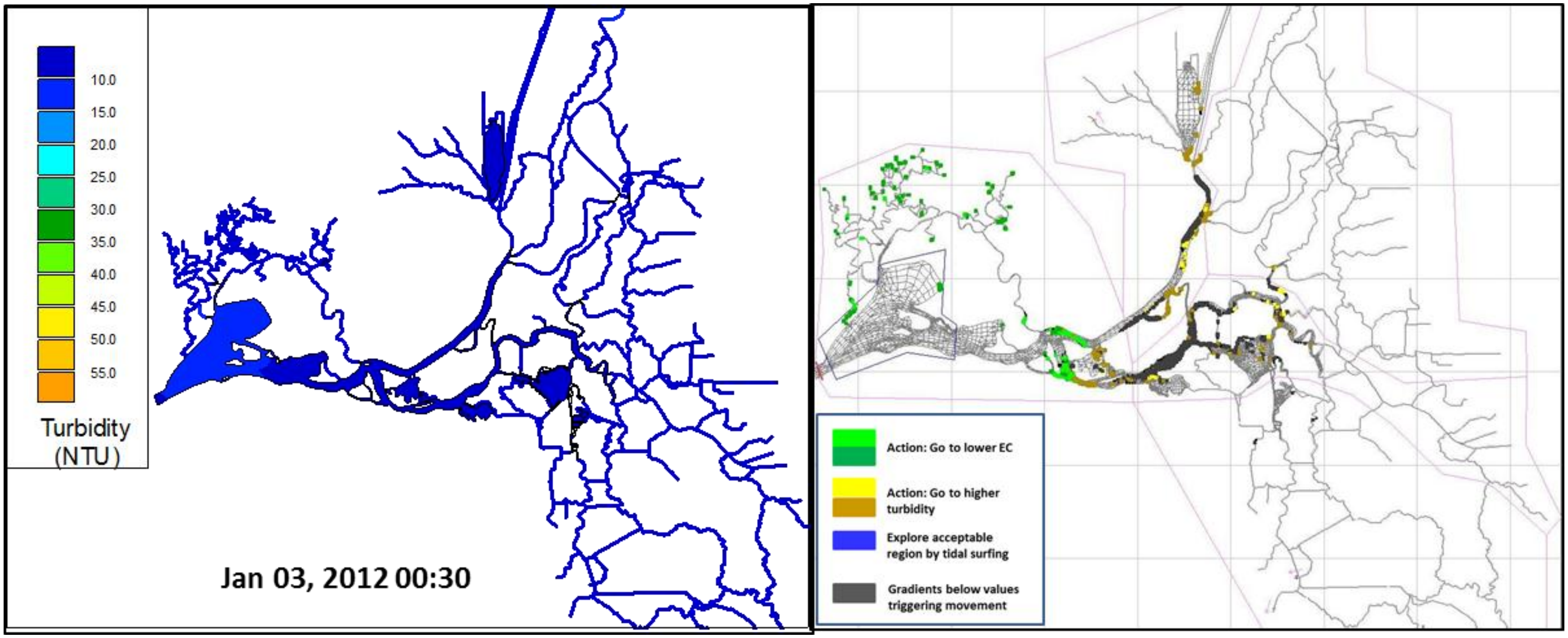

Figure 5-41 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on January 03, 2012. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

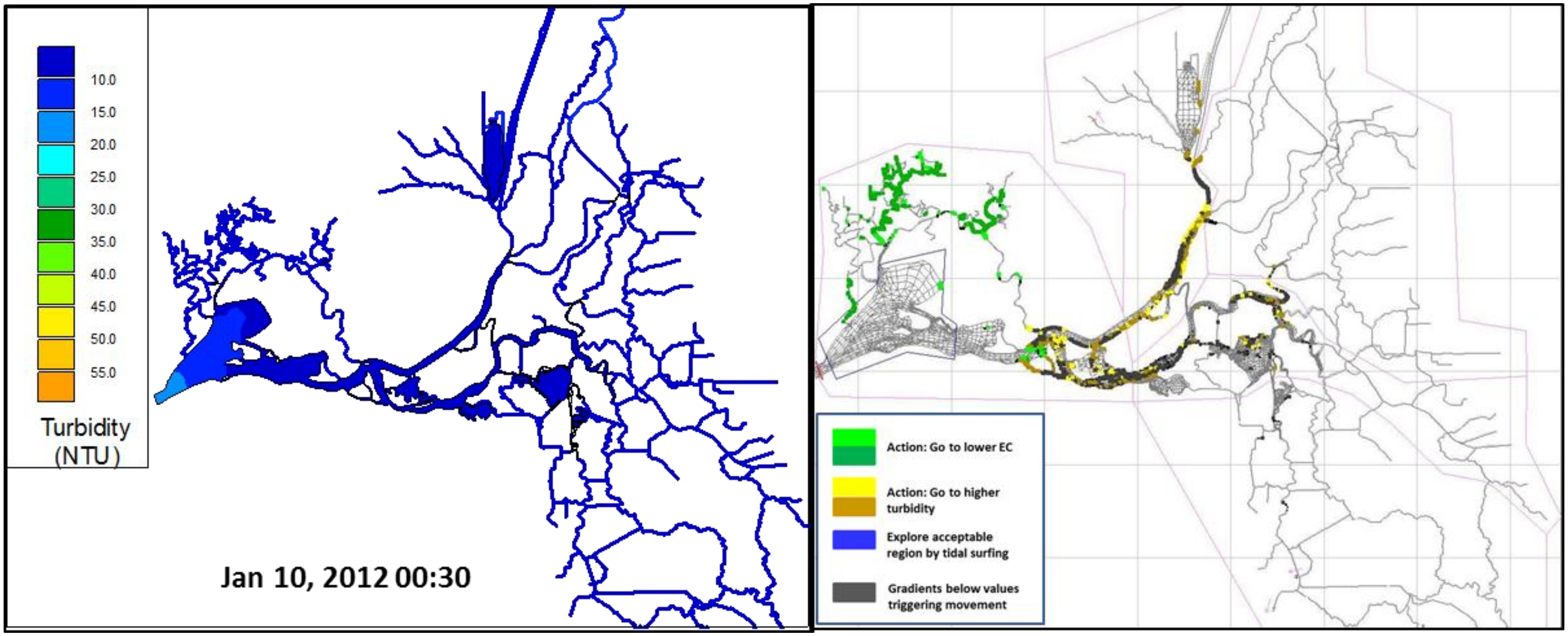

Figure 5-42 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on January 10, 2012. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

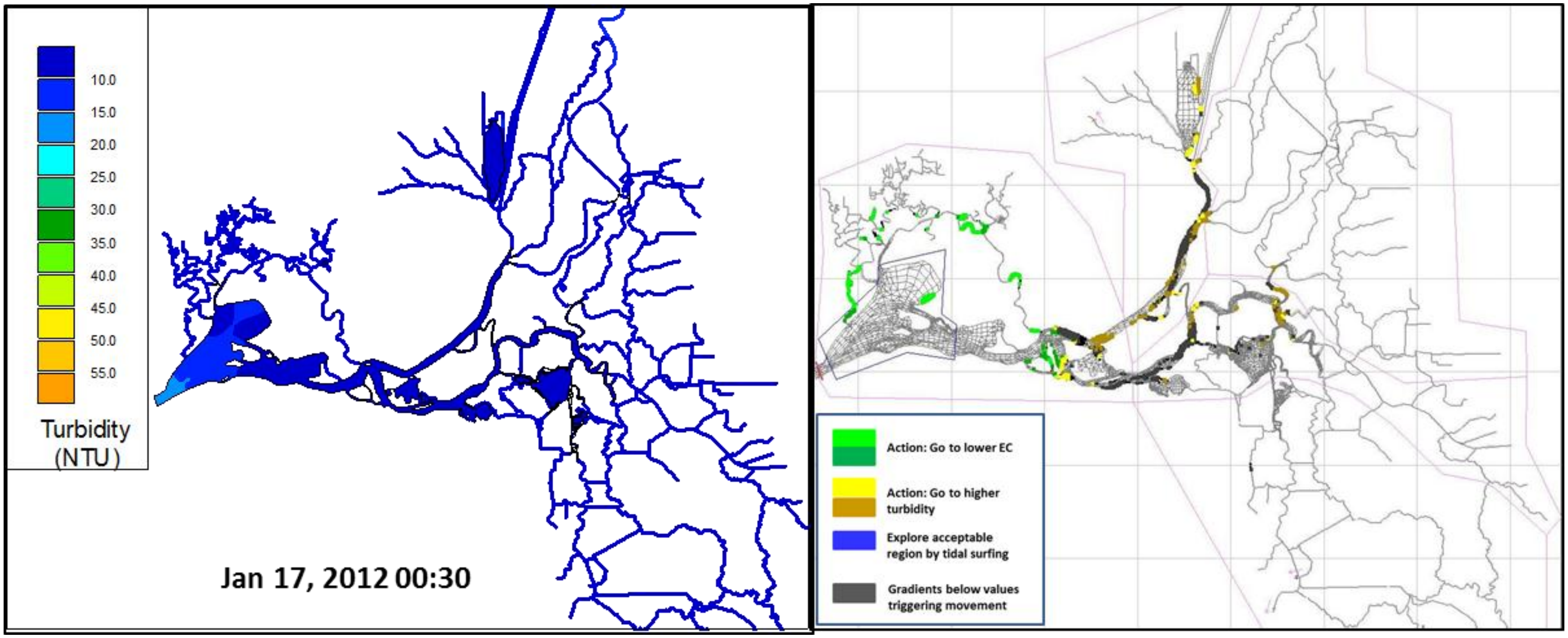

Figure 5-43 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on January 17, 2012. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

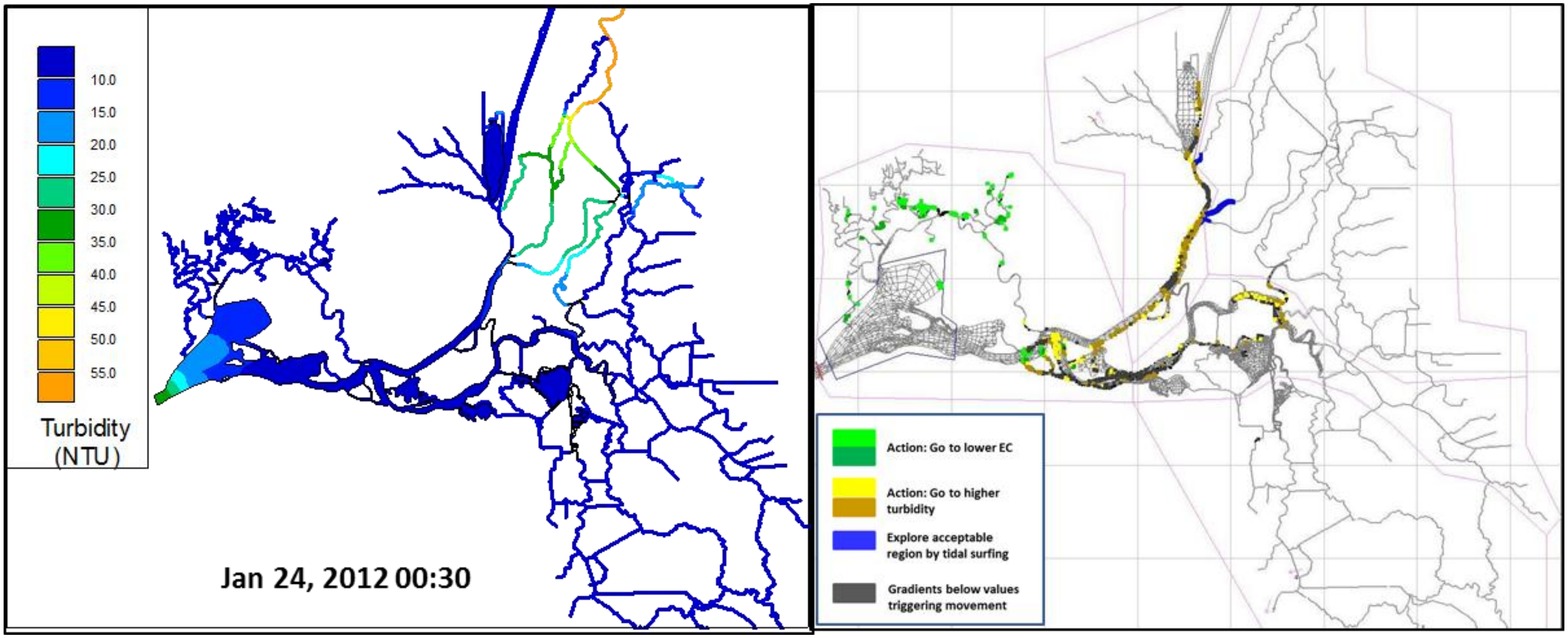

Figure 5-44 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on January 24, 2012. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

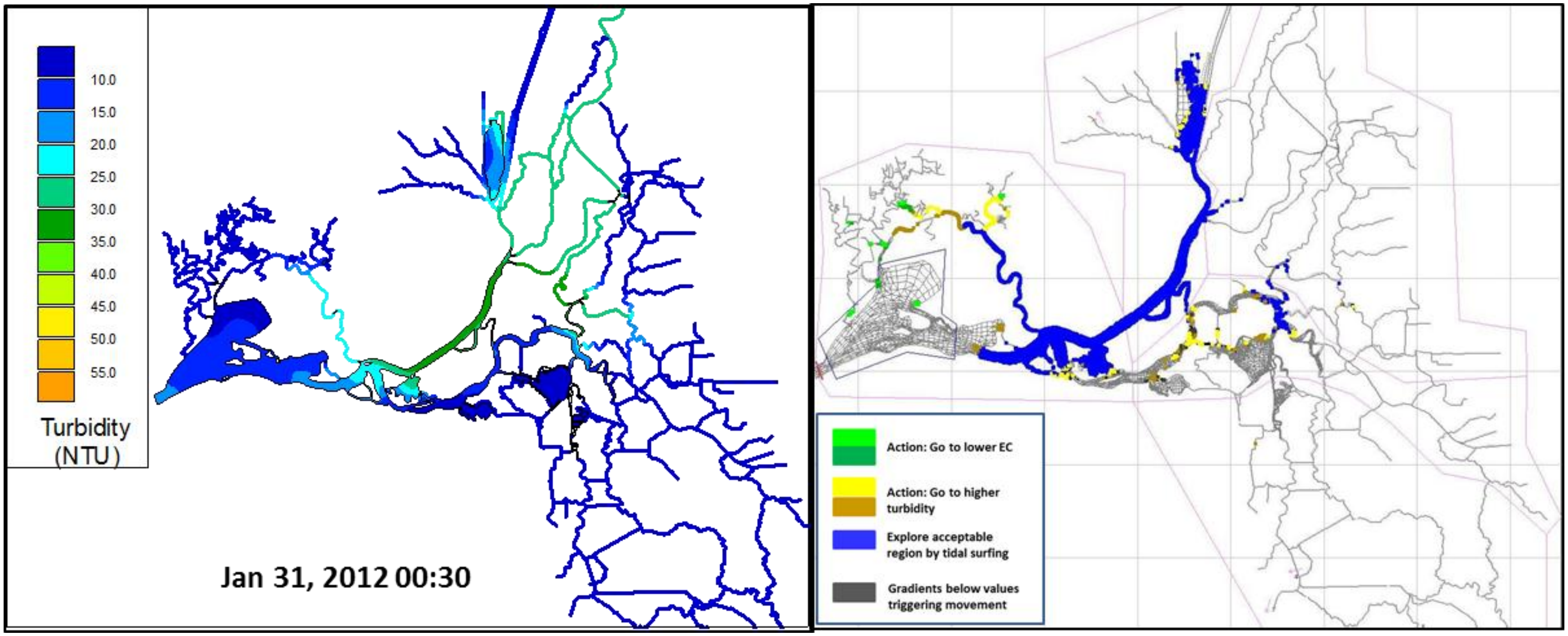

Figure 5-45 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on January 31, 2012. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

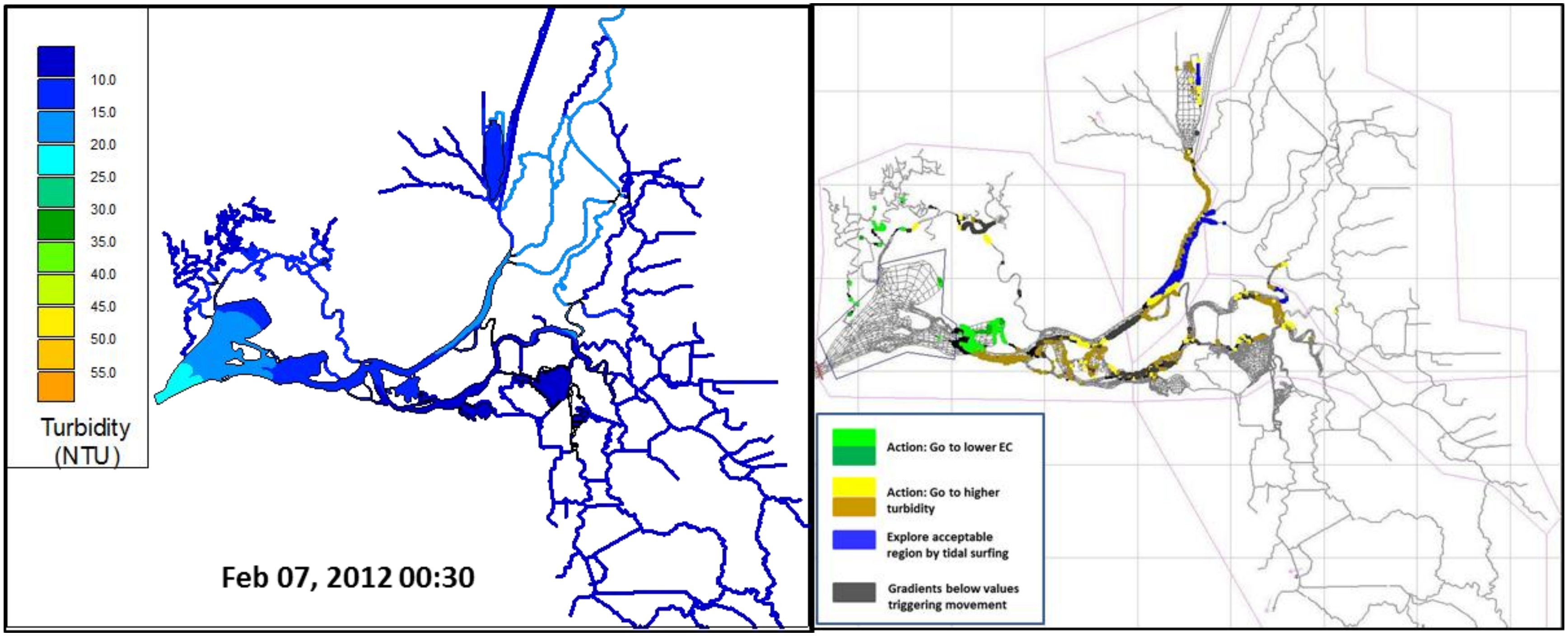

Figure 5-46 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on February 07, 2012. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

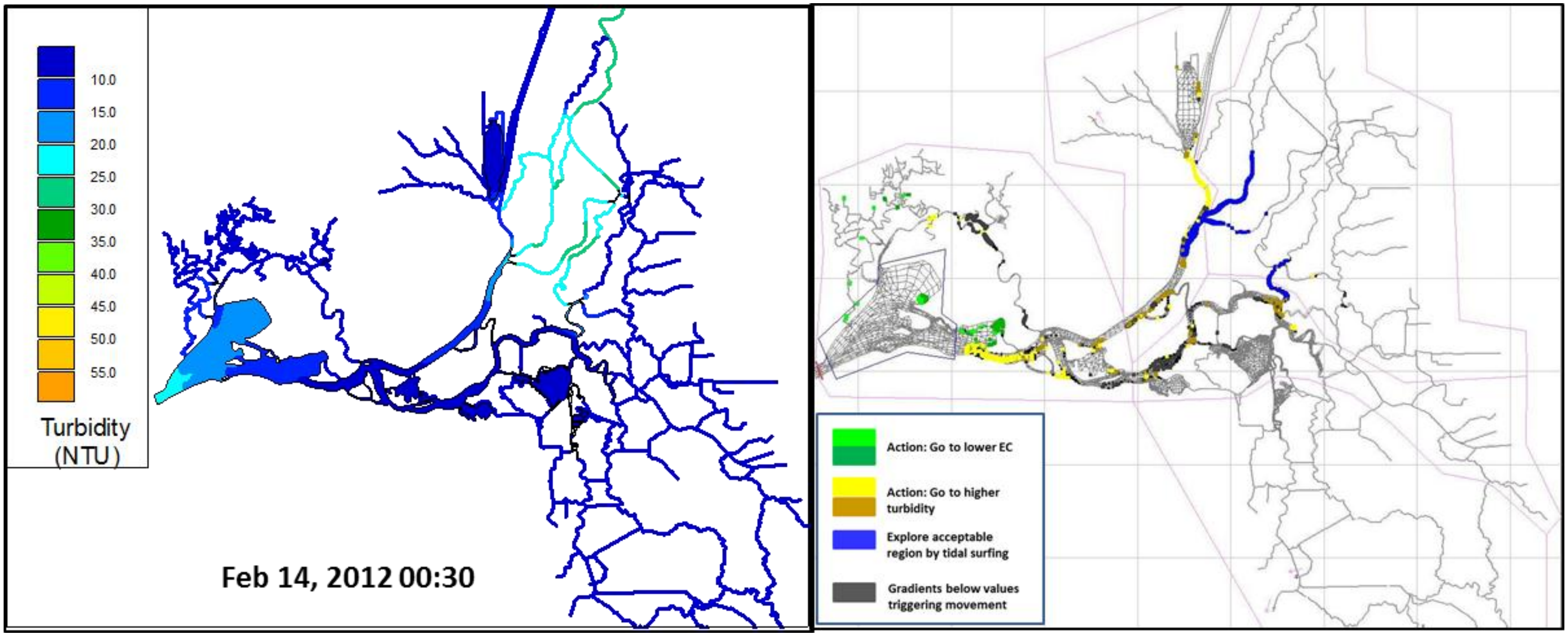

Figure 5-47 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on February 14, 2012. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

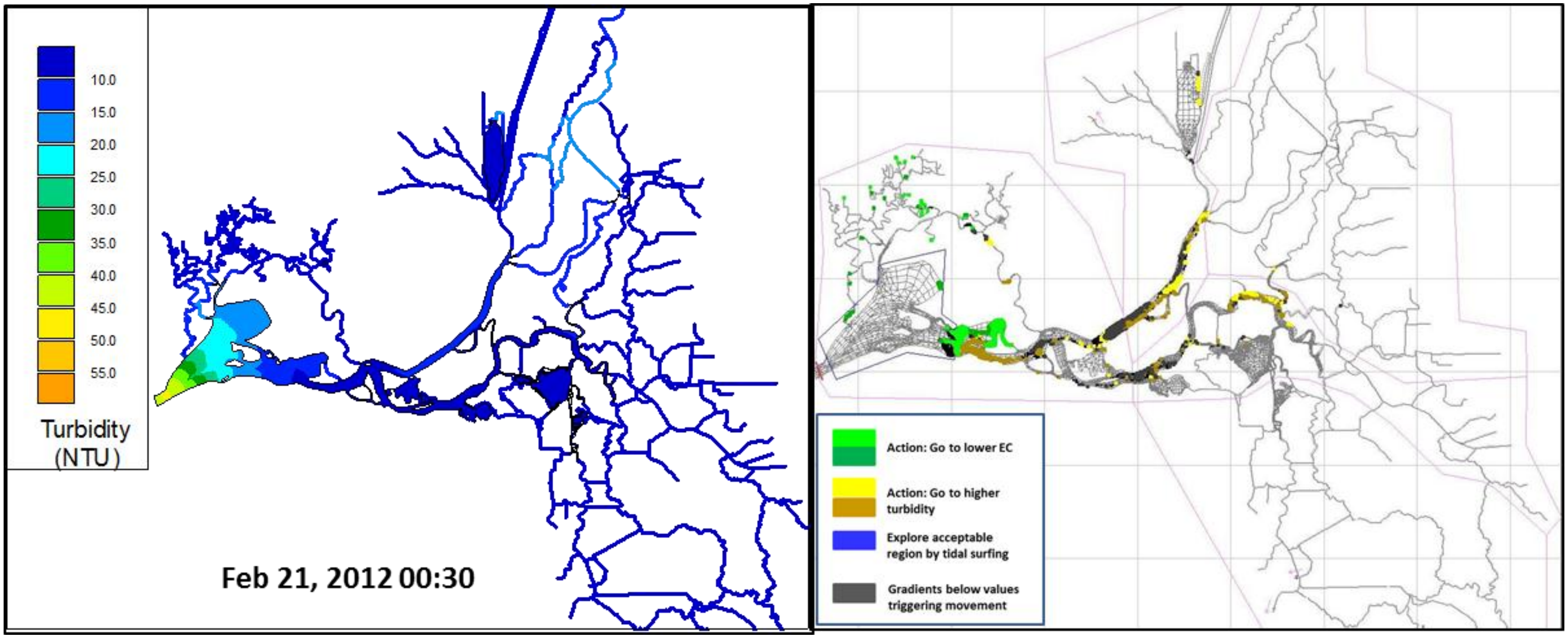

Figure 5-48 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on February 21, 2012. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

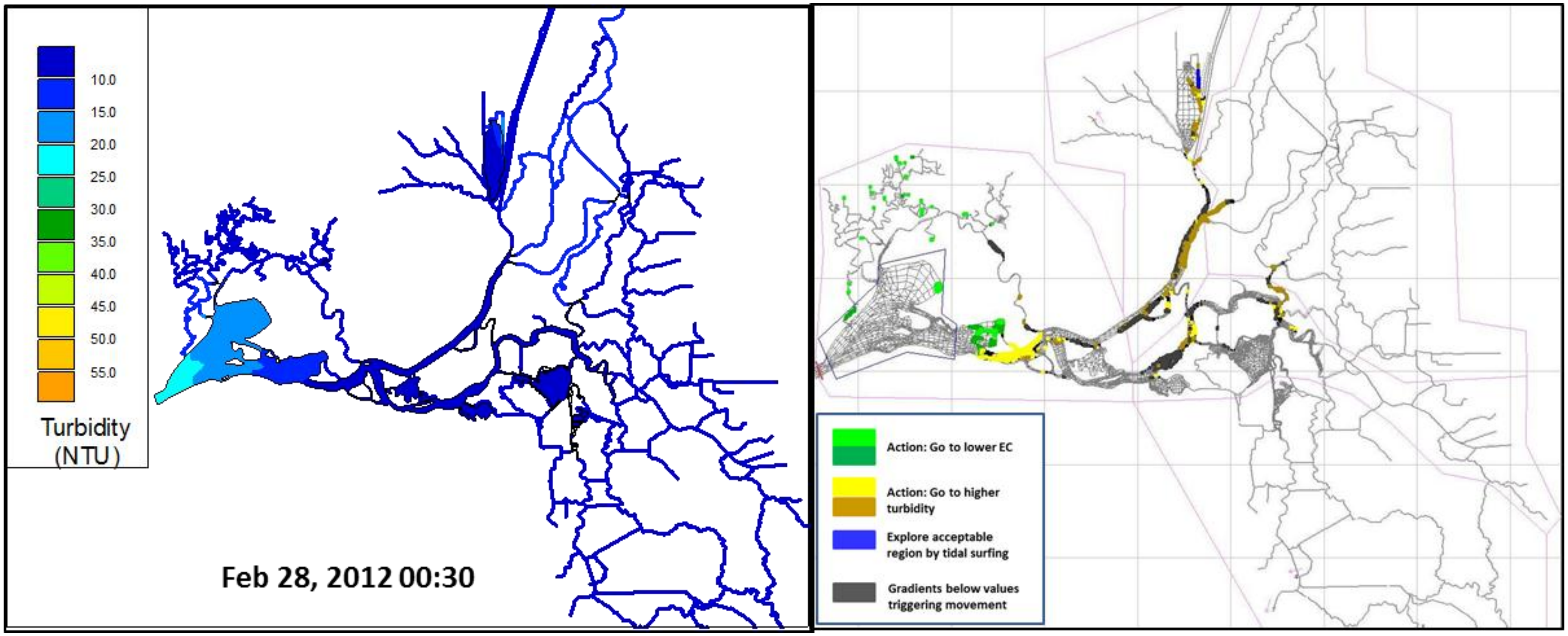

Figure 5-49 Turbidity concentration (left subplot) and adult delta smelt particle locations (right subplot) on February 28, 2012. Particle model results are individually colored according the behavioral rule governing the particle's motion at the time.

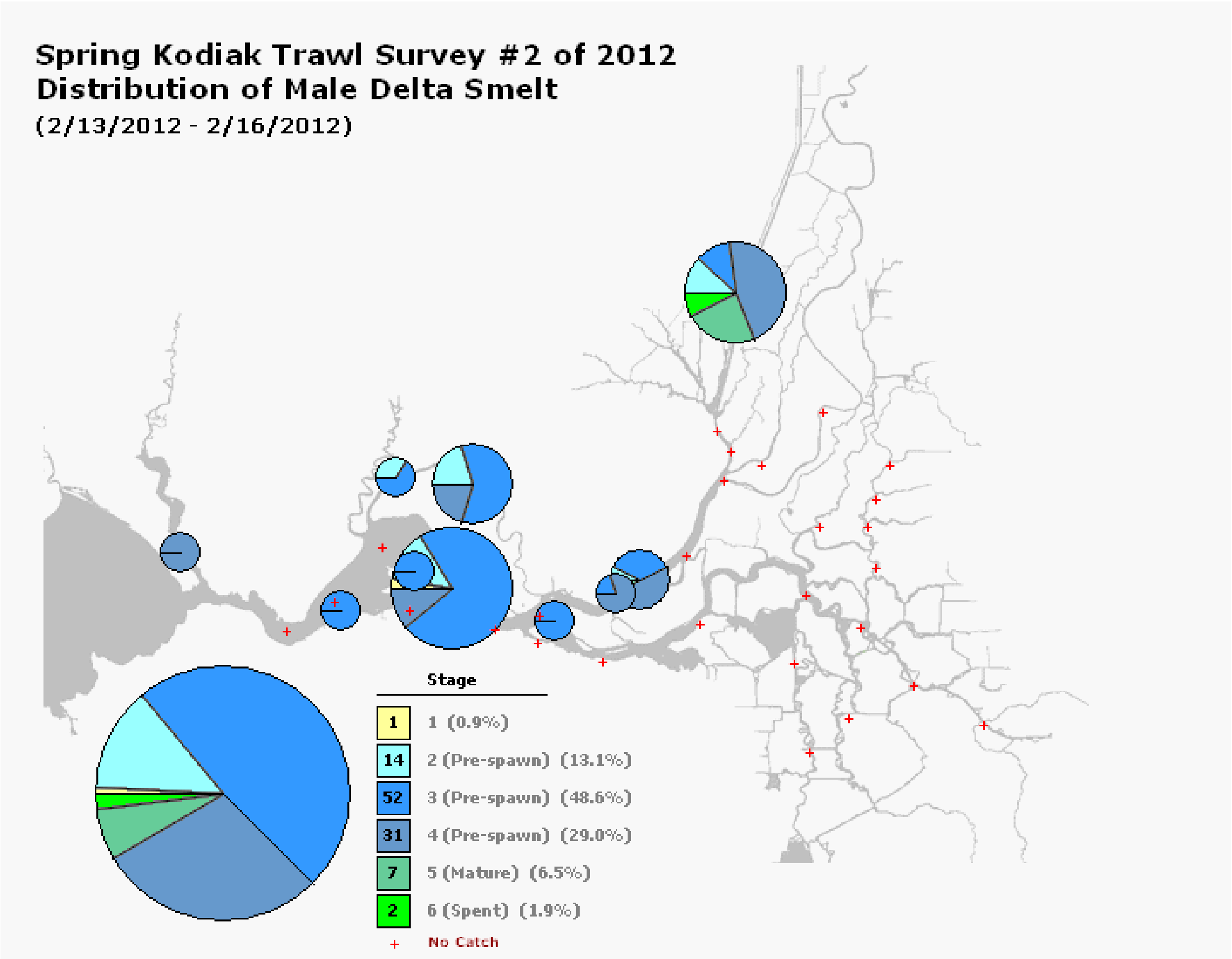

Figure 5-50 CA DFG Spring Kodiak Trawl Survey of male delta smelt distributions in mid-February 2012.

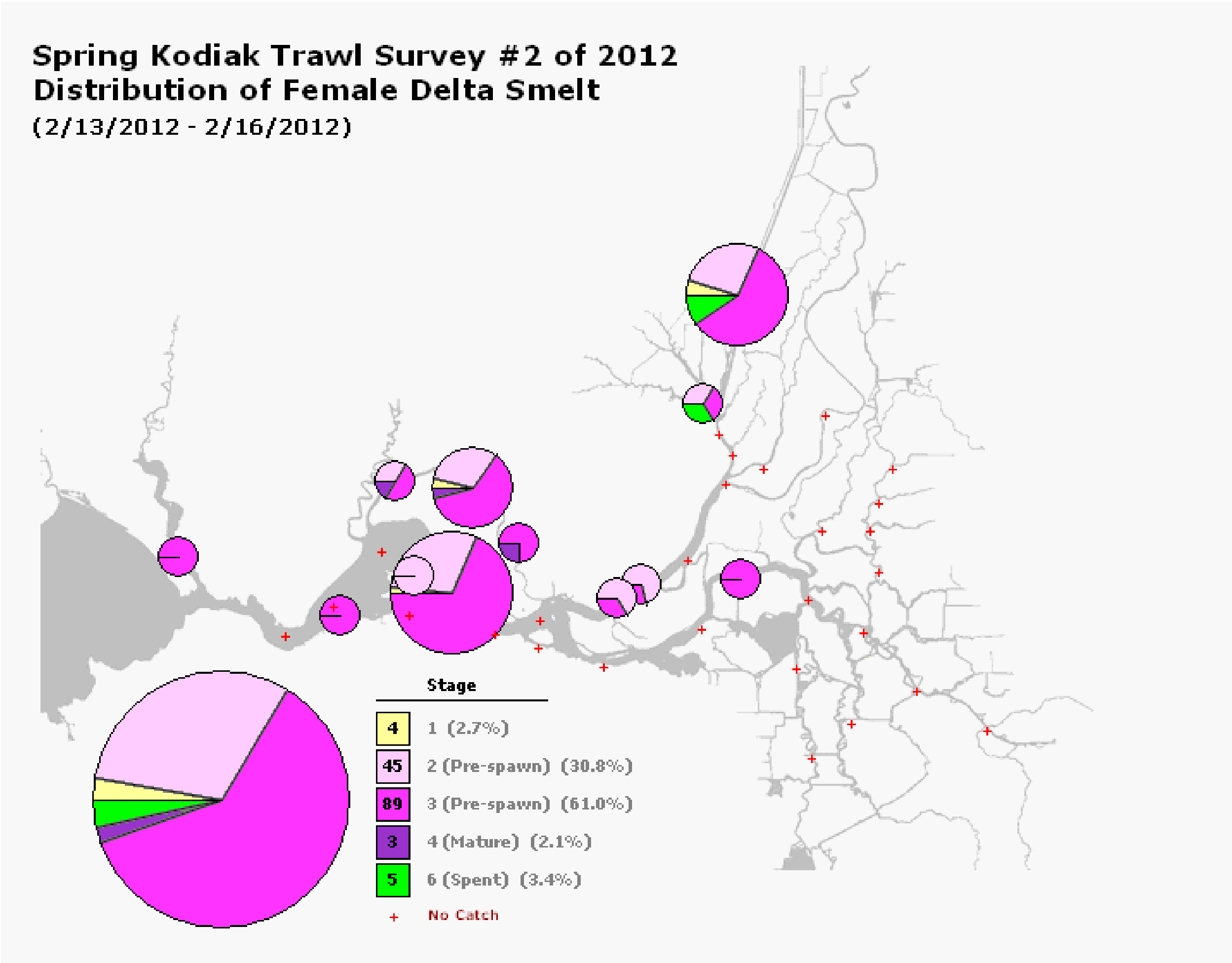

Figure 5-51 CA DFG Spring Kodiak Trawl Survey of female delta smelt distributions in mid-February 2012.

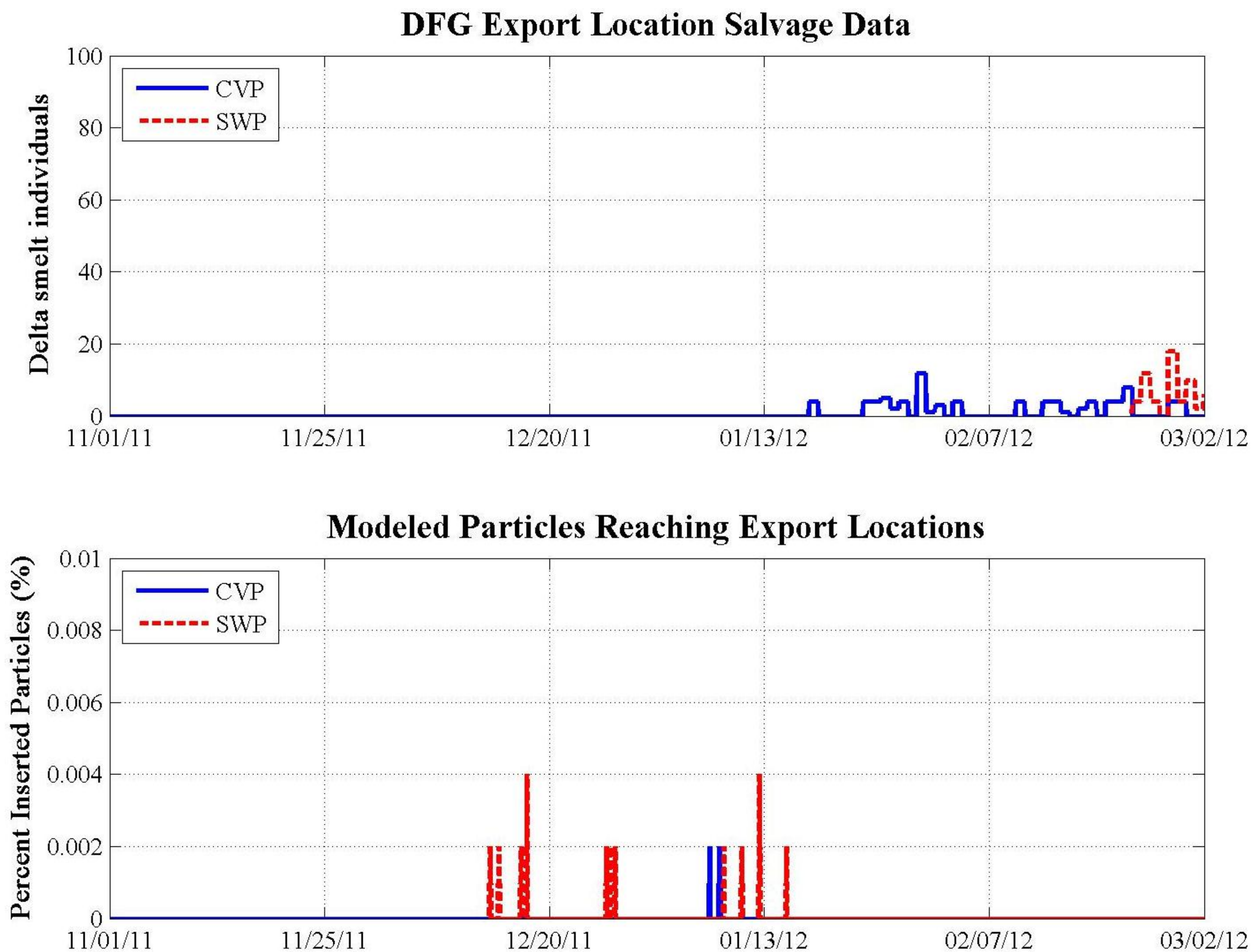

Figure 5-52 CADFG delta smelt salvage data at export locations (top plot) and percent of adult delta smelt model input particles reaching the export locations (bottom plot).

6 Boundary Condition and Scenario Utilities

User documentation for each of these utilities has been supplied to MWD on the computer available for MWD staff use (Wolverine).

The boundary conditions utility allows the user to join together time series data from different sources at stage, inflow and outflow locations, and for turbidity and salinity water quality time series data at model boundary locations. A simple example of an application using these utilities is joining together export time series from the previous forecast with export time series supplied to RMA from DWR each week.

The scenario utility allows the user to adjust a given Clifton Court Forebay time series representing SWP exports in the RMA2 model, typically composed of a historical and forecast time periods, to a different level of exports.

7 Bay-Delta Live Website Developments

The Bay-Delta Live (BDL) website developed by MWD and 34North provides a convenient interface for presenting RMA's forecast modeling work to the greater Delta science community. The site allows for the display of an interactive animation of turbidity forecast results, which can be customized with color scale changes, additional map data overlays, and the ability to zoom to areas of interest. It also provides a hierarchical organization structure which is ideally suited to display and group animation results, reports, image files, data files, and links to more detailed project documents. Its use in the WY2012, and future forecasts, enables quick dissemination of forecast results to project managers and scientists involved in Delta smelt movement.

From the Bay-Delta Live homepage, project information and a visualization of the results of each forecast can be reached from the Data Visualizations tab. Currently, the main Data Visualization page lists the most recent and most viewed RMA turbidity forecasts. Prior weekly forecasts can be found by clicking on the Search Visualizations tab and searching "forecast." Specific previous weekly forecasts can be found by searching using the forecast date. A screenshot of the main Data Visualizations panel of the BDL webpage is shown in Figure 7-1.

A forecast visualization may be loaded by clicking on the forecast icon. The main forecast page, and the primary focus for the display of forecast data, is the color contour animation of RMA's turbidity model results (see Figure 7-2). Approximately two thousand polygons are animated over a 3 week time period to visualize hourly modeled turbidity. Since the RMA forecast models produce turbidity output at roughly 39,000 points throughout the Delta, it was necessary to only use a small subset of the results in order to create a fast and efficient web-based animation. The model output locations chosen for use in the animation are intended to broadly and efficiently cover the Delta region and are shown in Figure 7-3. Outputs at these 61 stations are linearly combined to produce interpolated turbidity values for each polygon used in the animation. The interpolation procedure is performed via a standalone program provided to 34North by RMA, the details of which are given in the Appendix. The resulting web-based animation is highly interactive—users can play and stop the animation, zoom into areas of interest, and control the color bar properties.

In addition to the animation, an organized supporting document structure was created and attached to each weekly forecast. By clicking on the tabs above the map pane, users are directed to information about RMA's modeling methodologies and assumptions, a short forecast summary, a view the Delta smelt forecast distribution map, and links to the raw model outputs and model calibration reports (see Figure 7-4, Figure 7-5, Figure 7-6, and Figure 7-8). The full modeling methodology and assumptions document shown in Figure 7-4 is presented in its entirety in the Section 14 Appendix. Any of these supporting files or reports shown in Figure 7-8 may be hidden so that only viewers with specific access permission will be able to view them.

The smelt summary graphic presented on BDL (Figure 7-6 and Figure 7-7) was designed to show broad trends in the results of the smelt behavioral model. The spatial resolution of the smelt regions was decreased from WY2011 forecasts. The coarser polygons were used in order to provide a broader classification of smelt distribution throughout the Delta and reduce public misinterpretation of the capabilities of the smelt model. The five new regions were created to differentiate between areas of non-concern (Suisun, Cache, and Sacramento), a "watch" area (San Joaquin), and an "action" area (South Delta). The Section 13 Appendix provides a comparison between particle tracking results obtained with the WY2011 smelt regions and the coarser WY2012 regions.

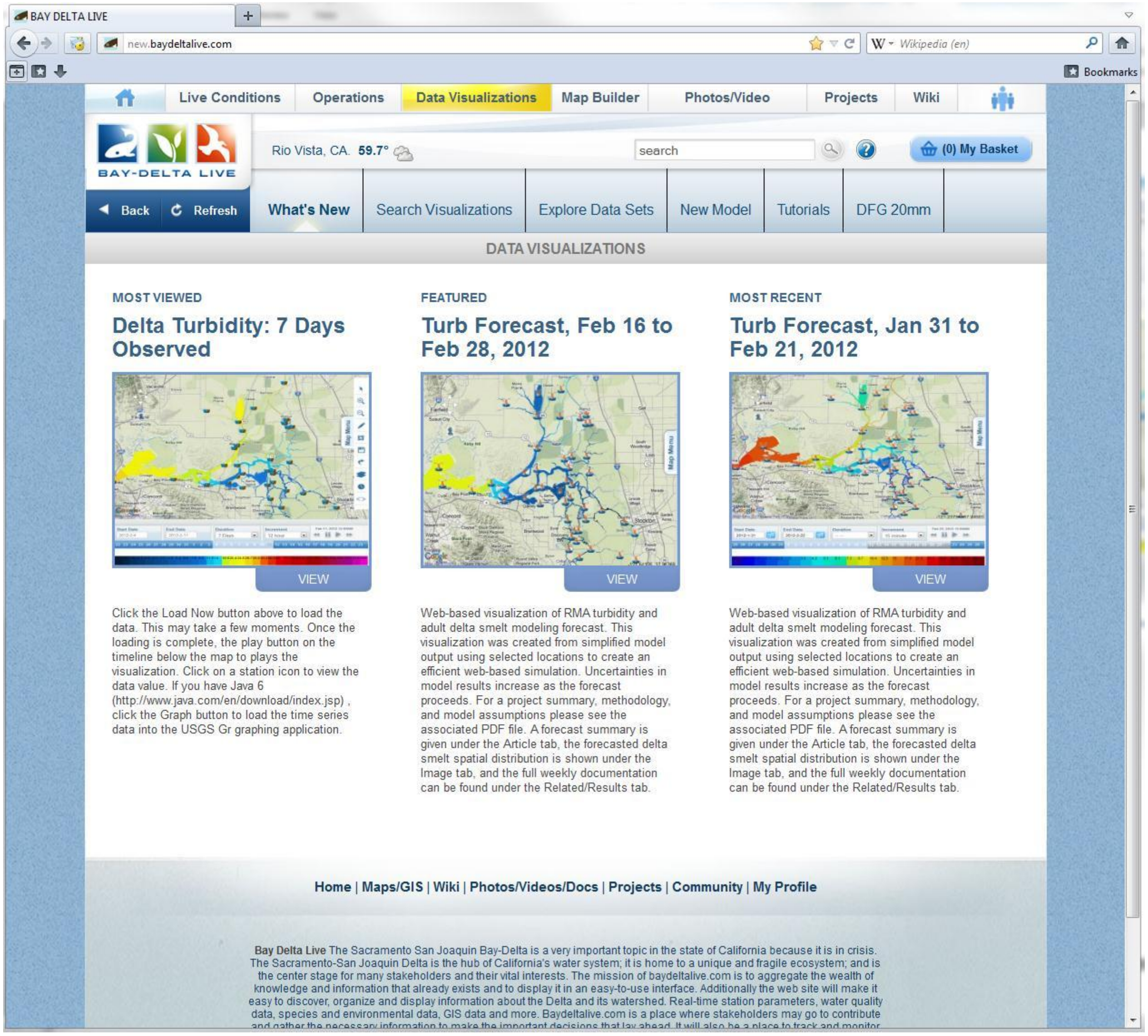

Figure 7-1 Bay-Delta Live Data Visualizations home page showing recent weekly forecasts.

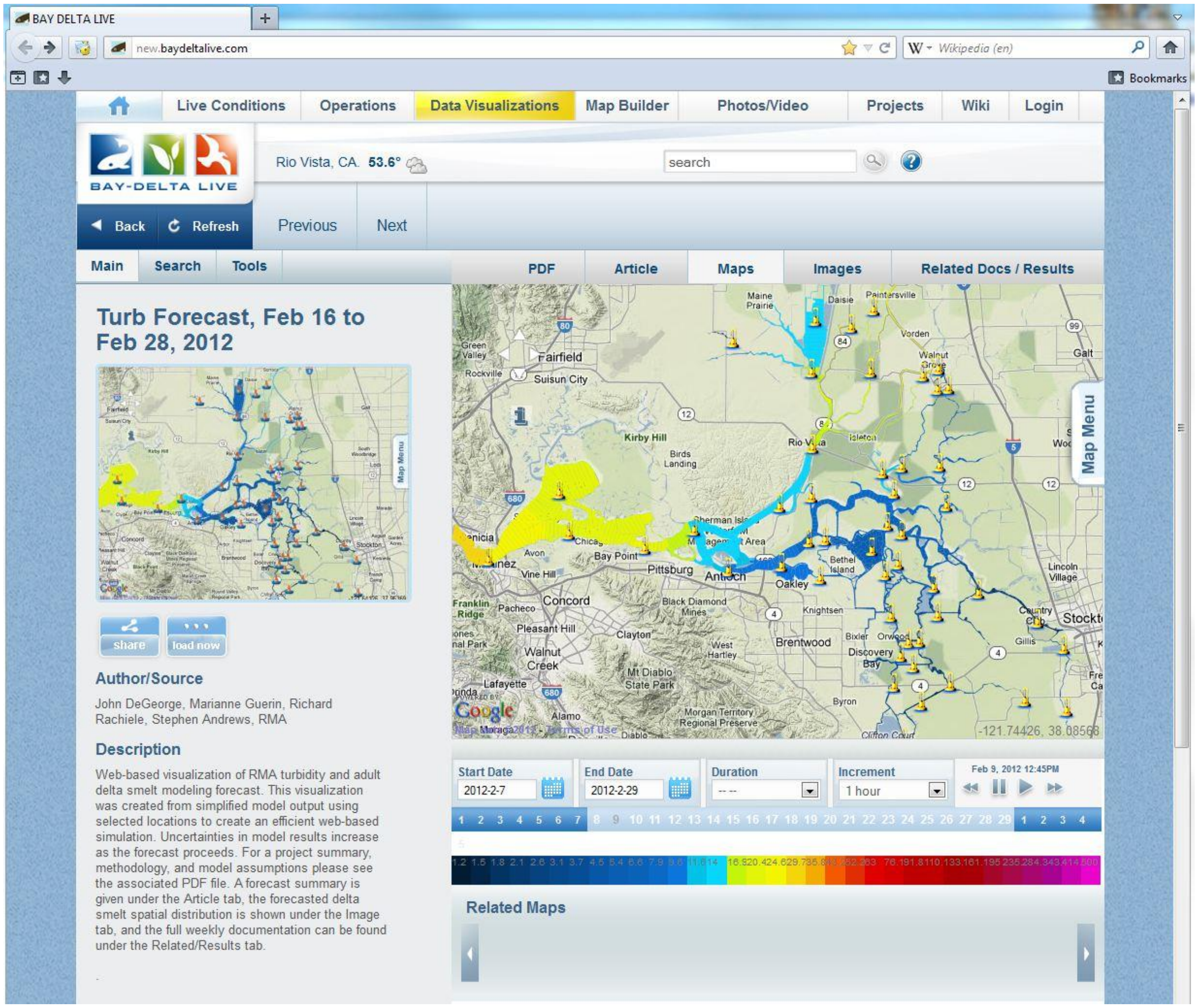

Figure 7-2 Bay-Delta Live interactive turbidity contour animation. Weekly RMA model results are shown as colored polygons, animated over 1 week of historical conditions and 2 weeks of model forecast. Users are able to modify the color scale, toggle through the time window, and zoom to areas of interest.

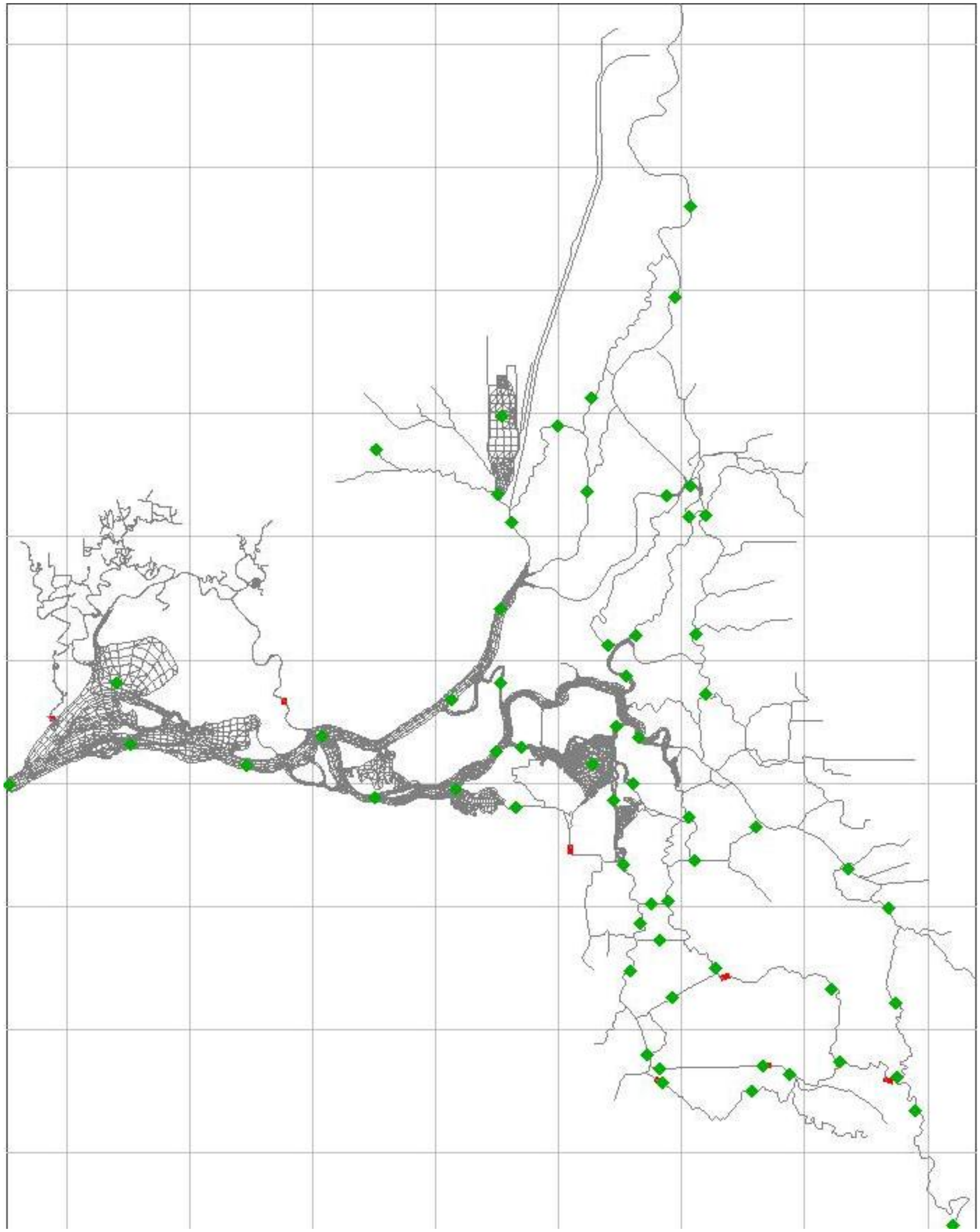

Figure 7-3 RMA turbidity model output locations for Bay-Delta Live web-based forecast visualization.

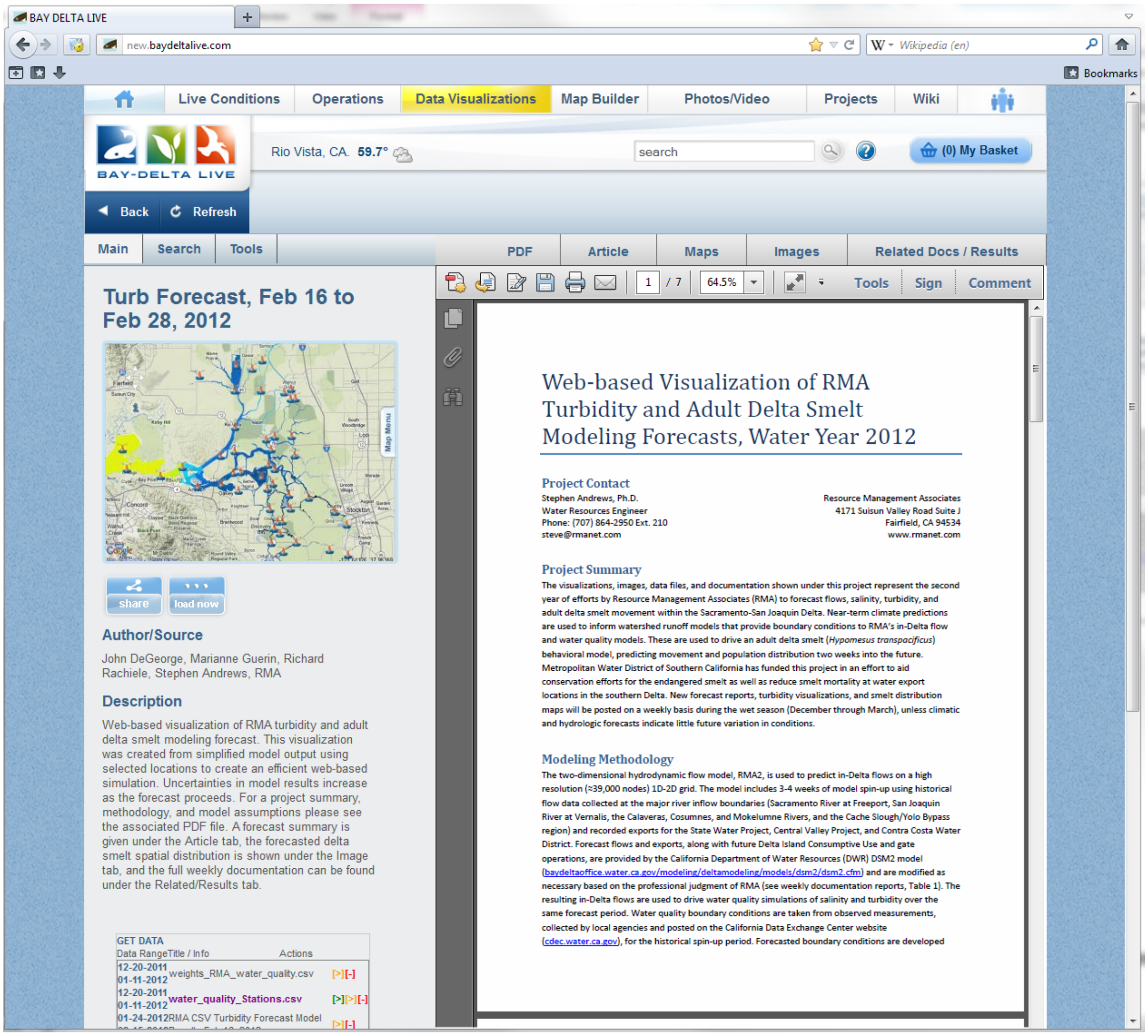

Figure 7-4 Bay-Delta Live turbidity forecast PDF tab display. A PDF document is shown with project information, modeling methodology, key model assumptions, and information about the translation of RMA model results into a web-based visualization. This document is given in full in Section 14.

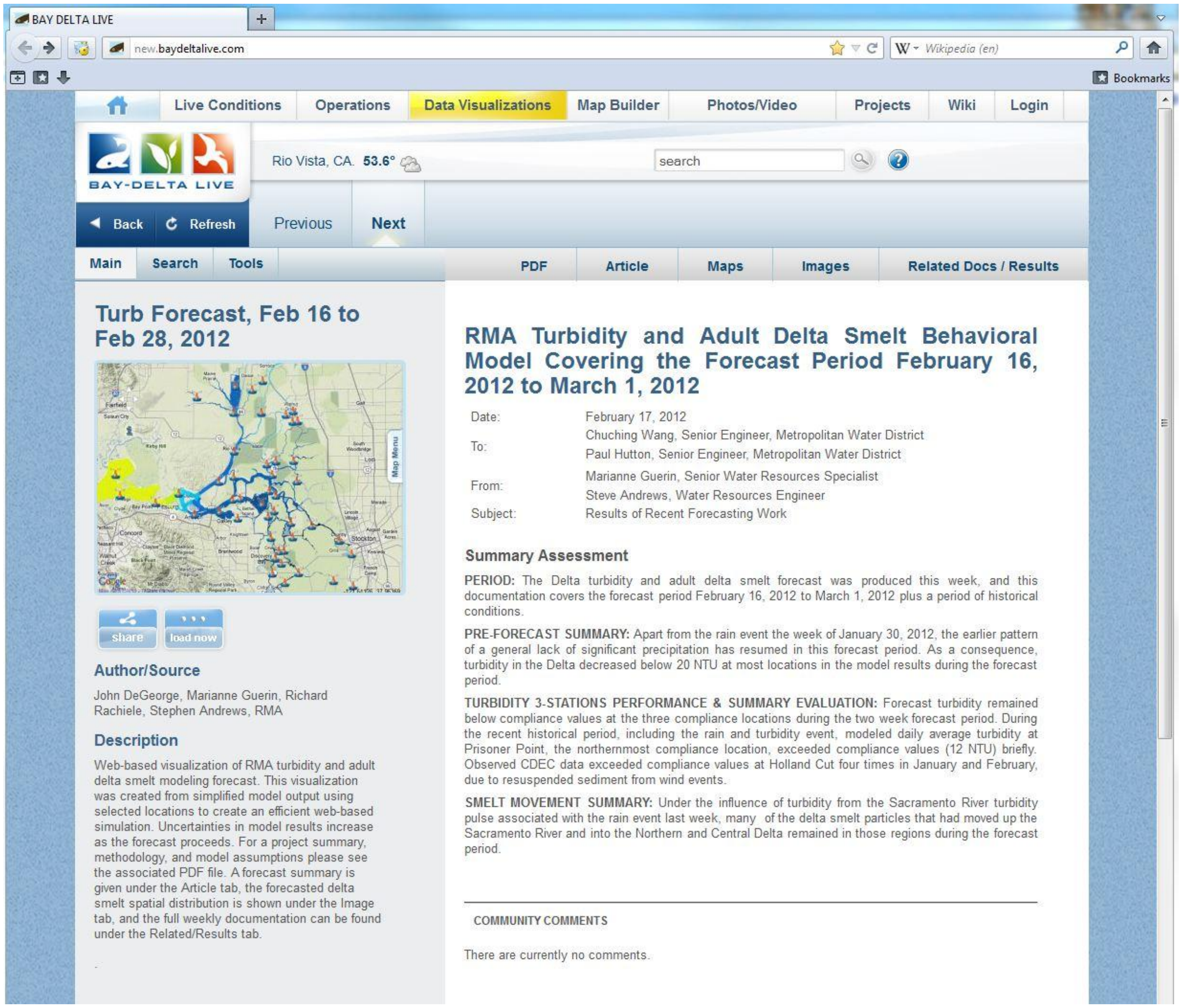

Figure 7-5 Bay-Delta Live turbidity forecast Article tab display. A brief summary of the forecast is given, with information about turbidity at compliance locations and the general direction of modeled adult smelt movements.

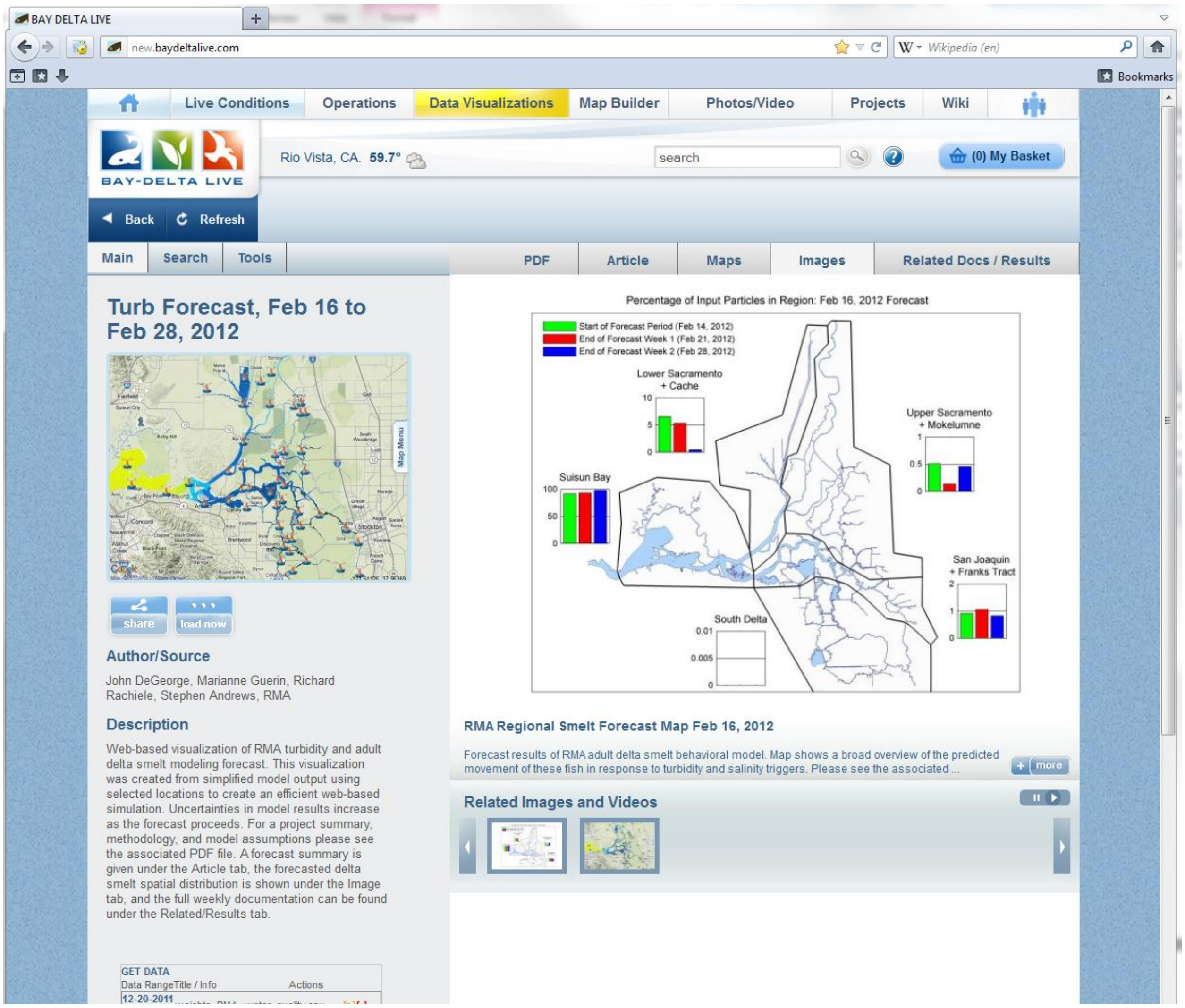

Figure 7-6 Bay-Delta Live turbidity forecast Images tab. A map of the Delta broken into 5 broad regions is given, with the relative particle populations at the start of the forecast, 1 week into the forecast, and 2 weeks into the forecast is shown. A more detailed image is given in .

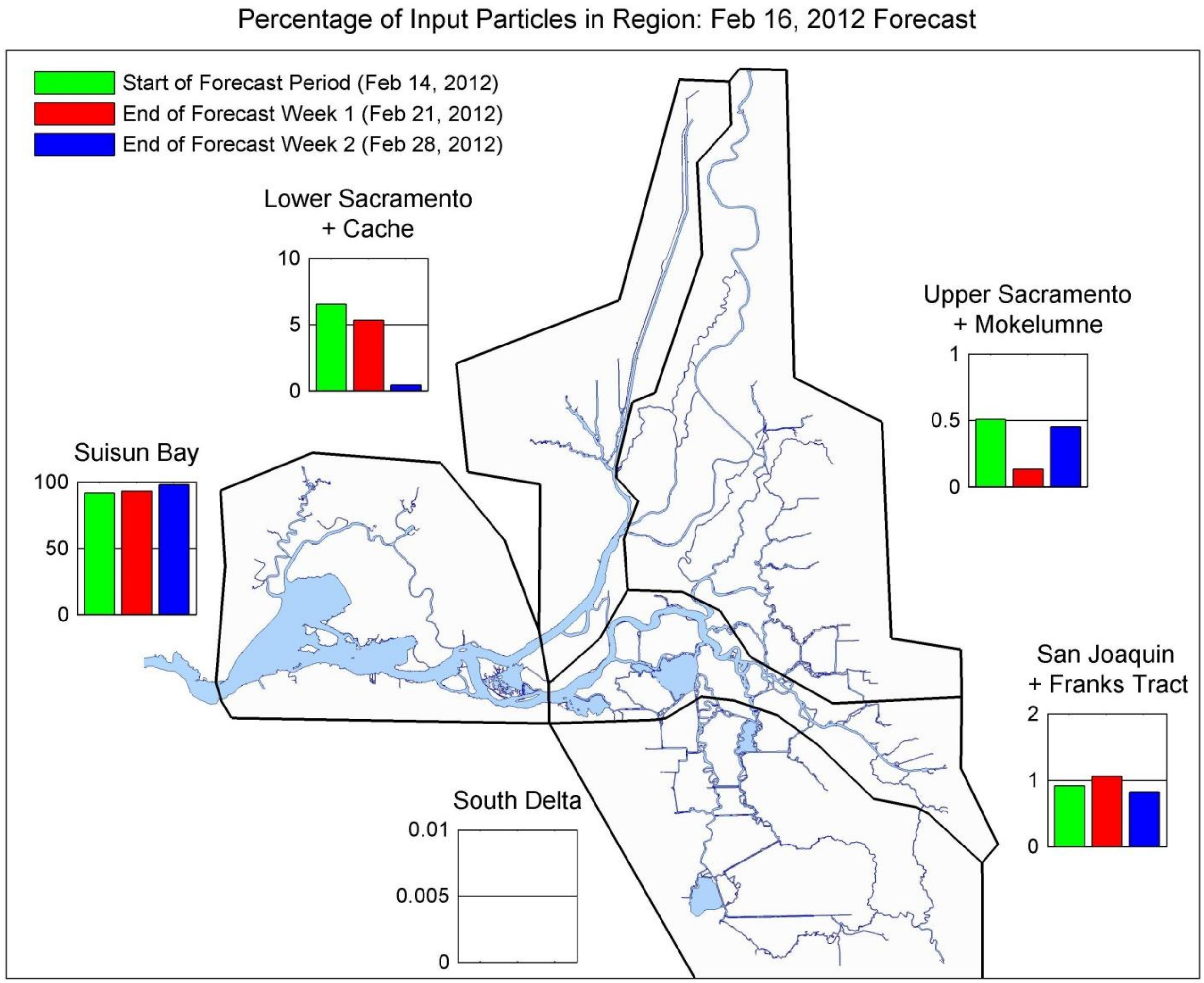

Figure 7-7 Summary graphic of the adult delta smelt particle tracking results for the February 16, 2012 forecast.

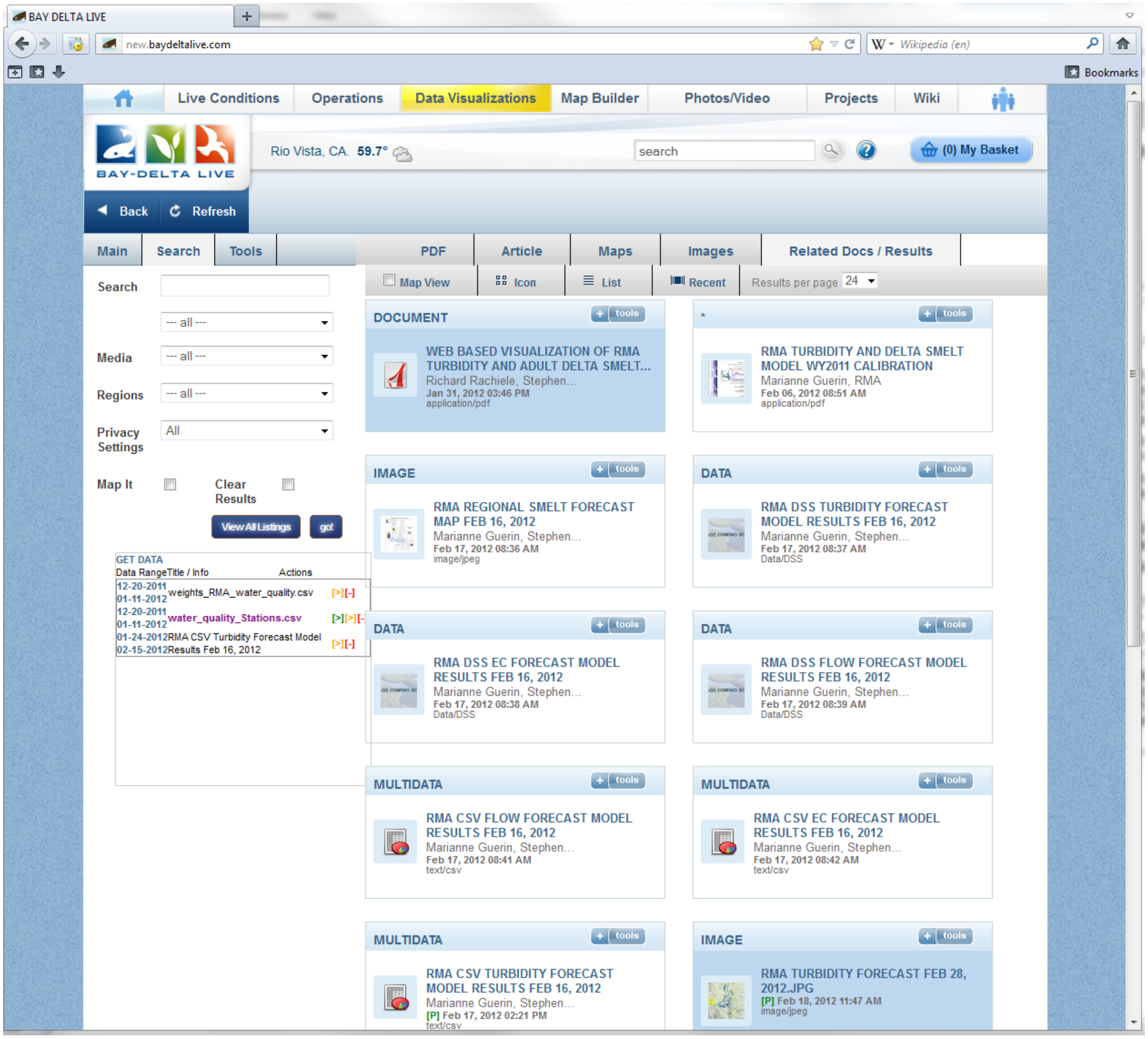

Figure 7-8 Bay-Delta Live turbidity forecast Related Docs / Results tab. Links to all supporting forecast data files, such as model result DSS and CSV files, and documents, such as previous WY calibration reports, are listed.

8 Summary

The wet season of the 2012 water year was uneventful in terms of high flow and high turbidity events. However, significant results were achieved in other ways: RMA refined the forecasting methodology and improved QA/QC of the forecasting procedure; utility programs were developed and implemented for boundary condition development, export scenario development, and salinity boundary conditions at Martinez; and, RMA worked collaboratively with Systech on WARMF model improvements and with 34North to integrate RMA forecasting results into Bay-Delta Live website.

The turbidity and delta smelt model results for the WY2012 hindcast were generally in good agreement with observed values in terms of both spatial trends and absolute magnitudes. However, the low flow and low turbidity conditions that dominated most of the hindcast simulation period highlighted some areas of improvement that can be made in the model. While the turbidity model accurately captured the transport and decay of high Sacramento River-derived turbidity through the delta, it failed to account for the genesis, transport, and decay of wind-induced sediment resuspension from large open water areas in the Delta. For a low-flow year such as WY2012 wind resuspended turbidity dominated the observed turbidity at two of the compliance stations, and was the major mechanism for turbidity concentrations above the compliance value of 12 NTU at Prisoner's Point. Migration to a full suspended sediment model would mitigate these low flow model deficiencies. However as shown in the WY2012 hindcast, the existing turbidity model and improved boundary conditions from WARMF and new USGS turbidity stations are sufficient for the accurate modeling of high flow turbidity transport though the Delta.

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10 Internal Boundary Condition Appendix

This appendix describes the application of "internal" boundary conditions in the RMA11 modeling of historical and forecast Delta turbidity. The purpose and application of the internal boundary condition are described. Comparison plots are presented for model runs with and without the use of the internal boundary conditions.

Internal boundary conditions have been used in other forecasting model to augment real-time observed measurements to adjust present time parameters to more accurate values (Hsu et al. 2003, USACE 1997).

10.1 Background

The upstream Sacramento River boundary condition typically dominates the computed model turbidity in the western Delta (Sacramento River below Rio Vista). However, Sacramento River flow and turbidities have been low for the current November-December 2011 period, with boundary condition turbidities below observed western Delta turbidities. An examination of the set of observed turbidity data indicated the Cache Slough complex and Suisun Bay as potentially significant sources of western Delta turbidity in the first two weeks of November and first week of December. An internal boundary condition was added for the Sacramento River at Mallard Island (CDEC record MAL) to better define the western Delta turbidity contribution from Suisun Bay (Figure 10-1). Similarly, an internal boundary condition was added for the Cache Slough at Ryer Island location (CDEC record RYI) to add the contribution to western Delta turbidity from the Cache Slough-Liberty Island region. A second turbidity simulation was performed without the internal turbidity boundary conditions for comparison.

10.1.1 Modifications to RMA11 Executable for Running Internal Boundaries

Typically, RMA11 specified value boundary conditions are applied at the external boundaries of the model network, for example EC and turbidity at Martinez. For the turbidity at Martinez, the turbidity value is only applied on the flood tide (flow into the network). With the internal boundary condition, the specified turbidity is applied for all flow direction conditions. The internal boundary condition capability was a feature of the current RMA11 program and no modification was necessary to the code. Observed turbidity data is readily available to be used for the internal boundary condition during the "historical" portion of the model run. Forecast turbidities may be estimated and also applied at the internal boundary condition. If the modeler does not wish to apply extrapolated values at the internal boundary, the boundary condition may be switched "off" for the forecast period.

10.2 RMA11 Results Using Internal Boundaries for Turbidity

10.2.1 Comparison Using WY2012 Forecast Run

Improvements in model accuracy corresponding to the use of the internal boundary conditions at Cache Slough and Mallard Island were assessed by performing model runs with and without internal boundary conditions for the November 1, 2011 - January 3, 2012 turbidity forecast run. Model comparison locations are shown in Figure 10-1. Model results are shown in Figure 10-2 through Figure 10-13 San

Joaquin River at Prisoner's Point comparison of CDEC data (blue) with RMA11 model results (green, red). Green line shows model results with additional internal boundary conditions, red line shows model run without. for these locations along with measured CDEC turbidities. Model accuracy is improved significantly throughout the western Delta. In the central Delta, differences between the two model runs are slight (e.g., at Middle River, Figure 10-11). In the south and eastern Delta, there were no discernible differences between the two models, and result plots are not shown.

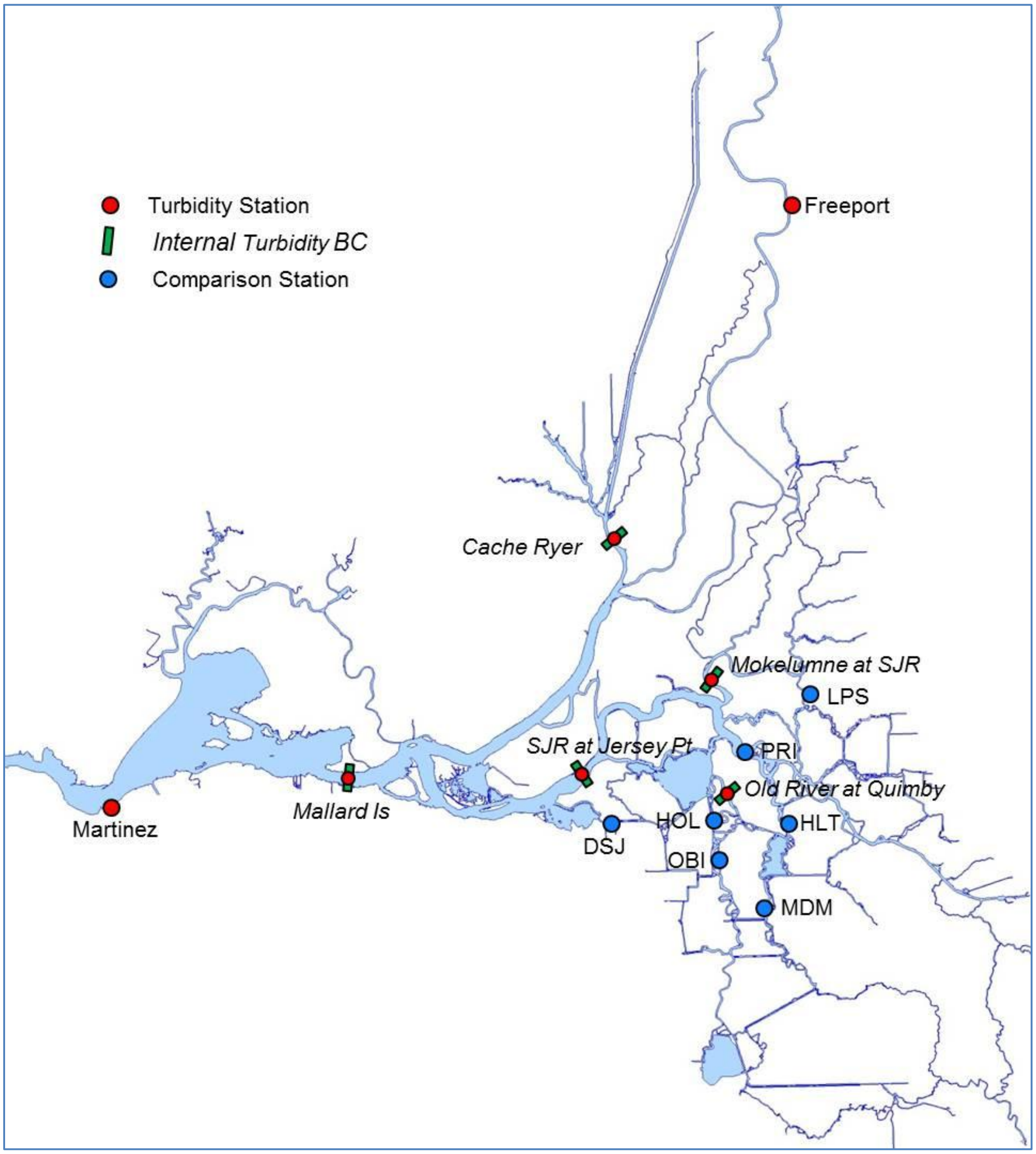

Figure 10-1 Locations of initial set of internal boundary conditions (Cache Ryer, Mallard Is) and additional internal boundary conditions (SJR at Jersey Pt, Mokelumne at SJR, Old River at Quimby), and model comparison locations.

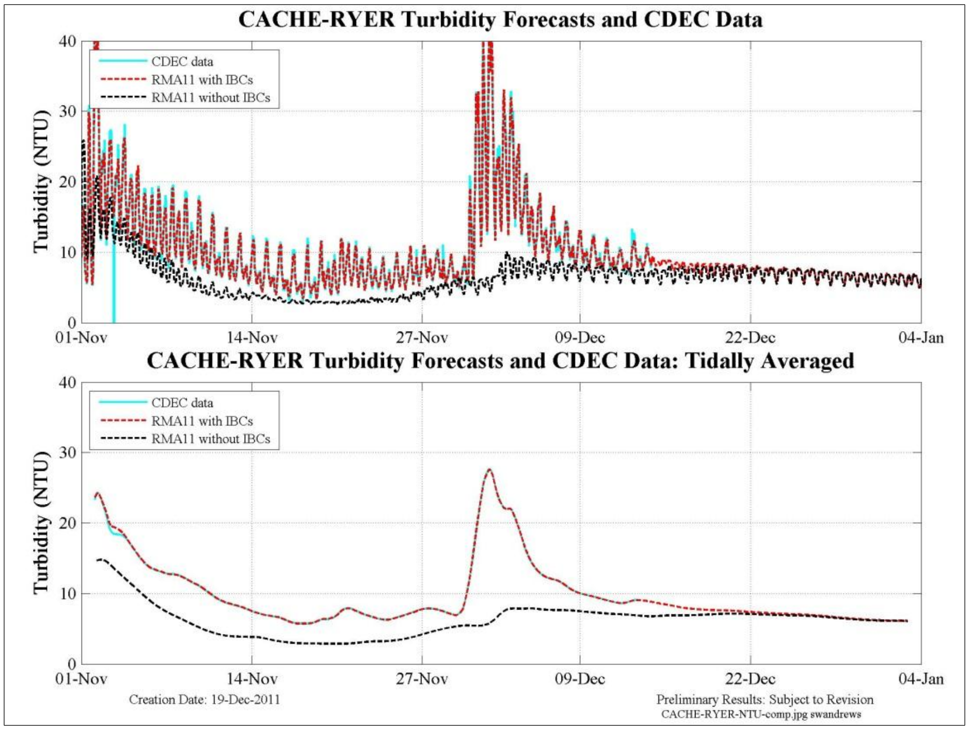

Figure 10-2 Comparison of Dec 15 2011 RMA11 Turbidity Forecast Model run with and without Internal Boundary Conditions (IBC's) and CDEC data at the Cache-Ryer location. Top panel shows 15min data and bottom panel shows tidally-averaged results.

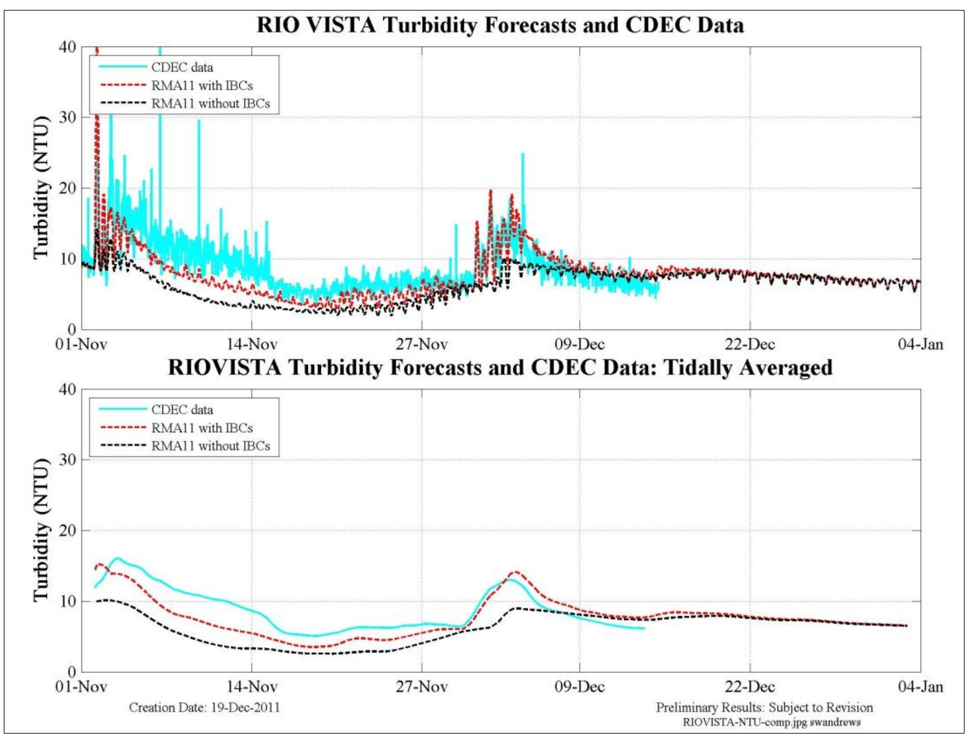

Figure 10-3 Comparison of Dec 15 2011 RMA11 Turbidity Forecast Model run with and without Internal Boundary Conditions (IBC) and CDEC data at the Rio Vista location. Top panel shows 15min data and bottom panel shows tidally-averaged results.

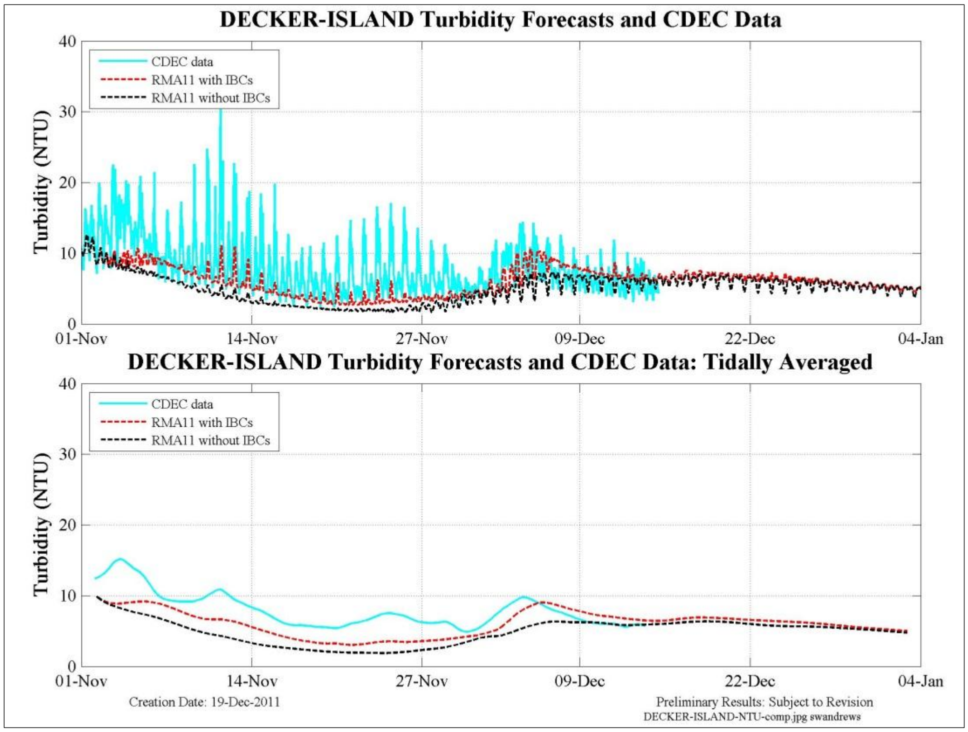

Figure 10-4 Comparison of Dec 15 2011 RMA11 Turbidity Forecast Model run with and without Internal Boundary Conditions (IBC) and CDEC data at the Decker Island location. Top panel shows 15min data and bottom panel shows tidally-averaged results.

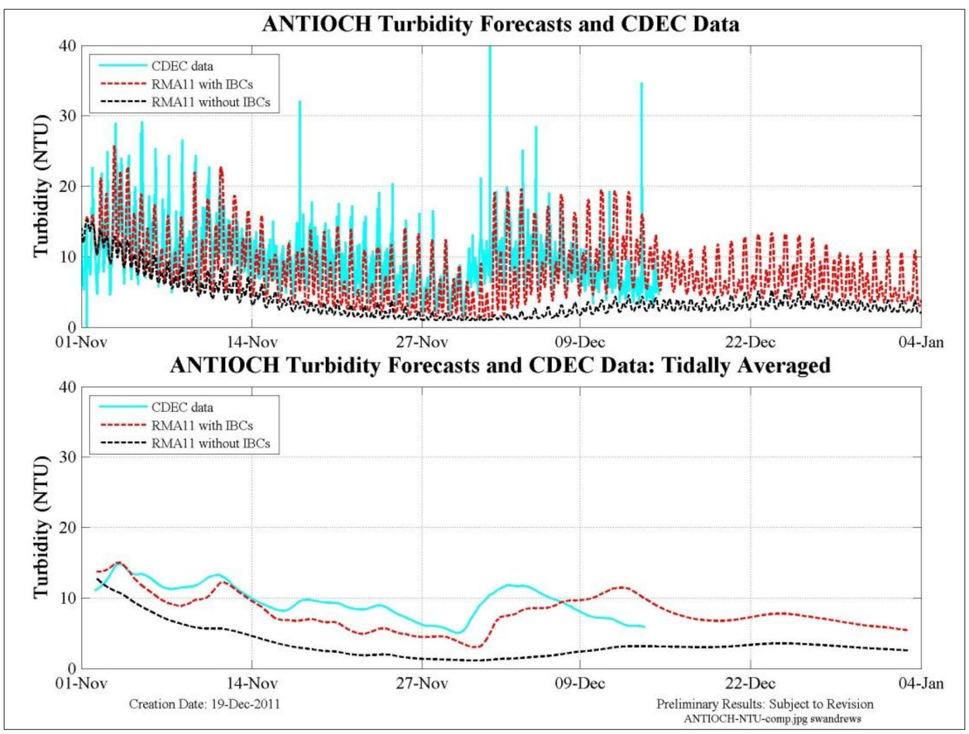

Figure 10-5 Comparison of Dec 15 2011 RMA11 Turbidity Forecast Model run with and without Internal Boundary Conditions (IBC) and CDEC data at the Antioch location. Top panel shows 15min data and bottom panel shows tidally-averaged results.

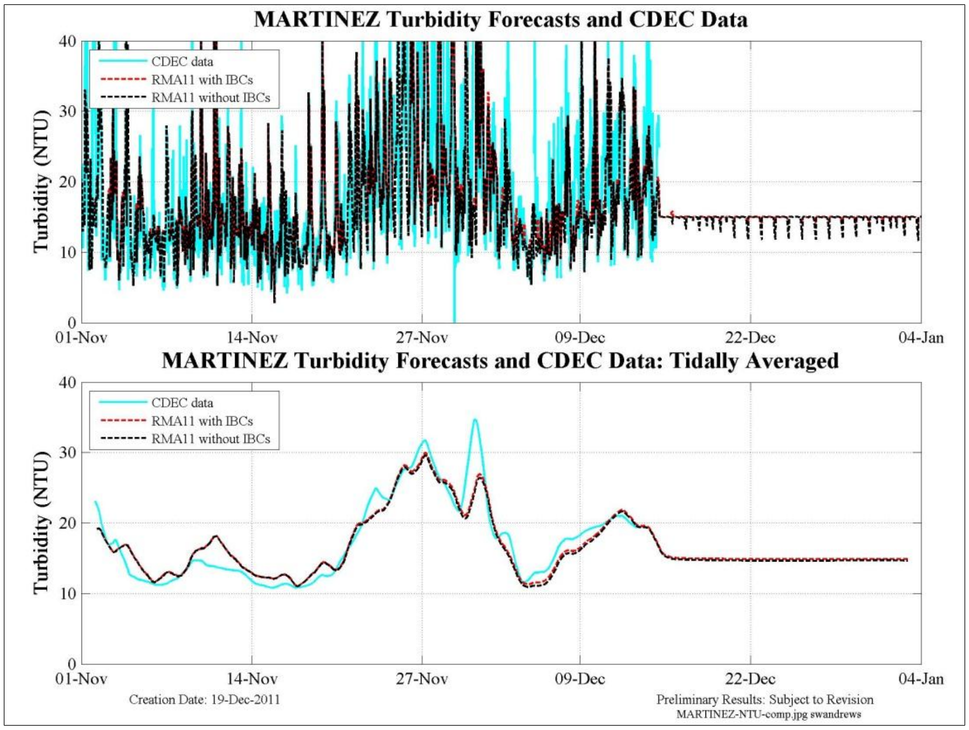

Figure 10-6 Comparison of Dec 15 2011 RMA11 Turbidity Forecast Model run with and without Internal Boundary Conditions (IBC) and CDEC data at the Martinez location. Top panel shows 15min data and bottom panel shows tidally-averaged results.

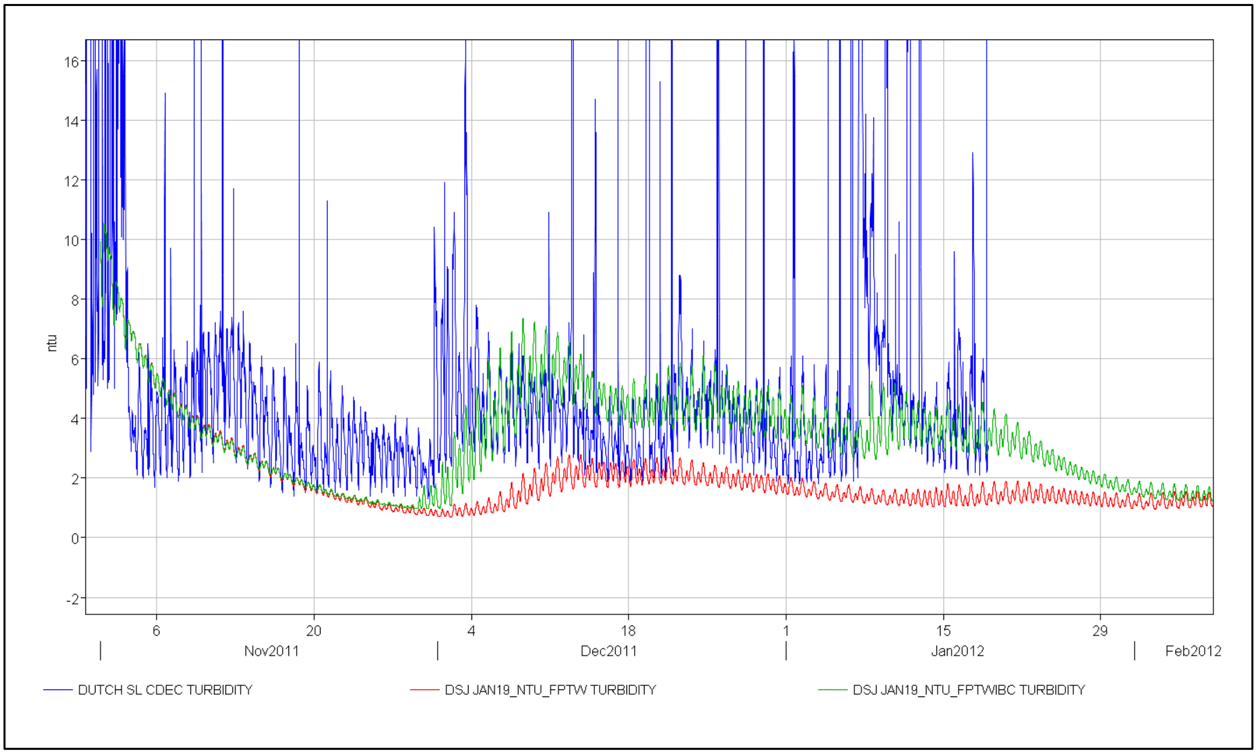

Figure 10-7 Dutch Slough at Jersey Island comparison of CDEC data (blue) with RMA11 model results (green, red). Green line shows model results with additional internal boundary conditions, red line shows model run without.

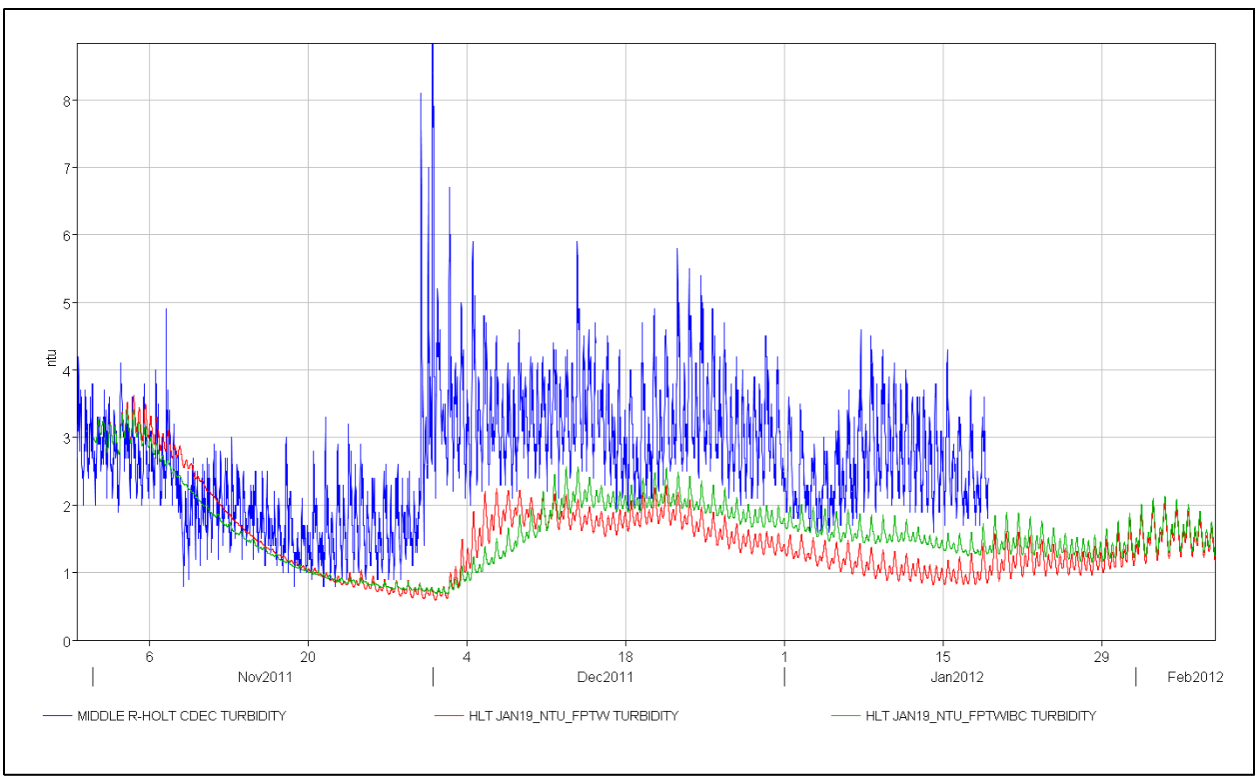

Figure 10-8 Middle River at Holt comparison of CDEC data (blue) with RMA11 model results (green, red). Green line shows model results with additional internal boundary conditions, red line shows model run without.

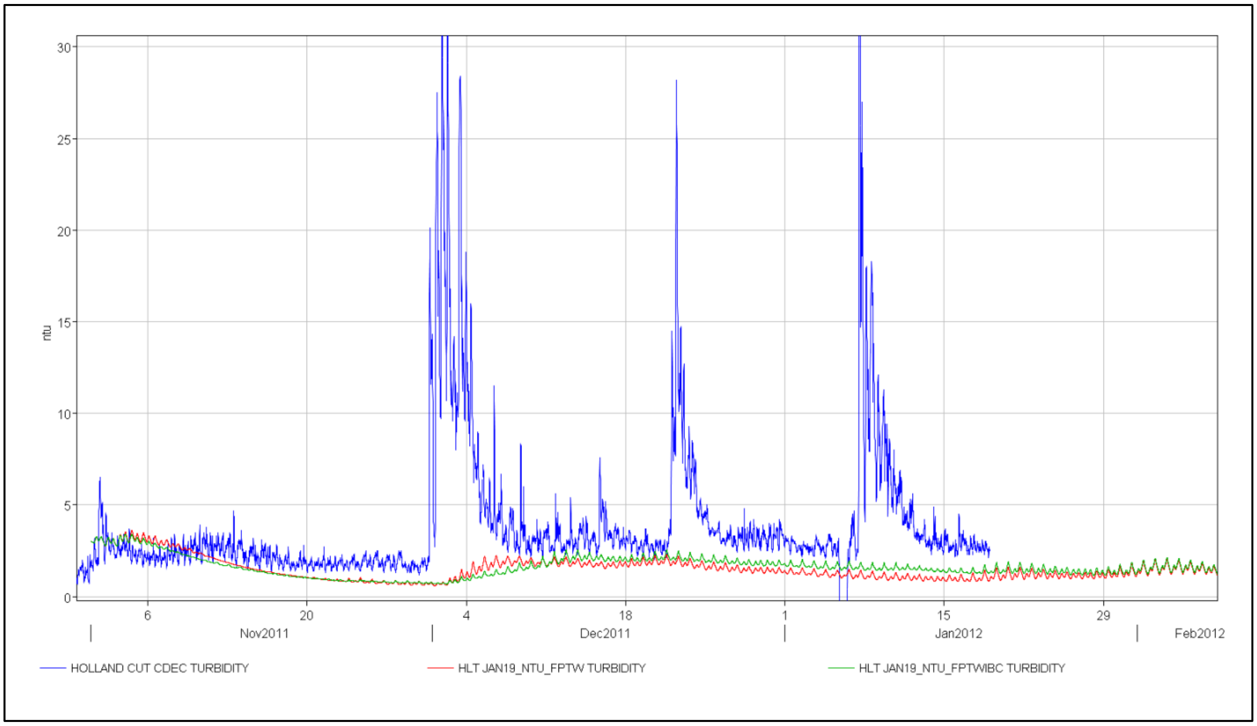

Figure 10-9 Holland Cut comparison of CDEC data (blue) with RMA11 model results (green, red). Green line shows model results with additional internal boundary conditions, red line shows model run without.

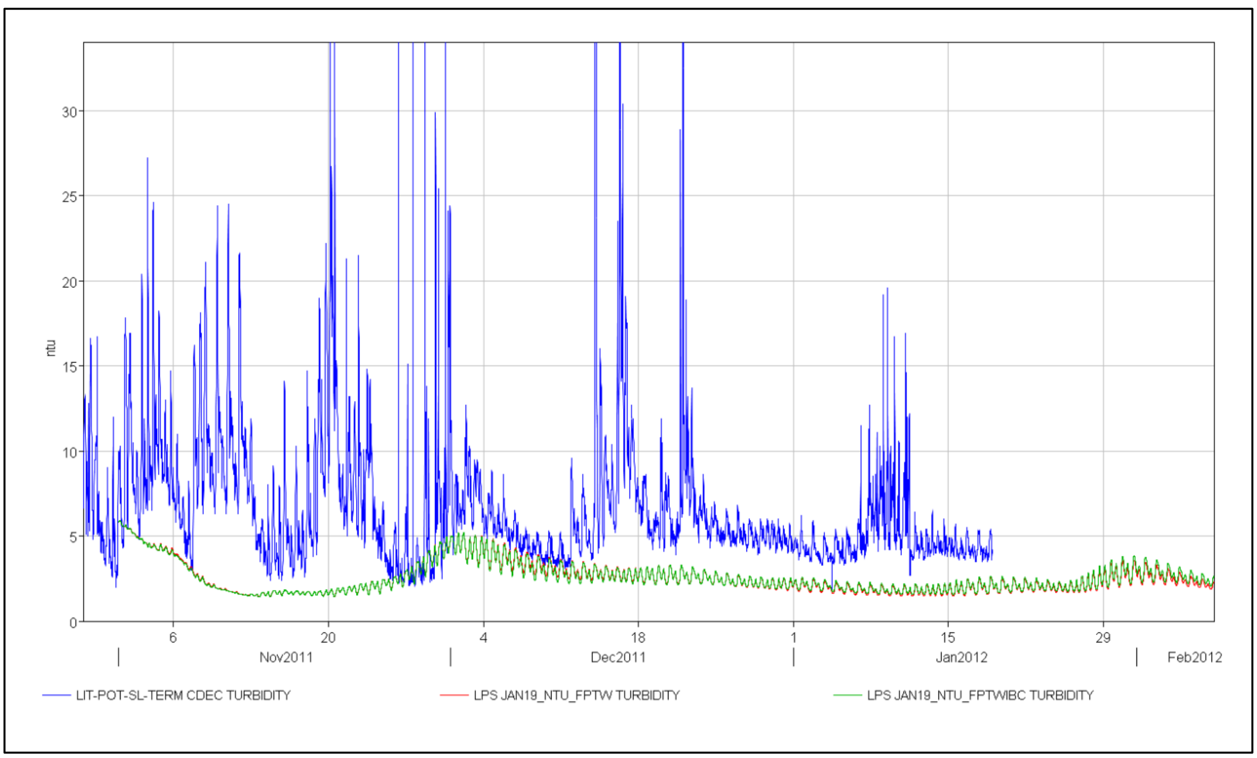

Figure 10-10 Little Potato Slough at Terminous comparison of CDEC data (blue) with RMA11 model results (green, red). Green line shows model results with additional internal boundary conditions, red line shows model run without.

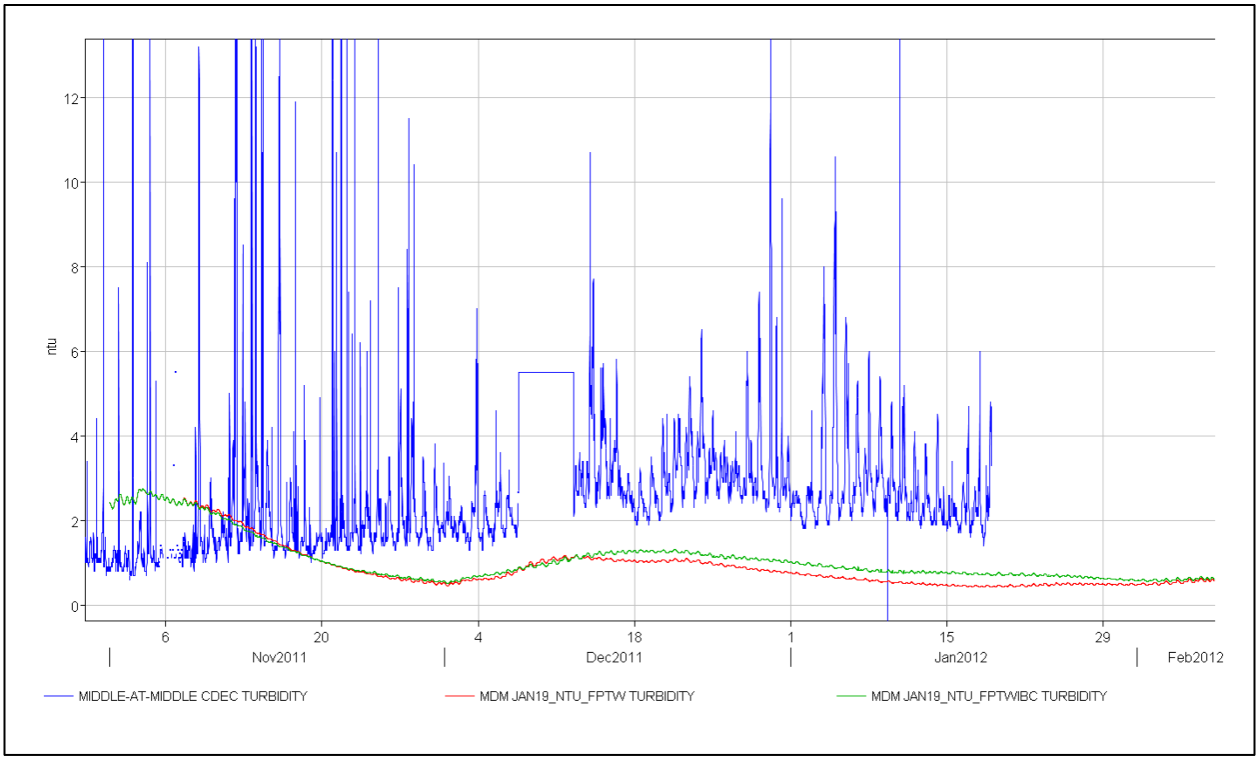

Figure 10-11 Middle River at Middle comparison of CDEC data (blue) with RMA11 model results (green, red). Green line shows model results with additional internal boundary conditions, red line shows model run without.

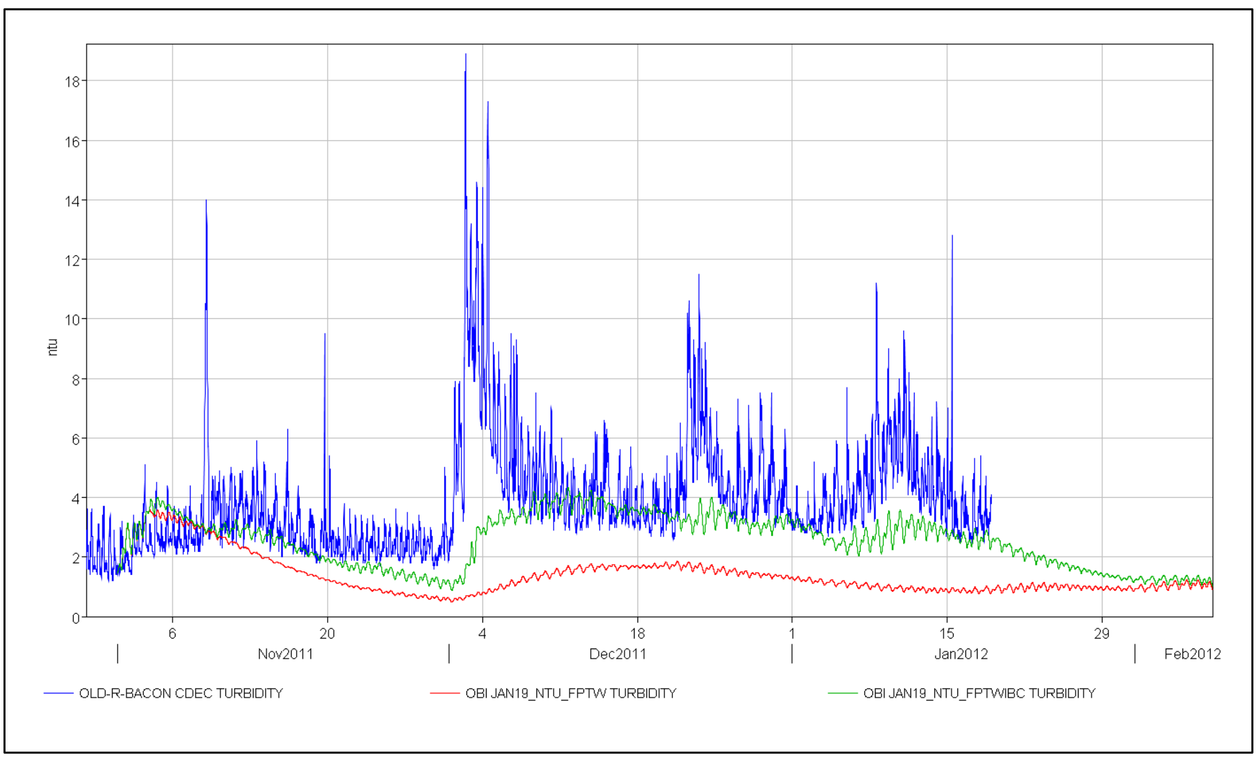

Figure 10-12 Old River at Bacon Island comparison of CDEC data (blue) with RMA11 model results (green, red). Green line shows model results with additional internal boundary conditions, red line shows model run without.

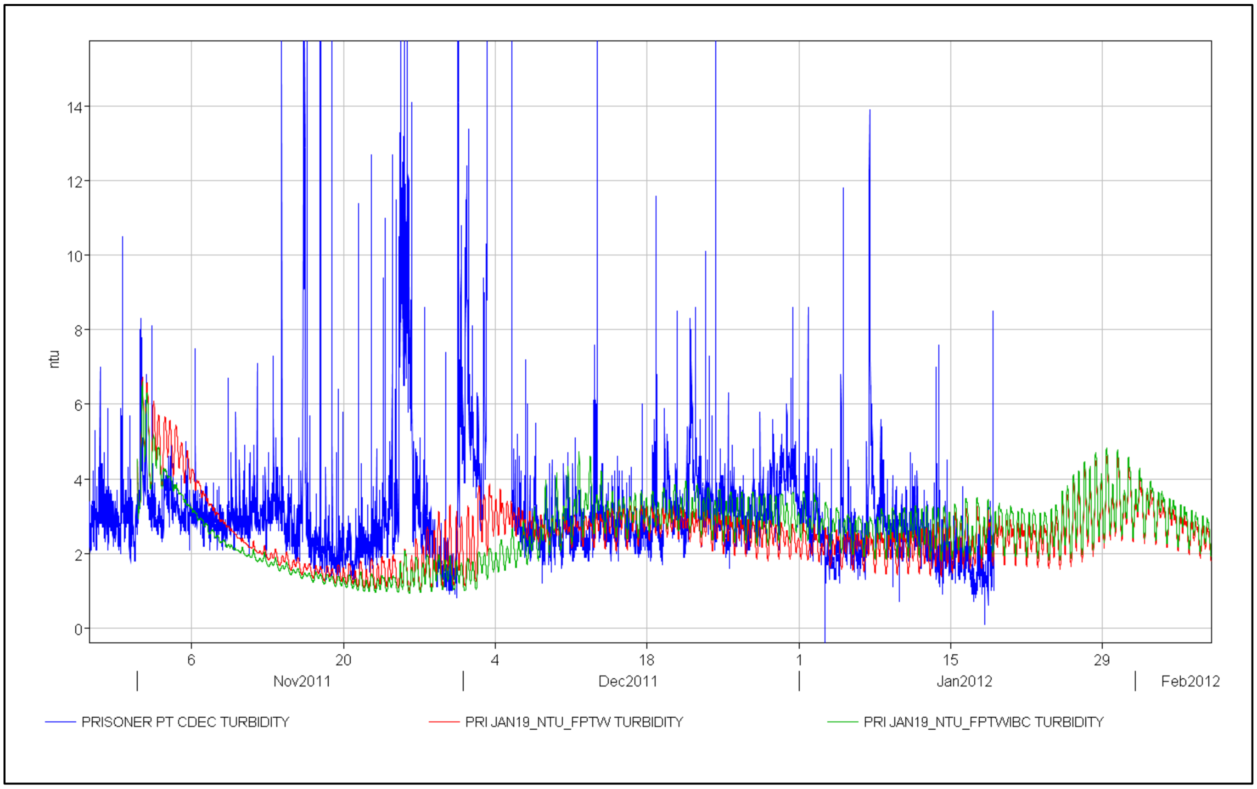

Figure 10-13 San Joaquin River at Prisoner's Point comparison of CDEC data (blue) with RMA11 model results (green, red). Green line shows model results with additional internal boundary conditions, red line shows model run without.

10.2.2 Comparison Using WY2011 Hindcast

Although the results for the initial period for WY2012 (Forecast #2) show that the use of internal boundary conditions improve RMA11 turbidity model results during low flow conditions, it was important to check whether the use of the internal boundary condition would negatively affect results during high flows. To this end, the WY2011 hindcast model was run with the internal boundary conditions applied. The results are documented in Figure 10-14 through Figure 10-19. The results show that even during high flow periods, the use of the internal boundary conditions improves the ability of the turbidity to reproduce data at locations along the Sacramento River identified as problematic at low flow conditions.

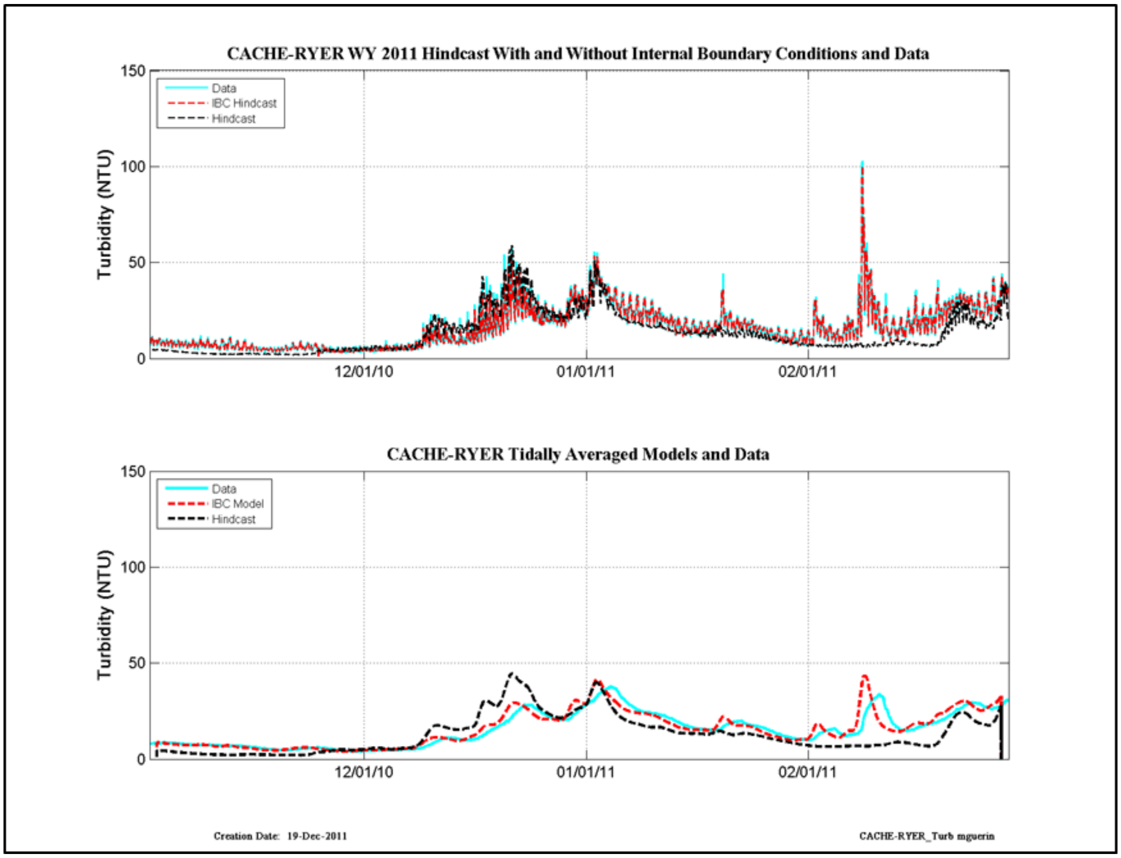

Figure 10-14 Comparison of 15min RMA11 Turbidity Hindcast Model run with and without Internal Boundary Conditions (IBC) with data (upper) – and the same comparisons tidally averaged (lower) – at the CDEC Cache at Ryer location.

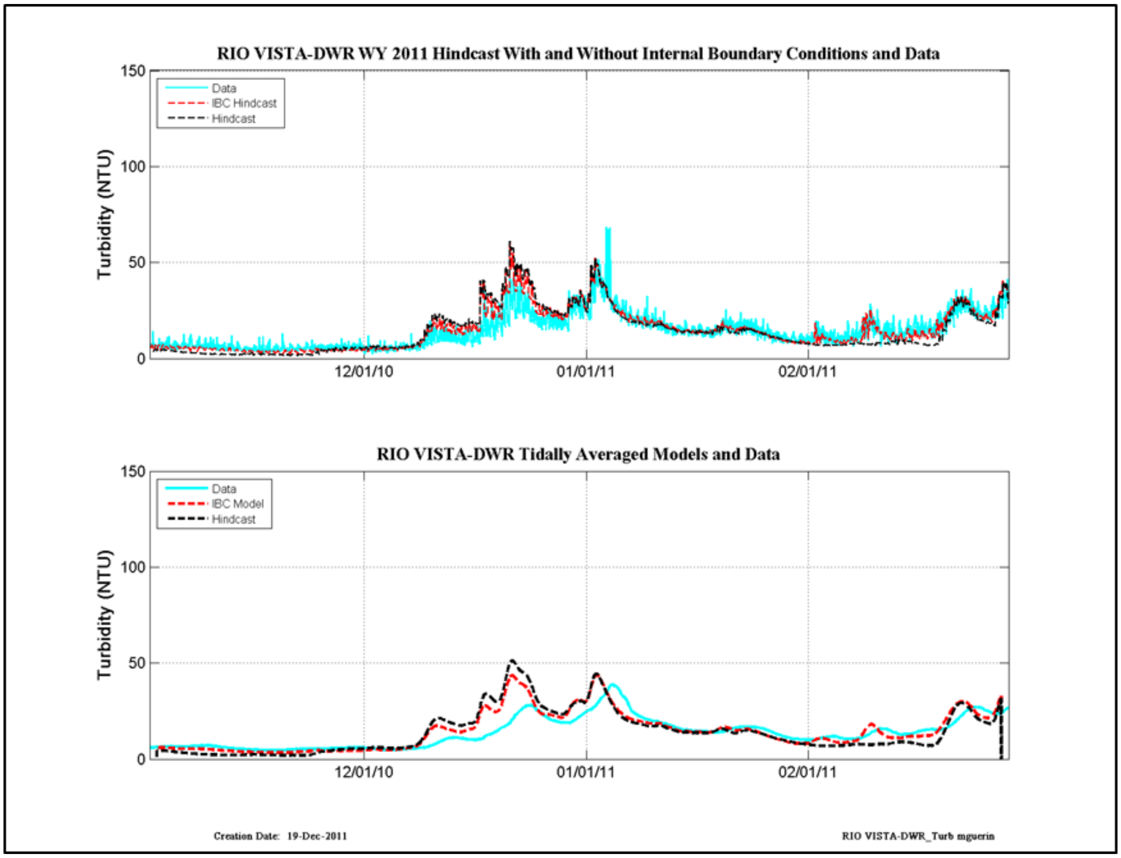

Figure 10-15 Comparison of 15min RMA11 Turbidity Hindcast Model run with and without Internal Boundary Conditions (IBC) with data (upper) – and the same comparisons tidally averaged (lower) — at the CDEC Rio Vista location.

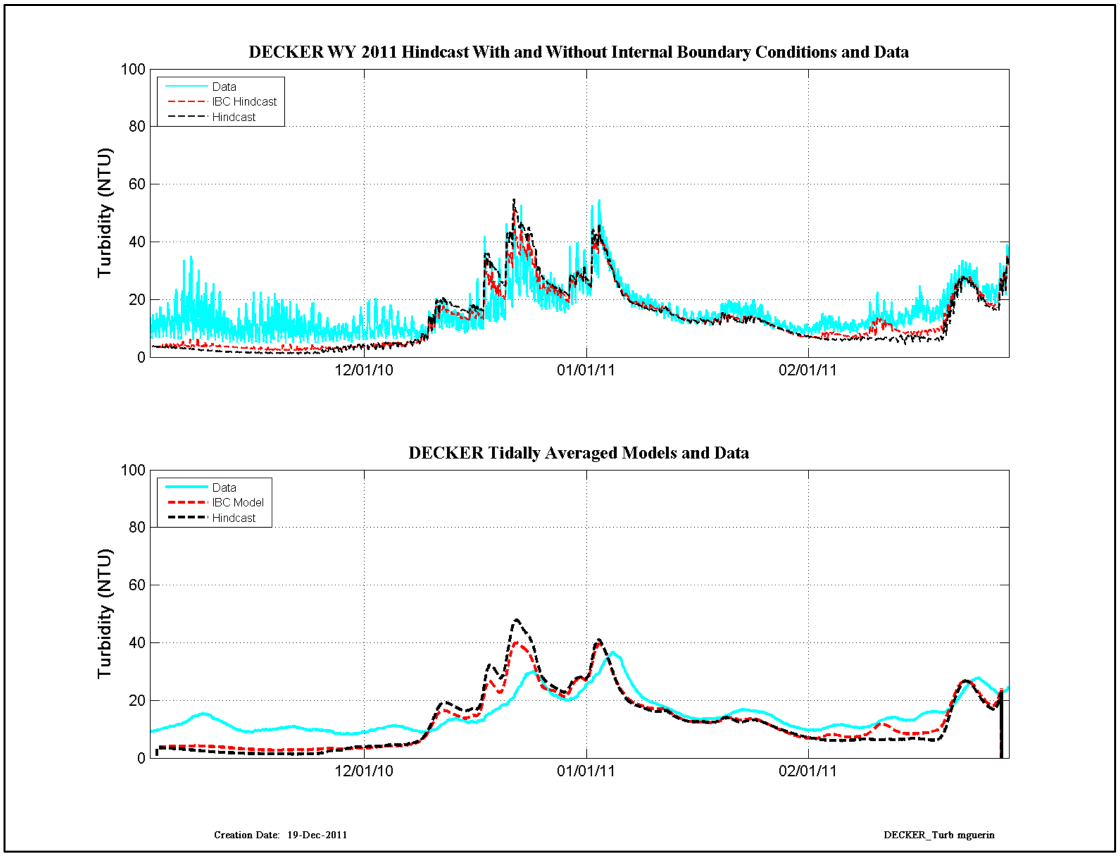

Figure 10-16 Comparison of 15min RMA11 Turbidity Hindcast Model run with and without Internal Boundary Conditions (IBC) with data (upper) – and the same comparisons tidally averaged (lower) – at the CDEC Decker Island location.

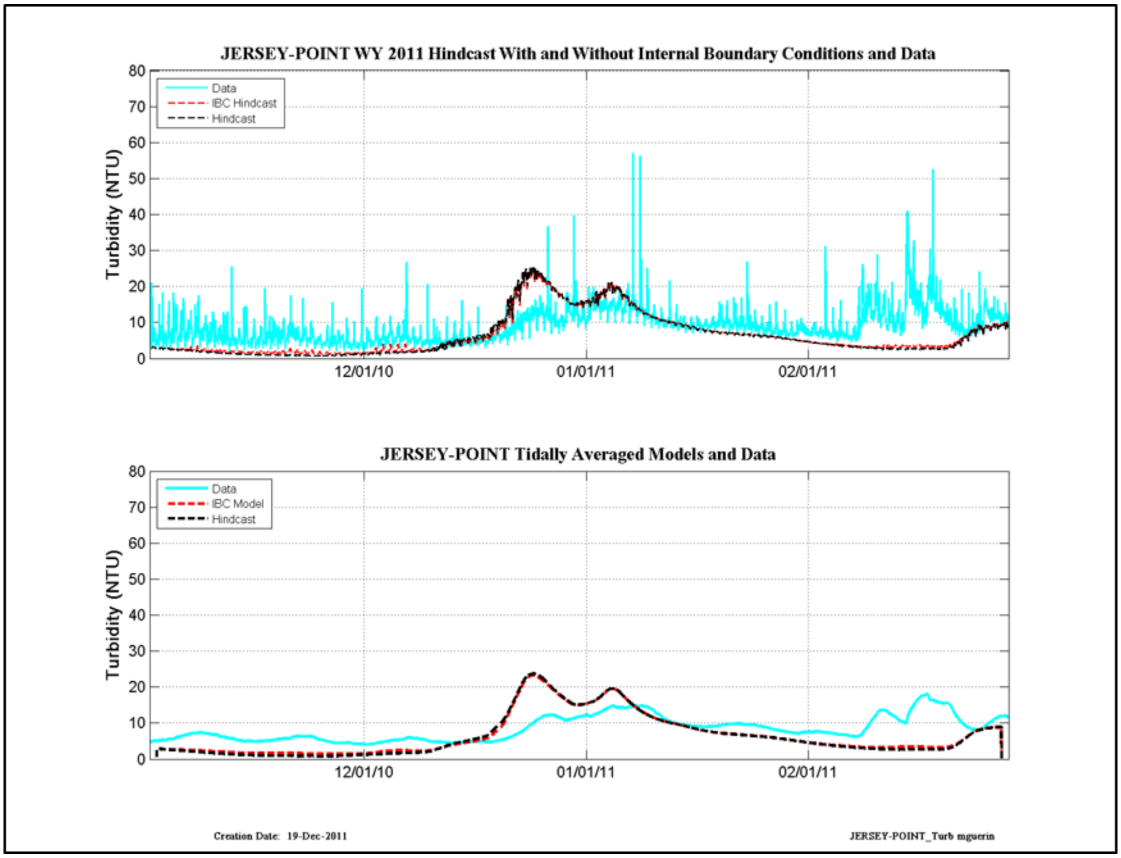

Figure 10-17 Comparison of 15min RMA11 Turbidity Hindcast Model run with and without Internal Boundary Conditions (IBC) with data (upper) – and the same comparisons tidally averaged (lower) – at the CDEC Jersey Point location.

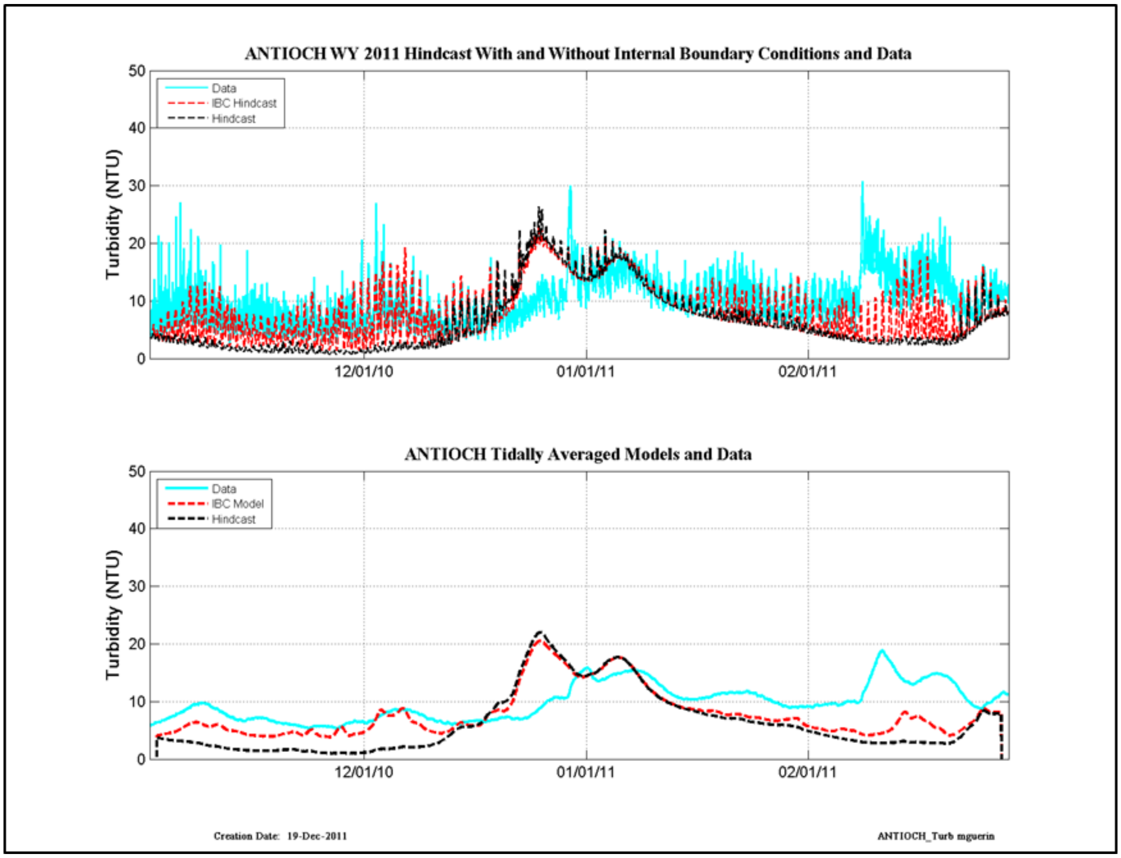

Figure 10-18 Comparison of 15min RMA11 Turbidity Hindcast Model run with and without Internal Boundary Conditions (IBC) with data (upper) – and the same comparisons tidally averaged (lower) – at the CDEC Antioch location

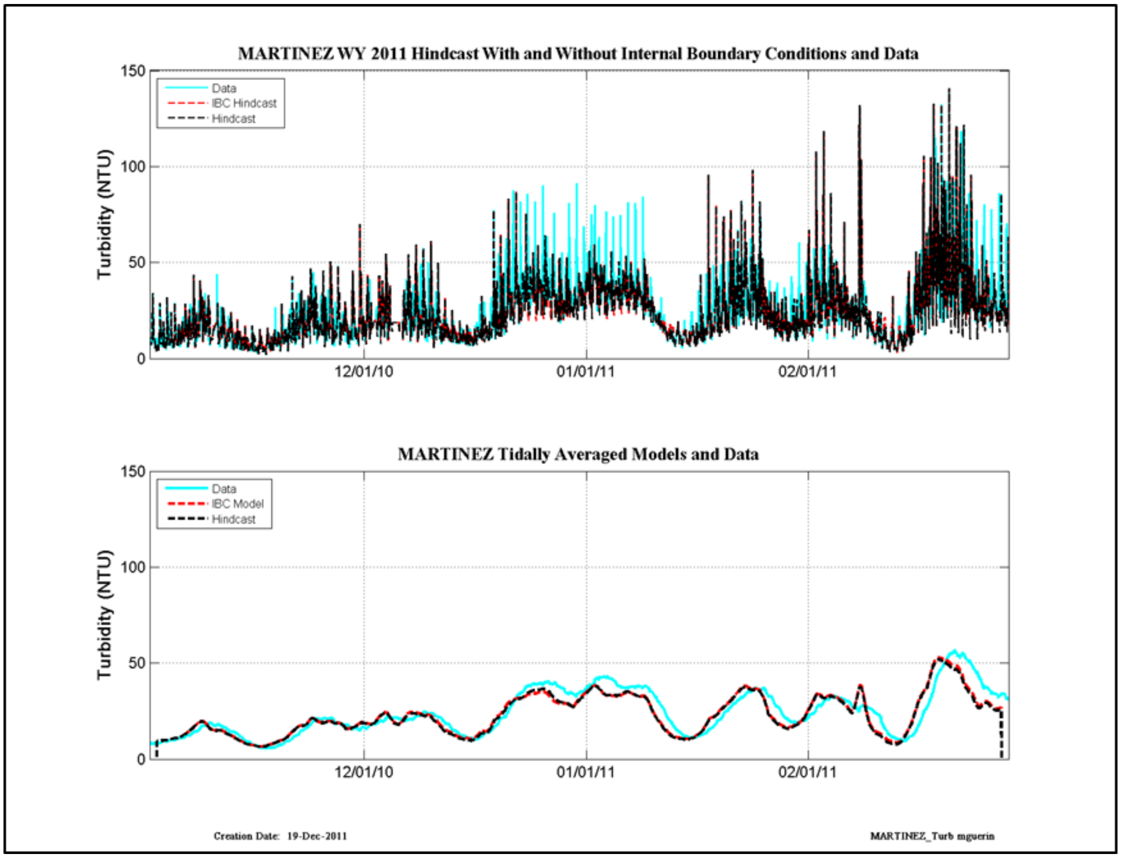

Figure 10-19 Comparison of 15min RMA11 Turbidity Hindcast Model run with and without Internal Boundary Conditions (IBC) with data (upper) – and the same comparisons tidally averaged (lower) – at the CDEC Martinez location.

10.3 Summary and Conclusions

The RMA11 model capability for applying internal boundary conditions was utilized for the turbidity model to improve the representation of turbidity particularly during low flow conditions. Comparison of model results with and without the internal boundary conditions using CDEC data applied at Mallard and at the Cache Slough at Ryer locations demonstrate the technique improves turbidity model results in the western Delta at both low inflow and high inflow conditions.

11 Salinity Modeling Appendix

This appendix describes applications of the RMA11 salinity model in support the WY2012 forecasting season, as well as a minor recalibration to better reflect salinity conditions in the western Delta under the low Net Delta Outflow (NDO) conditions encountered during the fall of 2011 and winter of 2012.

11.1 Background

An RMA11 salinity simulation is run during each forecast week to provide input for RMA's adult delta smelt behavioral model in addition to the RMA11 turbidity simulation. For forecasting applications, salinity is simulated in RMA11 using a previously calculated RMA2 hydrodynamic simulation – i.e., flow and salinity are uncoupled. (Note – there is an RMA model set-up in which flow and salinity are "coupled" – this set-up is not appropriate for forecasting applications).

For the uncoupled model set-up, the Martinez boundary condition is applied as the average of top and bottom EC as measured at Martinez. For historical simulations, this is generally easily accomplished using data from CDEC (unless too much data is missing in the desired time frame). However, in the forecast period there is no data available, so both and top and bottom salinity need to be synthesized. The methodology used in WY2012 to synthesize the Martinez BC is briefly described in Section 11.2. A separate PowerPoint file with detailed instructions and file folders with software and an example are available on RMA's system for remote login by MWD staff.

In Section 11.3, the effect of changed Delta operations during forecast periods on salinity boundary condition development is explored. It is anticipated that forecast scenario simulations will be developed during periods of relatively high inflow to the Delta to determine the effect of modified export operations in the south Delta based on the "Modified Deriso Model" (RMA, 2011).

In Section 11.4, the results of a minor recalibration of the RMA11 uncoupled salinity model are described. During the low inflow conditions in WY2012, it was suspected that the agricultural flows applied in RMA models as boundary conditions were too high in January 2012 (and possibly at other times). These monthly flows are applied using the Delta Island Consumptive Use (DICU) model time series. Monthly salinity time series are also included in the DICU model. The DICU conditions used during the forecast season were supplied to RMA by the Delta Modeling and Compliance Section in the Department of Water Resources (DWR). The effects of alterations to DICU flows and salinity on the modeled Delta salinity field are explored in this subsection.

11.2 Synthesizing the Martinez BC for Forecast Periods

11.2.1 Background

During the previous two turbidity forecast seasons (WY2010 and WY2011), the Martinez boundary condition in the RMA11 salinity model was applied in a non-standard manner as the capability to synthesize bottom salinity during the forecast period was not available. Instead, top Martinez salinity as supplied by DWR was used as a boundary condition during the entire modeled period – as a consequence, modeled Delta salinity was too low. Although the adult delta smelt behavioral model uses salinity as one of the conditions for movement, the effect of salinity is minor during the high outflow periods hypothesized to trigger delta smelt movement away from the Suisun Bay area into the northern and central Delta, so the offset due to the salinity boundary condition was considered unimportant.

For WY2012, software developed by DWR's Delta Modeling Section (DMS) was used to generate both top and bottom salinity during the forecast period. The software was developed to support early DMS forecasting efforts, and the application used here extends the initial application for forecasting top EC at Martinez to forecasting bottom EC at Martinez – documentation is found at: http://modeling.water.ca.gov/delta/real-time/ecdata.html.

11.2.2 Martinez Salinity Forecast Methodology

This section briefly describes the methodology for forecasting top and bottom EC at Martinez. Detailed instructions have been supplied to MWD in a PowerPoint file with an example developed for the forecast period starting Jan 12th, 2012.

The methodology is implemented in a Python software tool called *vplotter* which is run from a DOS window. There are several DSS time series inputs that are required for forecasting top and bottom EC at Martinez: calculated NDO for the combined Historical and forecast time window; 15-minute astronomical tide time series at RSAC045, RSAC054 and RSAC075 for the combined time window; and, top and bottom salinity time series data at Martinez and Mallard Island for the historical period. The salinity data should be cleaned of erroneous data before applying the tool – filling missing data is accomplished within the tool. In essence, a Kalman filter (available as an executable) is used to calculate the two forecast salinity time series (i.e., top and bottom salinity time series).

NDO is calculated on a daily basis by adding all inflows, subtracting all exports and diversions, and accounting for DICU flows. In RMA model applications, the NET monthly DICU is subtracted. The vplotter tool is used to calculate bottom salinity for the forecast period, while top salinity (calculated using this tool) is supplied by DWR.

The salinity time series for historical plus forecast top and bottom Martinez EC are then averaged to produce the final time series used in the RMA11 uncoupled model forecast application.

Figure 11-1 and Figure 11-2 illustrate the comparison between CDEC data and calculated top and bottom salinity time series at Martinez, respectively. The data for forecast ends on Jan. 11th, so discrepancies between the calculated time series begin to appear on Jan. 12th. For the conditions representing this time period, the top and bottom salinity forecasts appear to be relatively good for up to 10 days, although the forecast estimate deteriorates with time. Generally speaking, there are only 5 days of good inflow data to support the NDO calculation, so it is expected that the reliability of salinity forecast results will start to fall off after about 6-10 days.

Figure 11-3 is a comparison of the top and bottom calculated time series at Martinez – these time series are then averaged to produce the Martinez boundary condition used in the uncoupled RMA11 model.

11.2.3 Comment on the Methodology and the *vplotter* tool

The methodology developed to forecast top and bottom salinity at Martinez produced acceptable results, and was easy to develop as it used existing software and publically available time series data. However, the *vplotter* software was unstable and quirky, with errors and software glitches occurring with no apparent treason. For general use, it may be desirable to instead develop a software tool as an RMA standalone to address the problems experienced using *vplotter*.

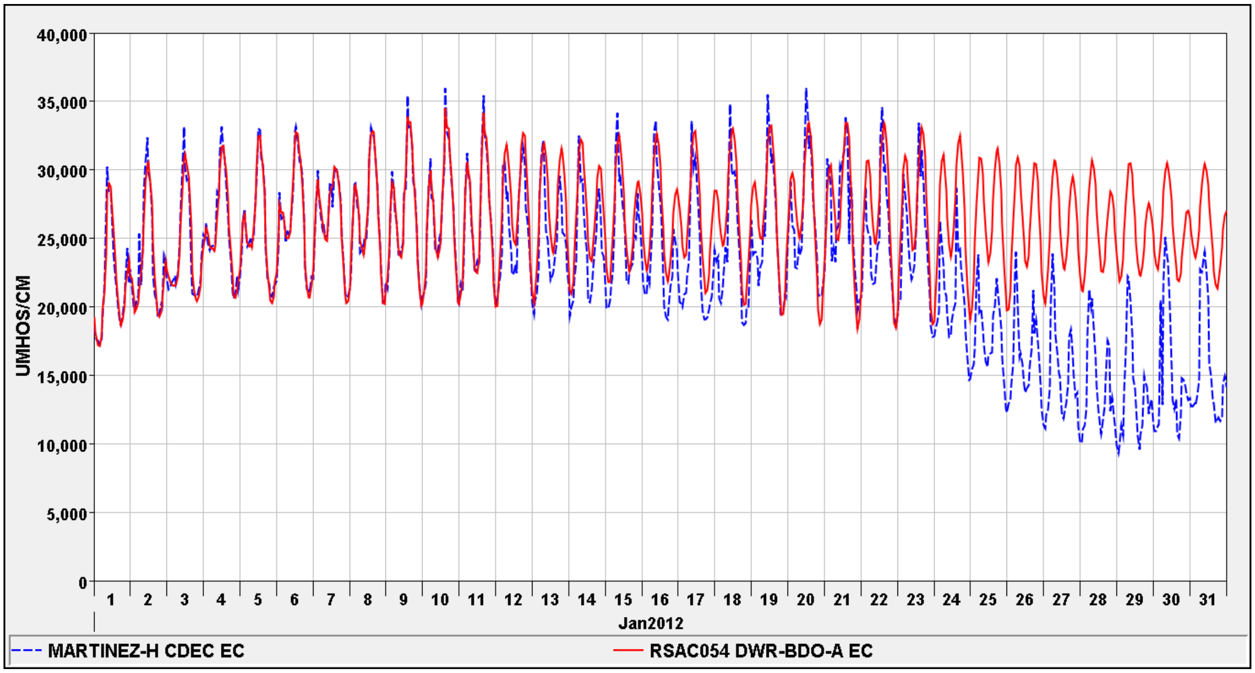

Figure 11-1 Figure shows the historical (hourly) time series CDEC top salinity data at Martinez (blue dash line) and the calculated historical plus forecast time series (red line) produced using the *vplotter* tool.

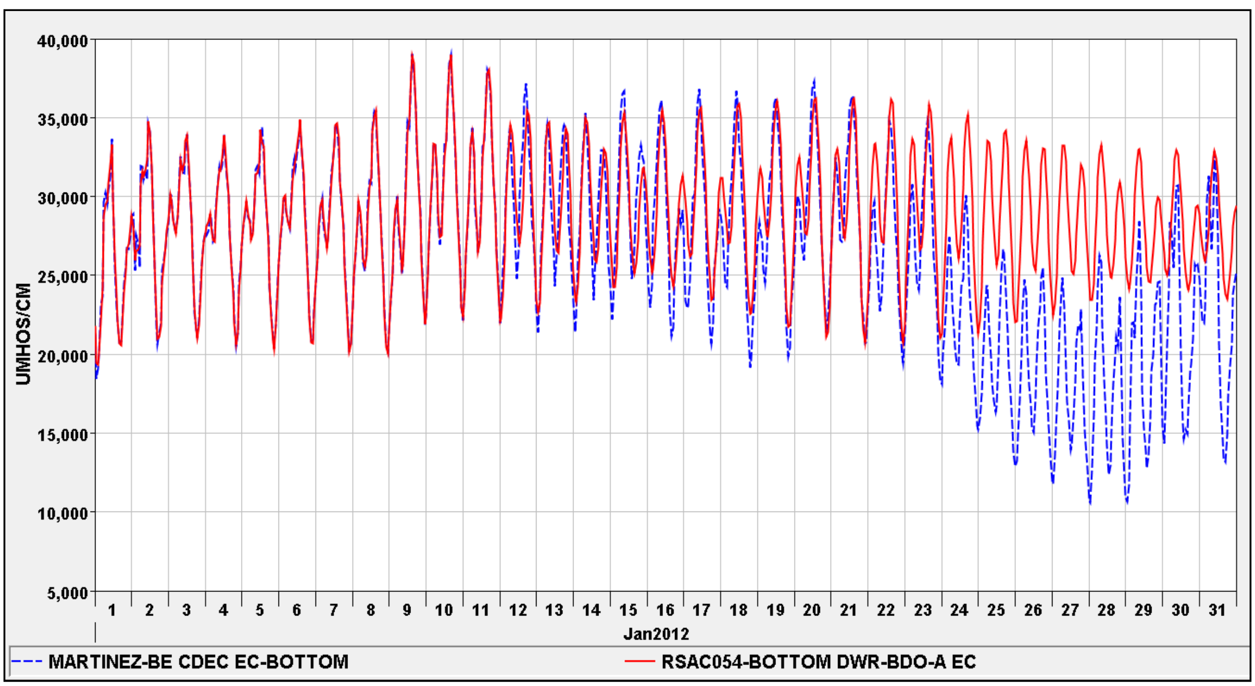

Figure 11-2 Figure shows the historical (hourly) time series CDEC bottom salinity data at Martinez (blue dash line) and the calculated historical plus forecast time series (red line) produced using the *vplotter* tool.

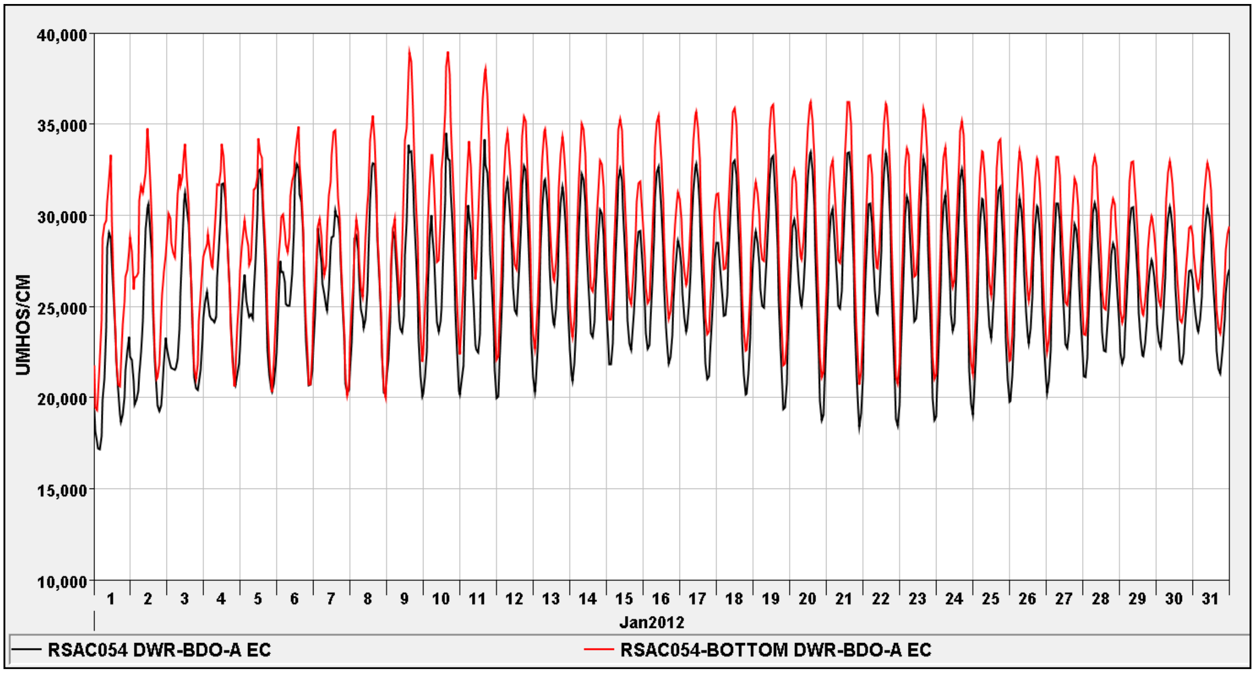

Figure 11-3 Figure shows the top (black line) and bottom (red line) historical plus forecast time series produced using the *vplotter* tool.

11.3 Martinez EC Boundary Condition Development for Scenarios

11.3.1 Background

It is anticipated that scenario simulations will be developed during forecast periods of relatively high inflow to the Delta to determine the effect of modified export operations in the south Delta based on the "Modified Deriso Model" (RMA, 2011). During periods of high inflow associated with storms, turbidity in the Delta is generally elevated due to increases in the suspended sediment load carried by the rivers and tributaries. In an operational sense, it is important to know how much water can be exported by the State and Federal pumps without drawing turbidity into the south Delta and potentially attracting delta smelt there.

Changes to the export operations result in a NDO that differs from the forecast model, potentially impacting EC at the downstream boundary at Martinez. There is a question as to whether this difference in EC is of such significance that it needs to be accounted for in the model by recalculating the Martinez boundary condition. Given the time-sensitive nature of forecast modeling, if the differences results in only minor changes in Martinez boundary condition EC the work involved in developing a new Martinez boundary condition may be considered an ineffective use of resources and time. This aspect of scenario development is explored in the following subsections.

11.3.2 Effect of changed exports on western Delta salinity

This section describes the testing of a modified Martinez EC boundary condition to reflect differences in NDO resulting from a scenario simulation in which export levels were changed. The G-model was used to create an estimated EC boundary condition at Martinez using 15-minute astronomical stage and daily NDO for a Hindcast simulation and a scenario.

The NDOs for the WY2011 Hindcast and a Modified Deriso scenario, denoted Scenario1 in the figures, were used as inputs for the G-model, producing two predicted Martinez EC boundary conditions. The 15-minute predicted EC is plotted in Figure 11-4 with the tidal averages in Figure 11-5. The maximum difference between tidally averaged EC for the Hindcast and Scenario 1 is 17%. A time series of the percent difference is plotted in Figure 11-6.

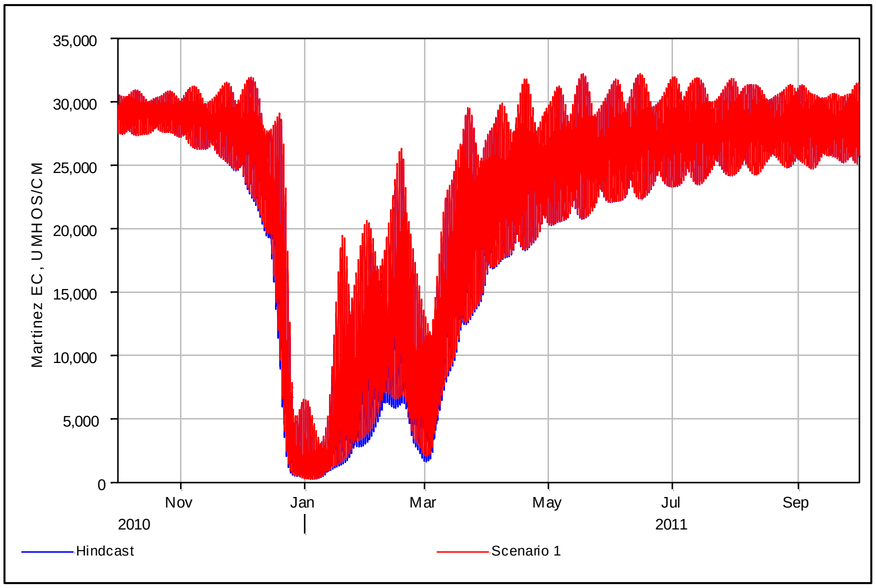

Figure 11-4 Martinez 15-minute EC predicted by the G-model for WY2011 Hindcast and Scenario 1.

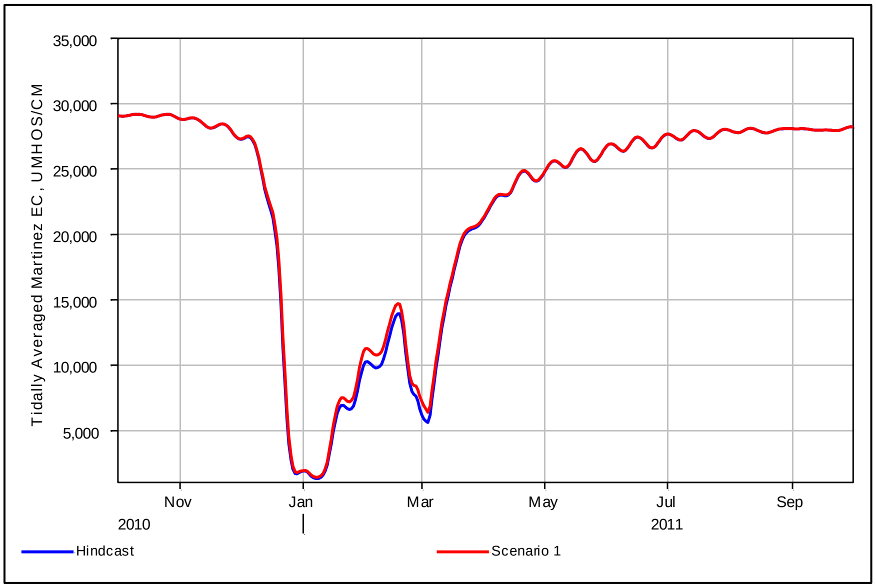

Figure 11-5 Martinez tidally averaged EC predicted by the G-model for WY2011 Hindcast and Scenario 1.

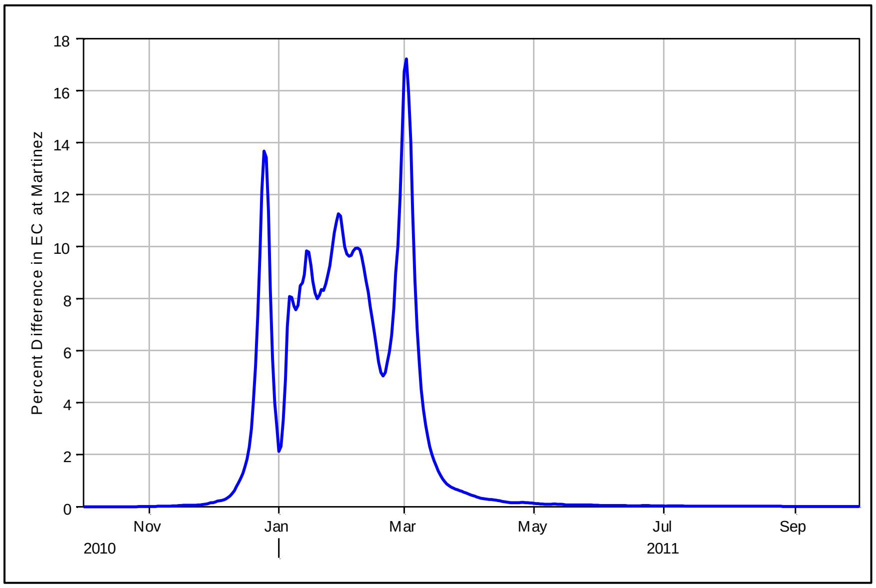

Figure 11-6 Percent difference between tidally averaged Scenario 1 and Hindcast EC at Martinez.

11.3.3 Testing a Modified EC Boundary Condition

Because the G-model generally gives a poor estimate of Martinez salinity (in comparison with data at the same NDO) the impact of the modified EC boundary condition was tested by altering observed data using the results of the G-model simulations as follows: the percent difference between the Scenario 1 and the Hindcast tidally averaged Martinez EC (output as a daily value) forWY2011 was applied to the 15-minute observed Martinez EC such that each day all 15-minute values were changed by the same percentage (illustrated in Figure 11-6). Scenario 1 was then re-run with the modified EC boundary as shown in Figure 11-7 in comparison with observed data.

Comparison of EC results with and without the adjusted Martinez EC boundary show very little difference. At Chipps Island (RSAC075), the adjusted boundary condition results in no more than a 7% increase in tidally averaged EC, and 10% increase in peak EC. Further upstream at Emmaton (RSAC092) or at Jersey Point (RSAN018), there is virtually no difference. Comparison plots of dynamic and tidally averaged EC at Chipps Island are shown in Figure 11-8 and Figure 11-9.

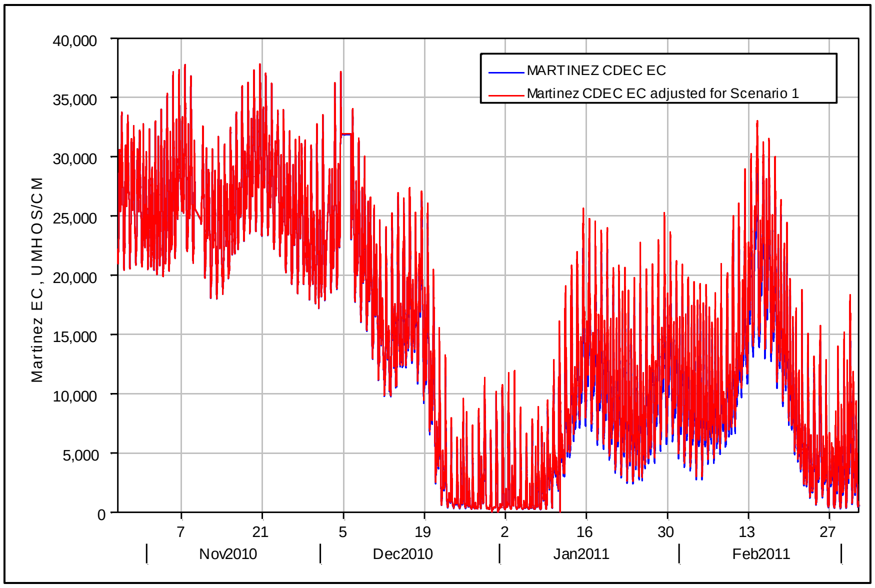

Figure 11-7 Comparison of historic and adjusted Martinez EC.

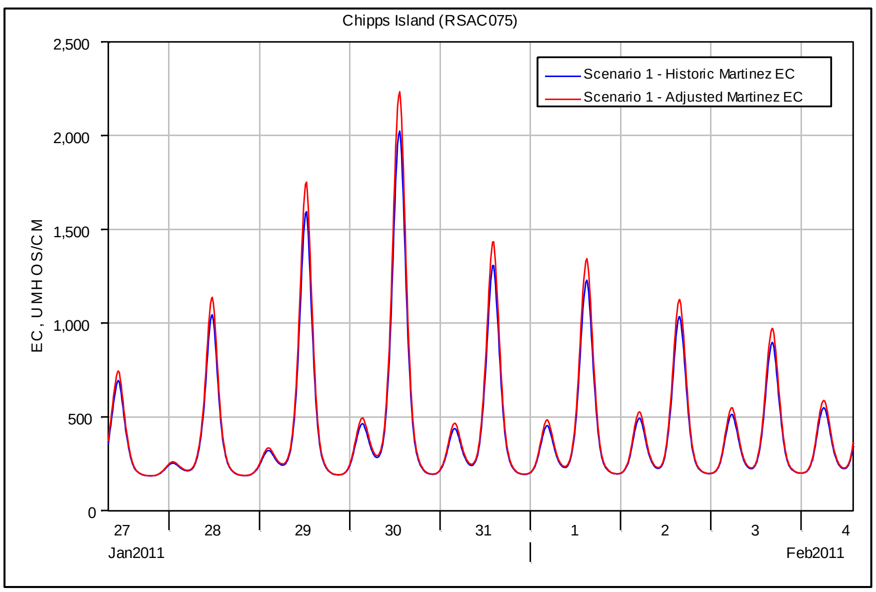

Figure 11-8 Comparison of computed EC at Chipps Island using historic and adjusted Martinez EC.

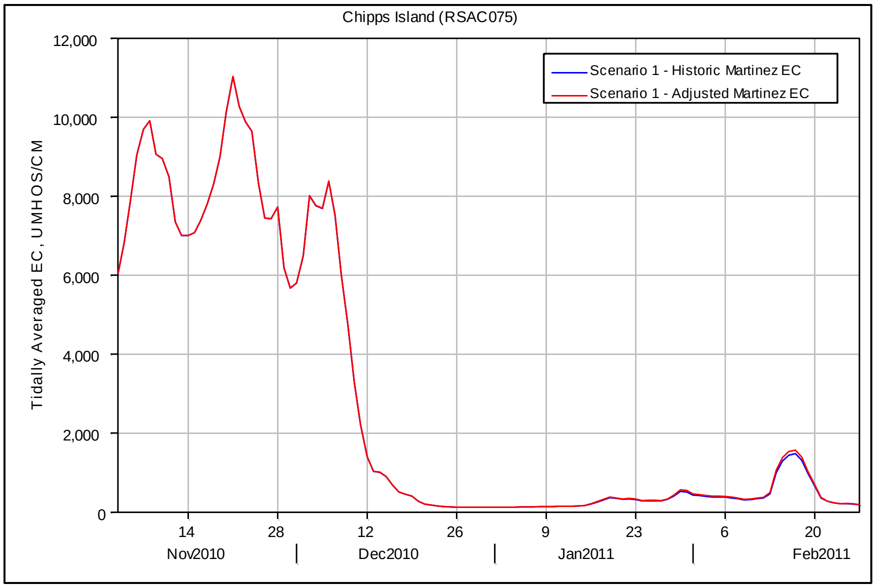

Figure 11-9 Comparison of tidally averaged computed EC at Chipps Island using historic and adjusted Martinez EC.

11.3.4 Findings of the Scenario Study

Adjustment of the Martinez EC boundary condition to account for changes in NDO has only small local impacts near the boundary and virtually no far field impacts for the scenario and period analyzed. Impacts are small because NDO changes are relatively small and occur during periods of higher flow.

Based on this finding, no attempt will be made to adjust Martinez EC for future scenario simulations with NDO changes of similar magnitude.

11.4 RMA11 Salinity Model Recalibration Results and the Effects of DICU in WY2012

11.4.1 Background

Due to a late start in funding for the WY2012 forecast season, the results of the RMA11 salinity model were not examined in detail until after the Martinez salinity boundary condition development had been addressed in early January (see Section 11.2). Once the boundary condition at Martinez was applied in the standard manner (as an average of top and bottom EC), it was noted that salinity in the western Delta was too low.

Two issues were identified as potentially contributing to the low EC: the dispersion coefficients near the western model boundary were too low to capture the transition between the high summer NDO in WY2011 to low late fall NDO in WY2012; and, the DICU inflow to the Delta during January was too high given the very dry conditions experienced in N. California in December and January. The latter problem results in a modeled NDO value that was almost certainly higher than the actual value, potentially resulting in too little salinity intrusion from the western model boundary.

The problem with inappropriate NDO values was first identified at the data acquisition locations on the North and South forks of the Mokelumne River, just downstream of the split. In January, the EC at these two locations was unrealistically high. Since the Delta Cross Channel was closed, and inflow from the Cosumnes and Mokelumne Rivers was extremely low, this indicated a likely problem in DICU values for January, at least at in the northeastern Delta.

To correct the low Delta salinities, the dispersion coefficients in the western Delta were recalibrated using WY2010 historical conditions. In simulations designed to test the effect of DICU flow and salinity boundary conditions, the DICU values for the January WY2012 model were altered to DICU values for the previous December. The results are discussed in the following subsections.

11.4.2 RMA11 Recalibration Results and Examination of DICU flow and EC conditions

The recalibrated RMA11 salinity model was applied under historical conditions from Nov. 01, 2011 until Jan. 31, 2012, but with dispersion coefficients updated and DICU flows and salinity in January varied in order to test the effect of these changes. The following table details the conditions used in the model simulations, and specifies the scenario names used in the figures:

Scenario Name	Dispersion	DICU flow	DICU EC
Old Dispersion	Old	Original	Original
New Dispersion	New	Original	Original
NewDisp-LowJanDICU-Flow	New	December Used in January	Original
NewDisp-LowJanDICU-FlowEC	New	December Used in January	December Used in January

DICU boundary conditions are applied in over 220 locations in the RMA Delta grid[2] on a monthly basis. Figure 11-10illustrates that the decrease in NDO obtained by applying December DICU flows in January was nearly 2000 cfs. This change in NDO was tested to examine the effect of changes in outflow (due to DICU) on salinity. River inflow was generally low during the modeled period, as illustrated in Figure 11-11 through Figure 11-14. Figure 11-11 is a comparison of Delta Outflow data downloaded from CDEC (code is “DTO”[3]) with net Delta outflow (NDO) calculated from RMA model boundary flows. There are two things to note –first, Delta Outflow in December, 2011 and through the middle of January is quite low, and second, starting in December RMA’s NDO value is generally biased higher than DTO on a daily basis. Some of the difference between the two time series may be due to differences in the way state and federal exports are calculated, but this is unlikely to introduce a regular bias.

Throughout the Delta, the new dispersion coefficients either improved the representation of Delta salinity, or in outlying locations, had no effect. DICU withdrawal and return flows (and EC in inflow) are applied regionally, so the effects of changing DICU inflows and EC will vary by location. These effects are illustrated in a series of figures - Figure 11-15 through Figure 11-32. For each location (N. Mokelumne R., S. Mokelumne R., Antioch, Cache-Ryer, Decker Island and SJR-Garwood), there are three plots

[2] DSM2 has 258 DICU locations – there are small differences between the two models to accommodate differences in the grids, however total and net flows are the same Delta-wide.
[3] The components of the DTO calculation are not listed on CDEC.

illustrating the November 2011 to January 2012 results for each of the scenarios, as well as an expanded plot illustrating results for January 2012 alone.

For the North and South Mokelumne River locations, before any changes were implemented modeled salinity was much higher than the data (Figure 11-15 through Figure 11-21).The scenario reducing January DICU flow did not improve the salinity results measurably. However, additionally changing the applied DICU salinity values resulted in a substantial improvement by lowering modeled salinity by approximately a factor of two. Note that the Delta Cross Channel was closed December 2011, and inflow from the Cosumnes and Mokelumne Rivers was very low December through January (Figure 11-14), so the effect of DICU contributions to flow and salinity was amplified in this region.

At Antioch (Figure 11-21 to Figure 11-23), the new dispersion coefficients improved the representation of salinity, but changes to DICU flow and salinity had only a minor effect. The result was similar at Mallard Slough (not shown).

The Cache Slough complex has long been problematic for capturing the local sources of salinity in simulations, and in WY2012 modeled salinity was too low in this region. At the Cache-Ryer location (Figure 11-24 to Figure 11-26), changes to the dispersion coefficient had no noticeable effect, while changes to January DICU flow improved the results (increased modeled salinity locally). Additionally changing DICU salinity in January had the effect of reversing the improvements made by altering DICU flow alone.

The effect of the new dispersion coefficients reached Decker Island on the Sacramento River, where the representation of salinity was clearly improved. Additionally changing the January DICU resulted in additional minor improvements, although the two DICU scenarios have similar results.

On the San Joaquin River at Garwood location (Figure 11-30to Figure 11-32), the results with no changes to DICU are generally better than the other scenarios – note that the effects of the new dispersion coefficients do not reach this upstream location.

11.4.3 Summary of Scenario Results

The new dispersion coefficients significantly improved the representation of salinity near the western model boundary in WY2012, and in locations where salinity intrusion is an important factor, such as at Jersey Point (not shown). Although not shown, RMA11 turbidity model scenarios with the new dispersion coefficients and changes to DICU flow values showed little or no measureable change from simulations run with the original set of dispersion coefficients.

The results of the two scenarios varying DICU indicate that there is no single solution to the misrepresentation of DICU flows and salinity as applied under historical conditions. Under very low inflow conditions, such as those experienced this fall and winter, differences between the DICU estimates and actual agricultural (and runoff) contributions can have a major effect that may be variable regionally, as was demonstrated in this modeling exercise.

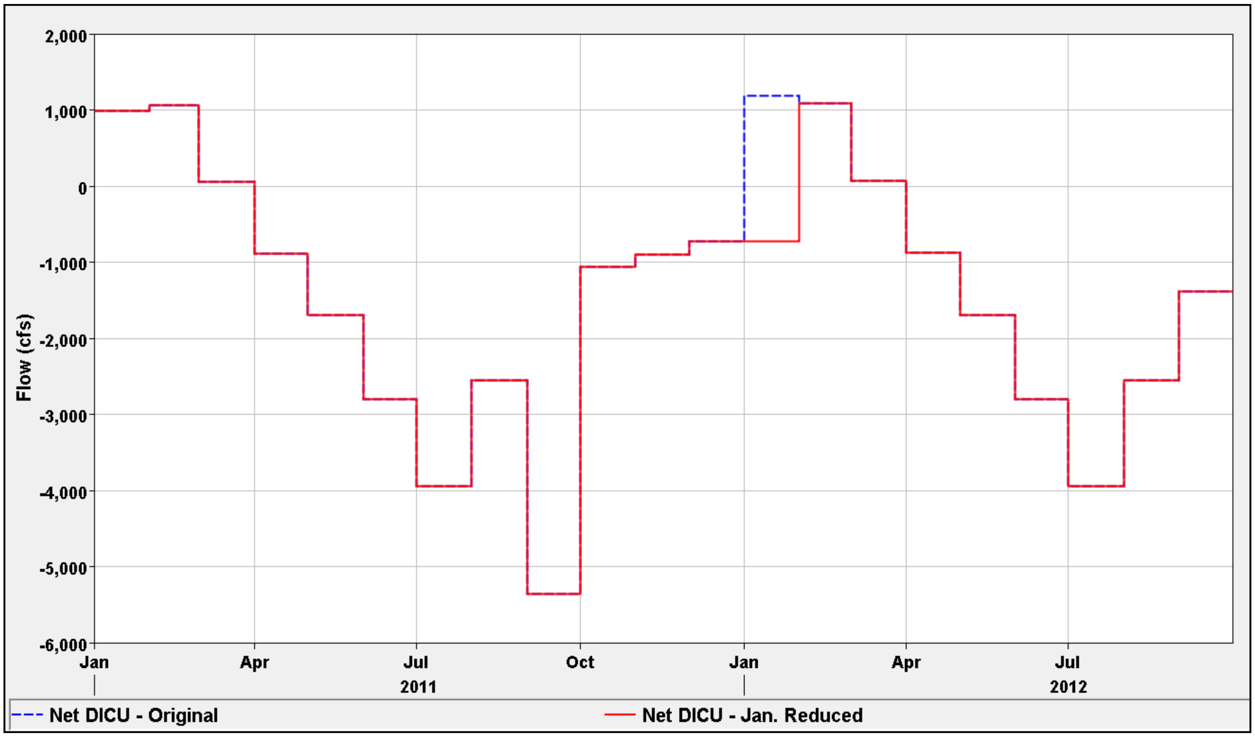

Figure 11-10 Net DICU as supplied by DWR – Original (blue dash) net DICU in January was reduced by nearly 2,000 cfs (red line) to decrease modeled NDO for January. Positive values in this figure represent contributions to NDO, and negative values represent withdrawals from the Delta.

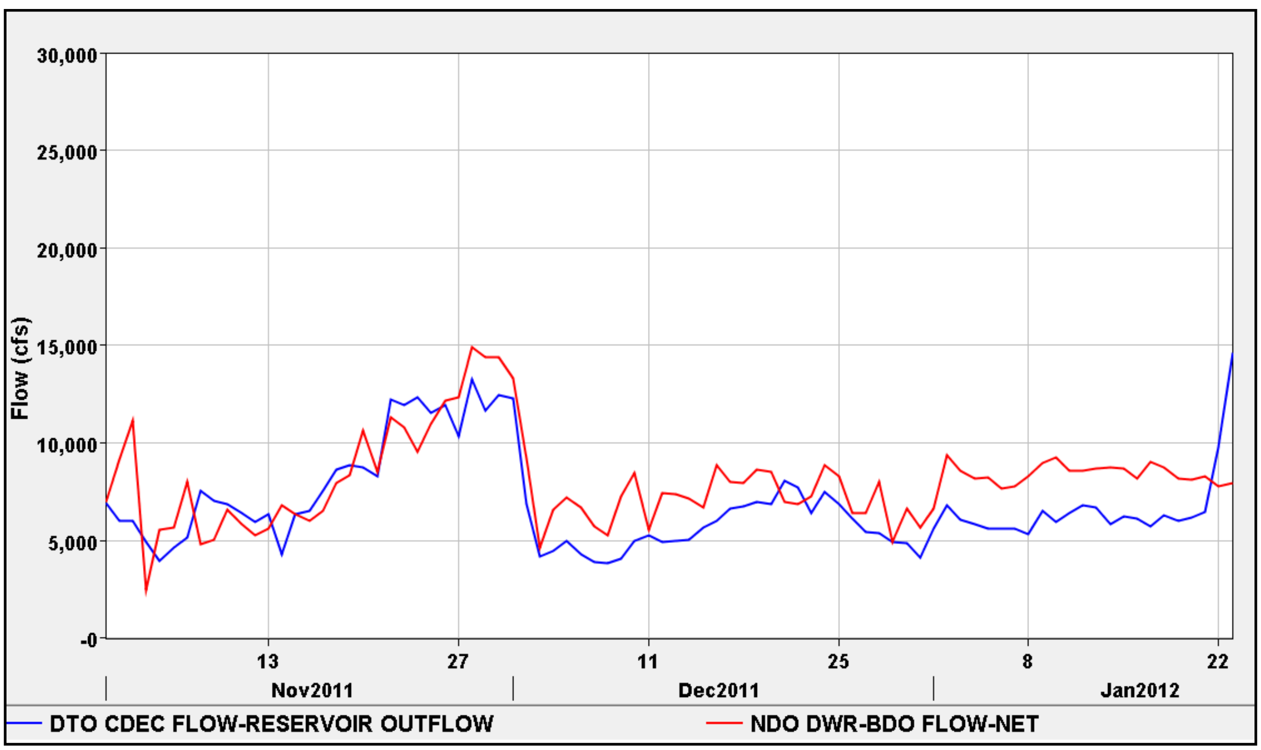

Figure 11-11 Figure compares the CDEC data available for daily Delta Outflow (DTO, blue line) with value calculated from model boundary conditions (NDO, red line).

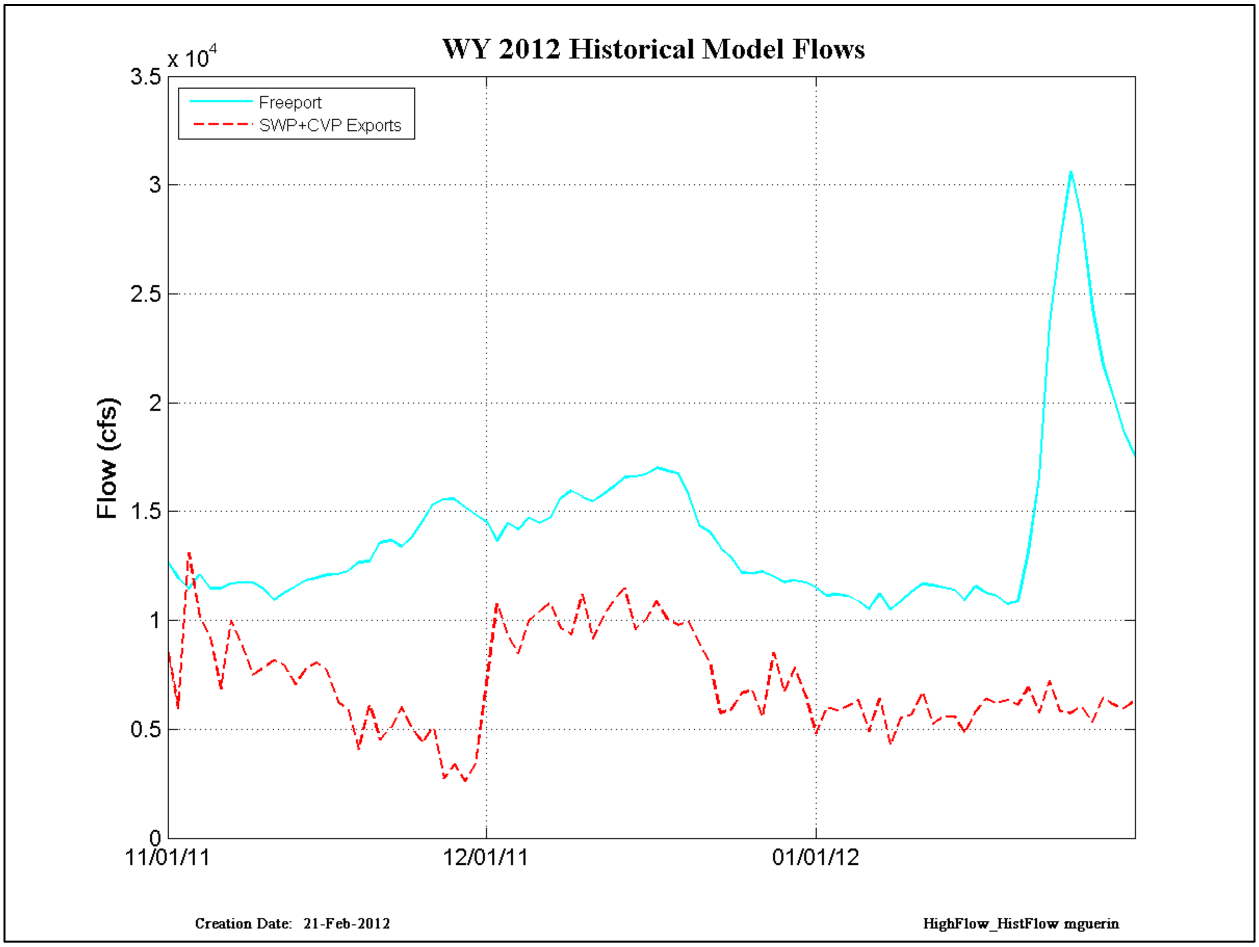

Figure 11-12 Historical Sacramento River inflow at Freeport and combined SWP+CVP exports. Note vertical scale is cfs*1000.

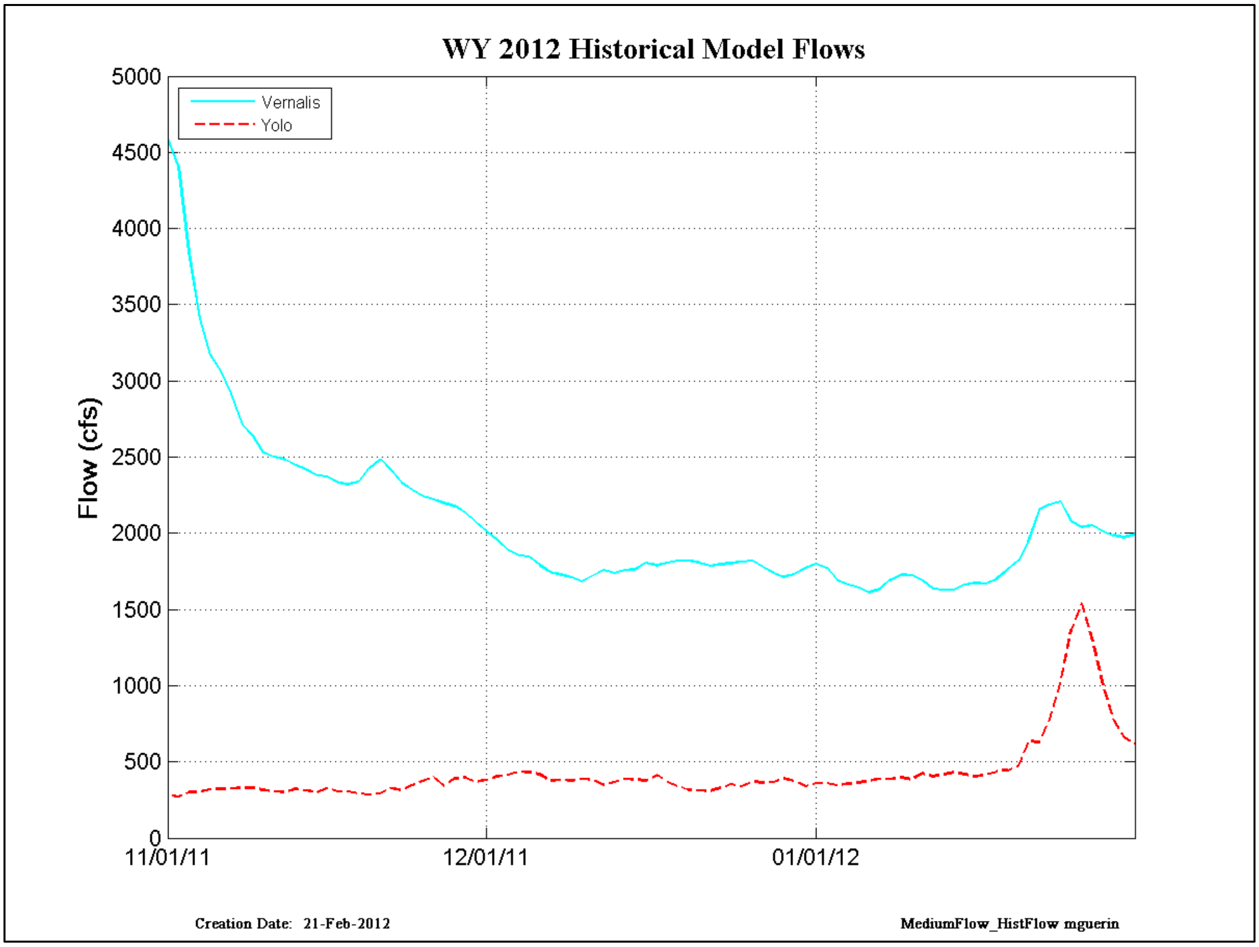

Figure 11-13 Historical San Joaquin River at Vernalis and Yolo Bypass inflows.

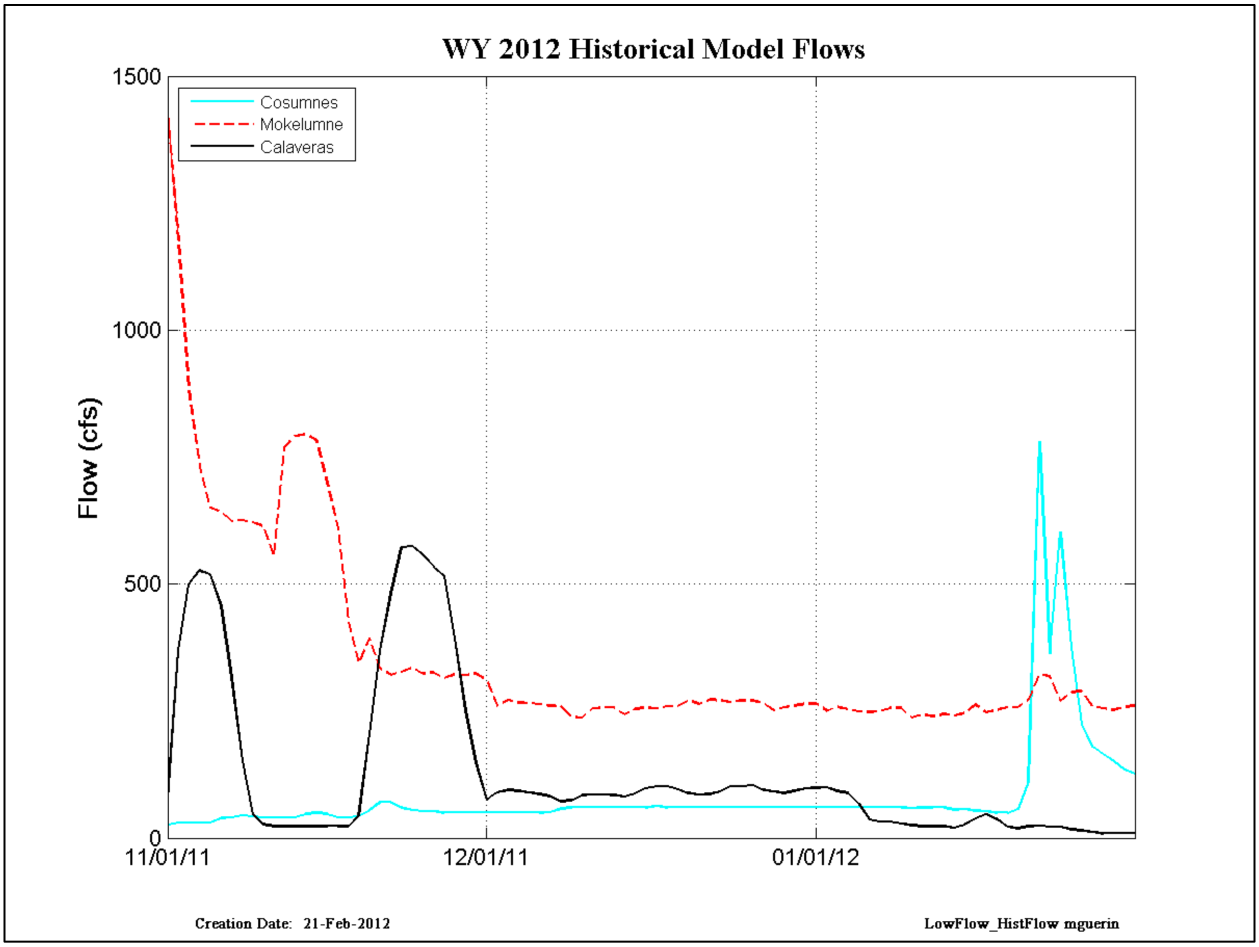

Figure 11-14 Historical Cosumnes, Mokelumne and Calaveras River inflows.

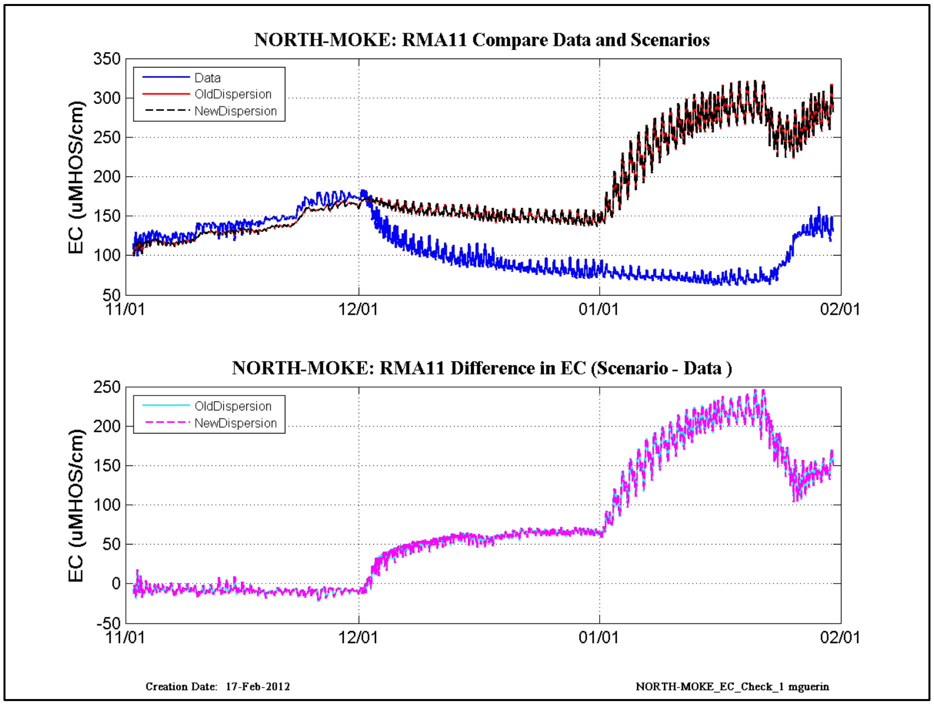

Figure 11-15 The upper plot compares data (blue line) at the North Mokelumne River location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot shows the difference between the model scenario output and the data.

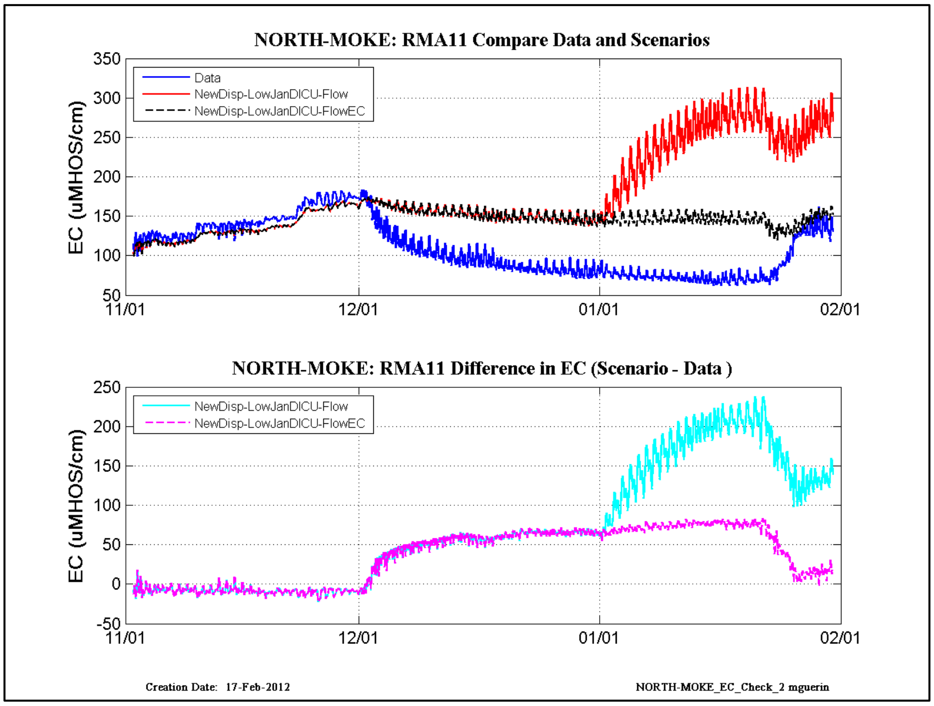

Figure 11-16 The upper plot compares data (blue line) at the North Mokelumne River location and model scenarios with new dispersion coefficients, and adjusted DICU flow (red line) or adjusted DICU flow and EC (black dash). The lower plot shows the difference between the model scenario output and the data.

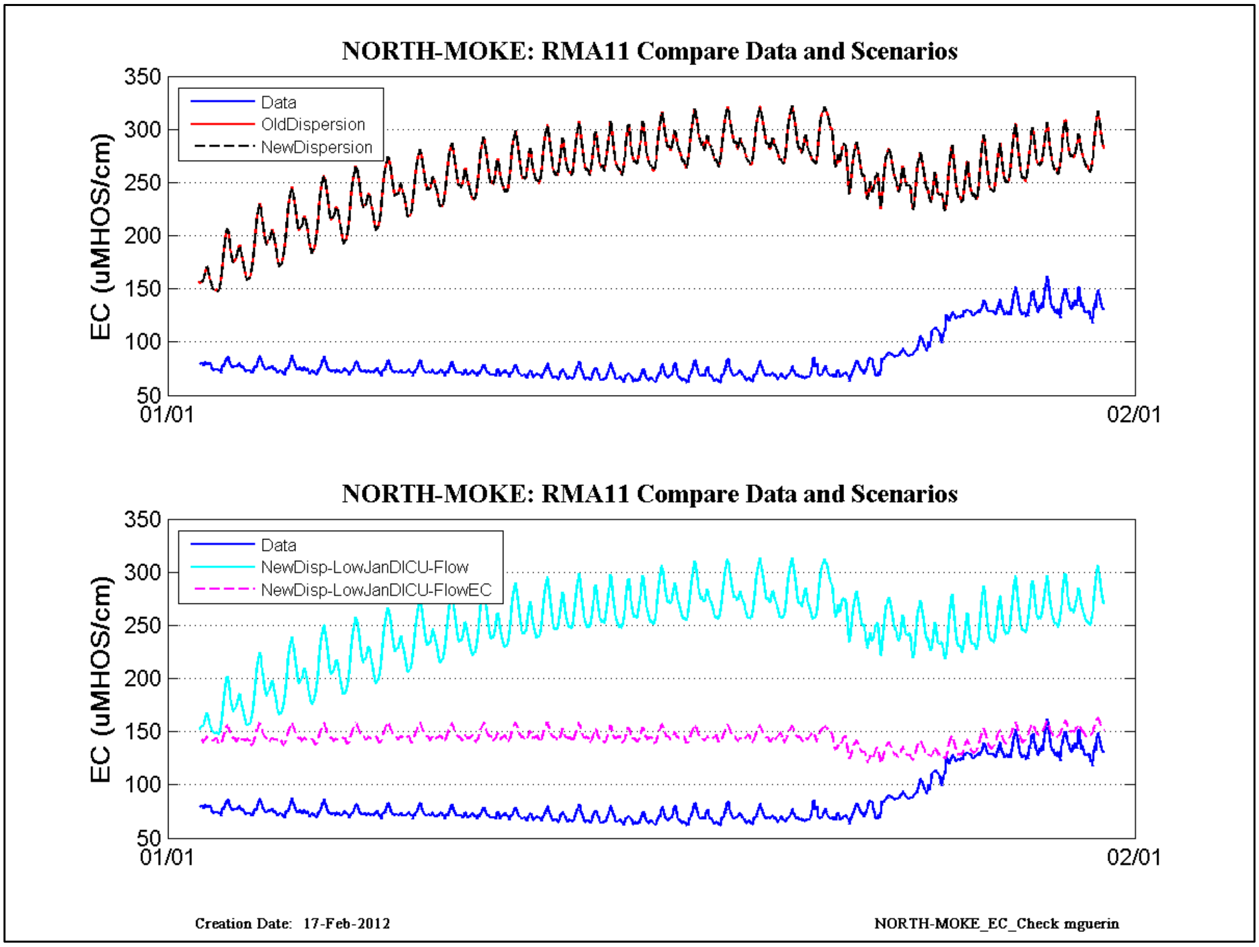

Figure 11-17 The upper plot compares January 2012 data (blue line) at the North Mokelumne R. location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot compares data (blue line) at the North Mokelumne R. location and model scenarios with new dispersion coefficients and adjusted DICU flow (cyan line) or adjusted DICU flow and EC (pink dash).

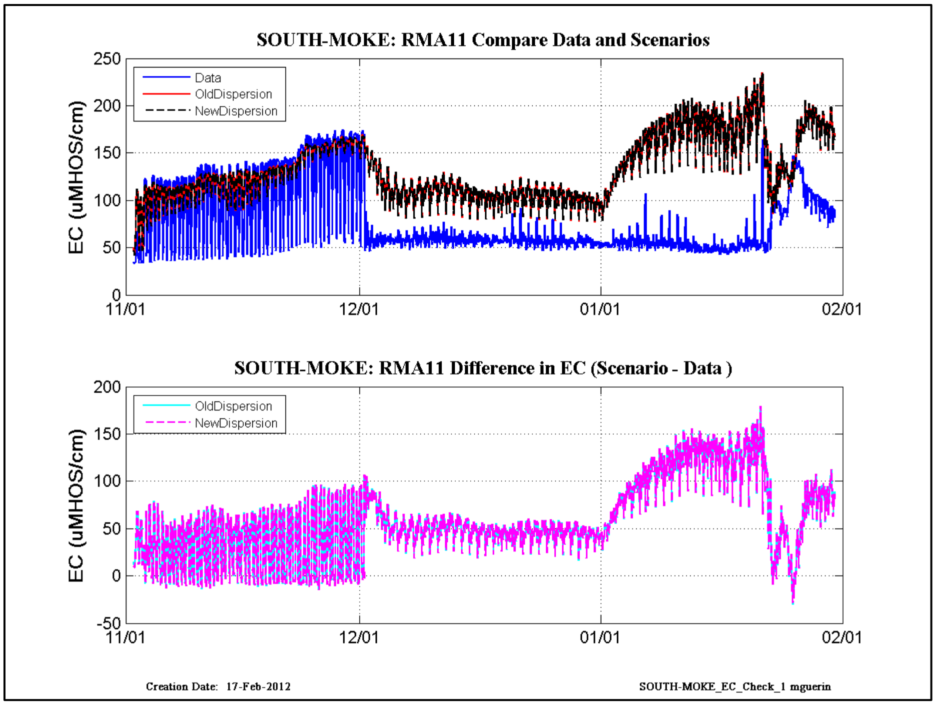

Figure 11-18 The upper plot compares data (blue line) at the South Mokelumne River location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot shows the difference between the model scenario output and the data.

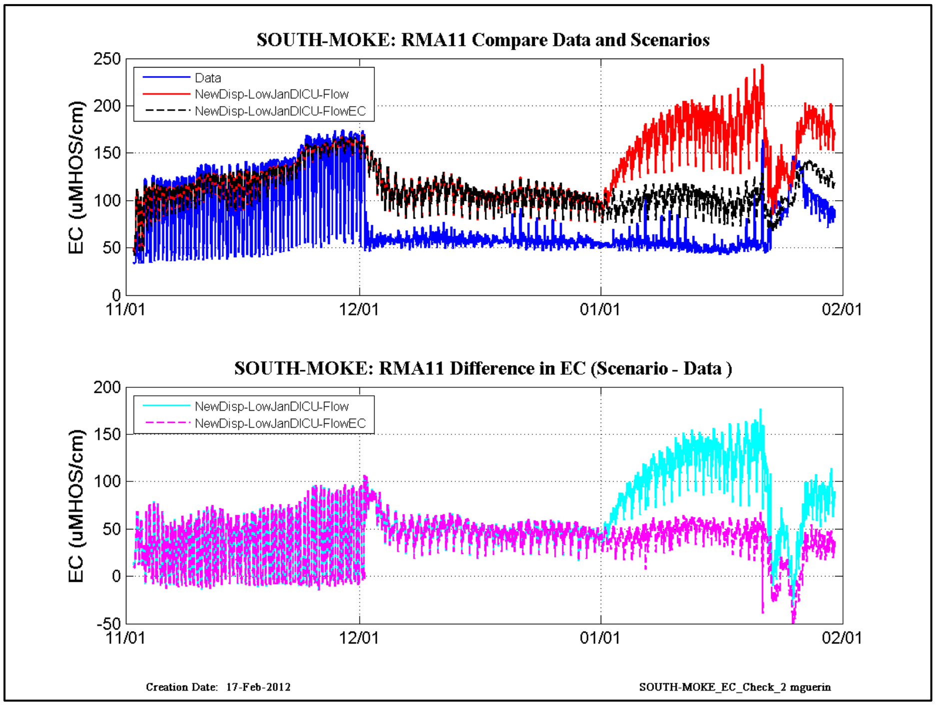

Figure 11-19 The upper plot compares data (blue line) at the South Mokelumne River location and model scenarios with new dispersion coefficients, and adjusted DICU flow (red line) or adjusted DICU flow and EC (black dash). The lower plot shows the difference between the model scenario output and the data.

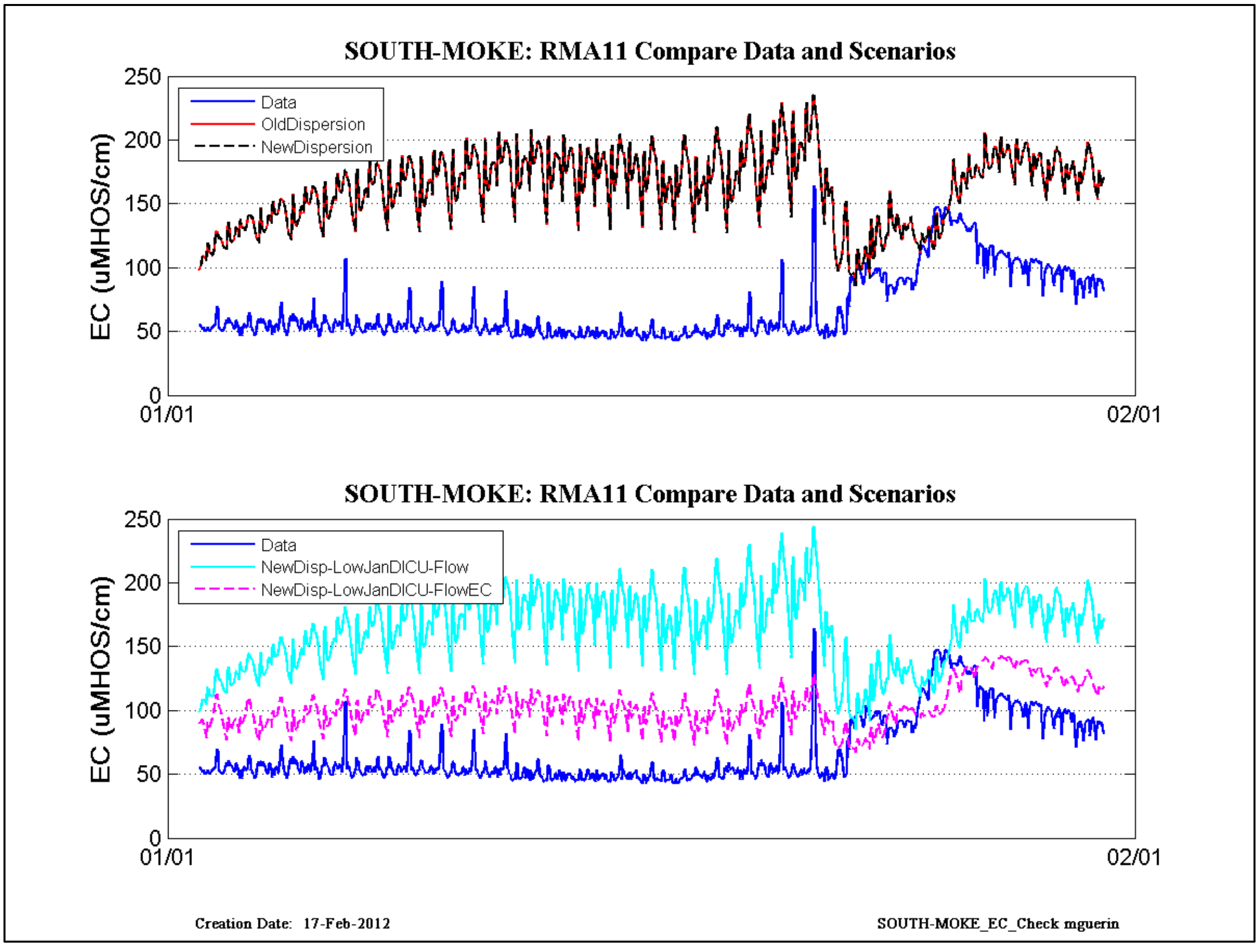

Figure 11-20 The upper plot compares January 2012 data (blue line) at the South Mokelumne R. location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot compares data (blue line) at the South Mokelumne R. location and model scenarios with new dispersion coefficients and adjusted DICU flow (cyan line) or adjusted DICU flow and EC (pink dash).

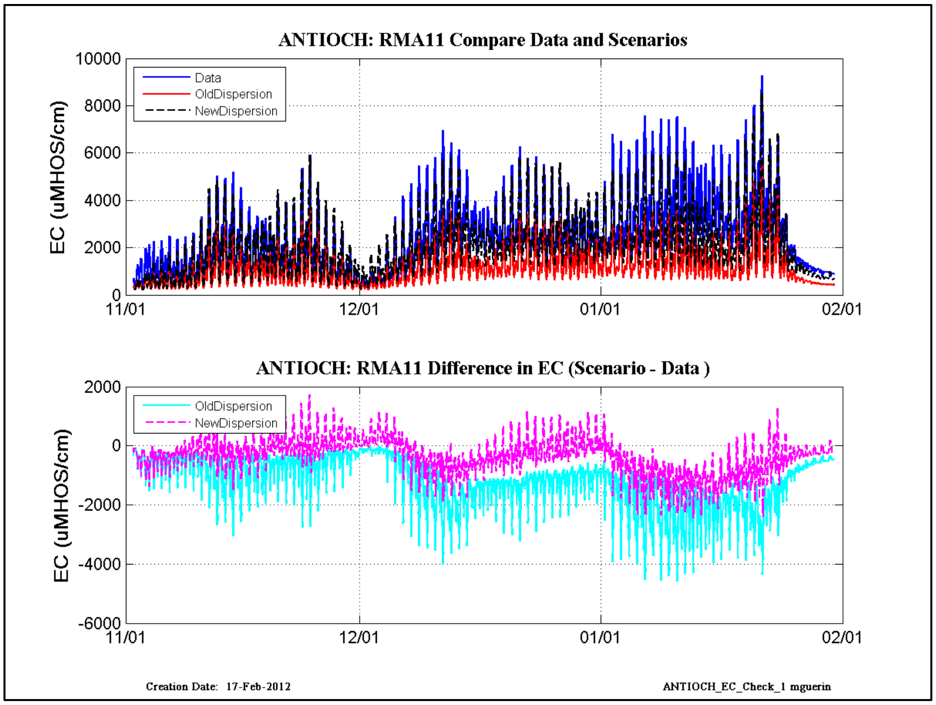

Figure 11-21 The upper plot compares data (blue line) at the Antioch location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot shows the difference between the model scenario output and the data.

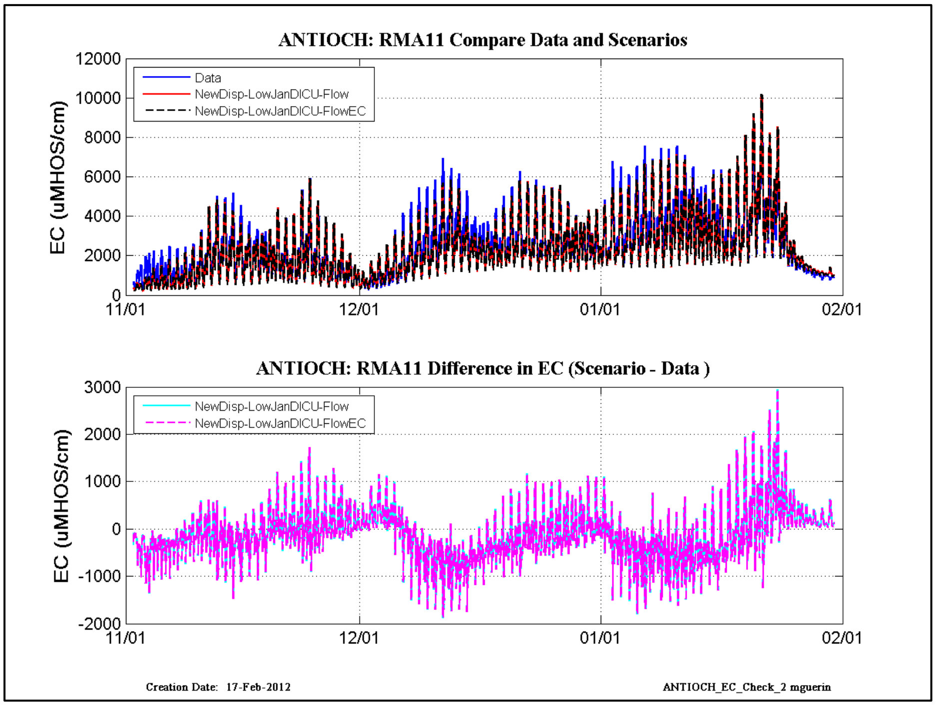

Figure 11-22 The upper plot compares data (blue line) at the Antioch location and model scenarios with new dispersion coefficients, and adjusted DICU flow (red line) or adjusted DICU flow and EC (black dash). The lower plot shows the difference between the model scenario output and the data.

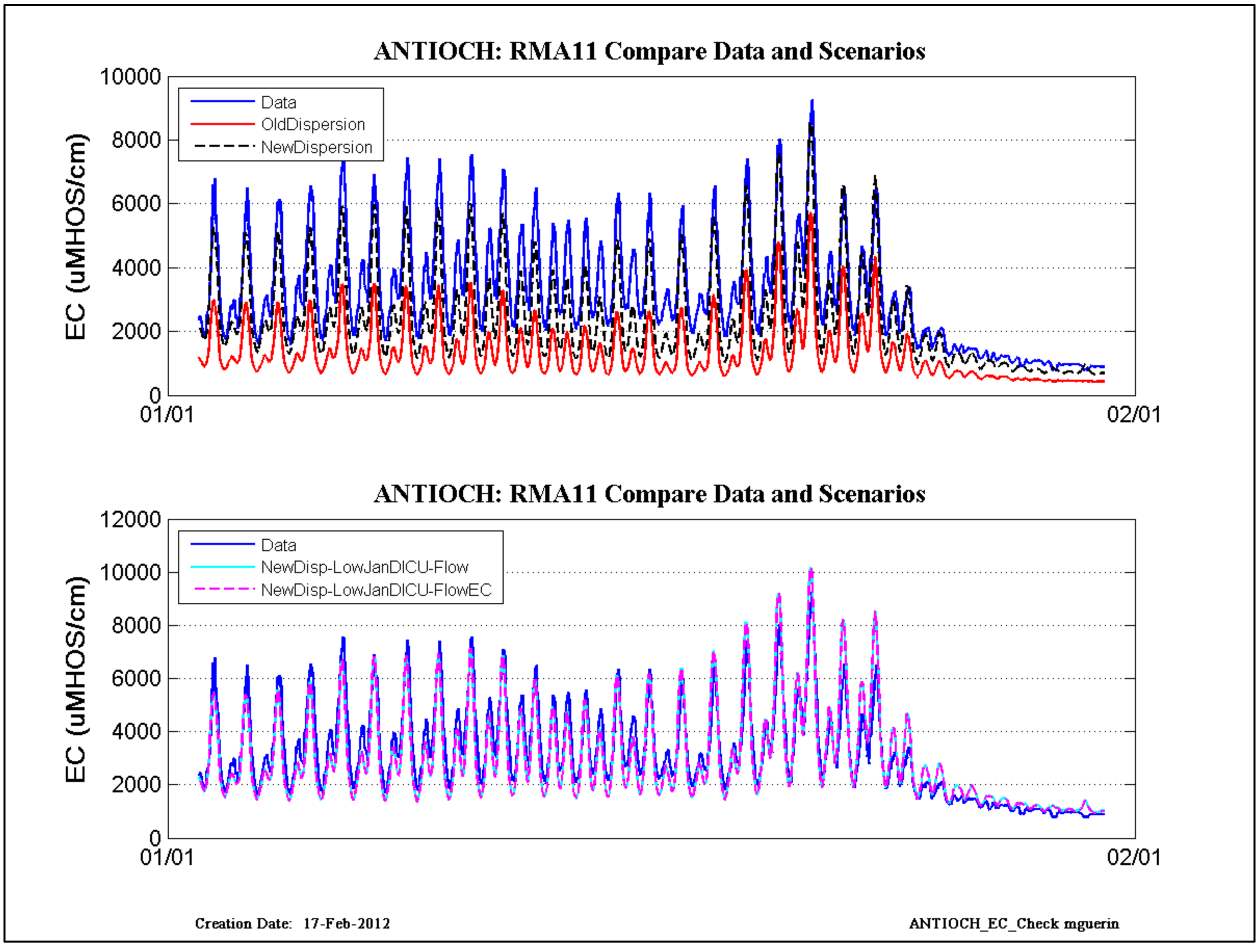

Figure 11-23 The upper plot compares January 2012 data (blue line) at the Antioch location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot compares data (blue line) at the Antioch location and model scenarios with new dispersion coefficients and adjusted DICU flow (cyan line) or adjusted DICU flow and EC (pink dash).

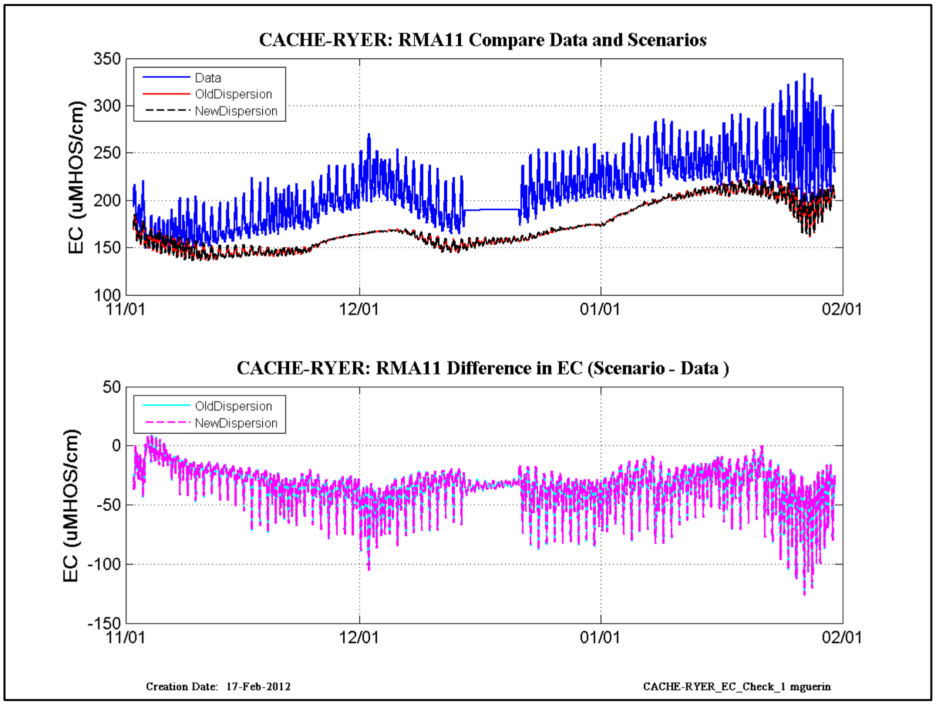

Figure 11-24 The upper plot compares data (blue line) at the Cache-Ryer location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot shows the difference between the model scenario output and the data.

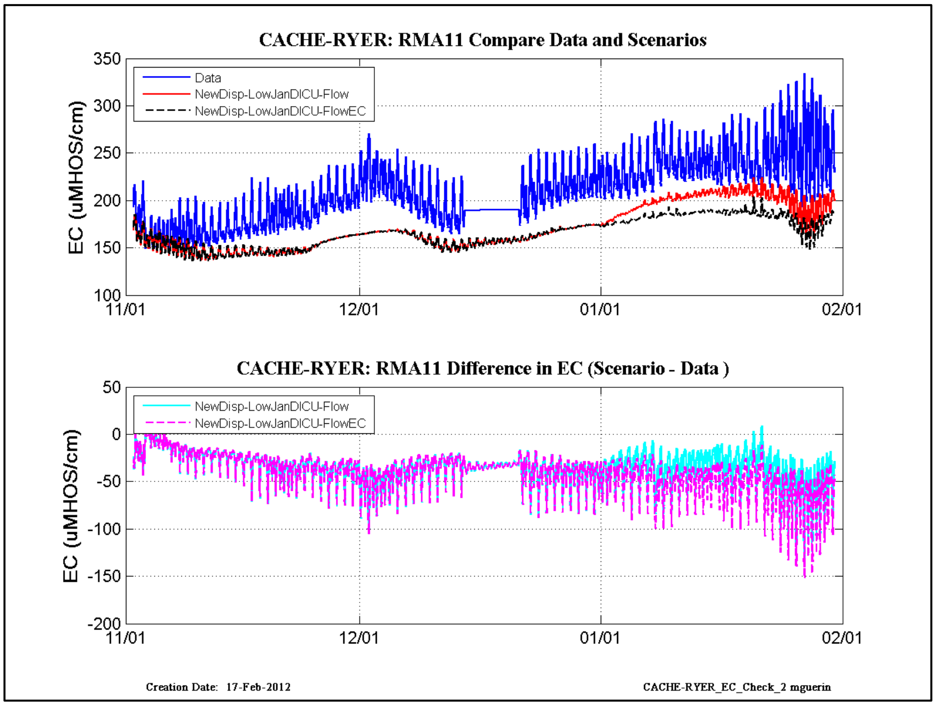

Figure 11-25 The upper plot compares data (blue line) at the Cache-Ryer location and model scenarios with new dispersion coefficients, and adjusted DICU flow (red line) or adjusted DICU flow and EC (black dash). The lower plot shows the difference between the model scenario output and the data.

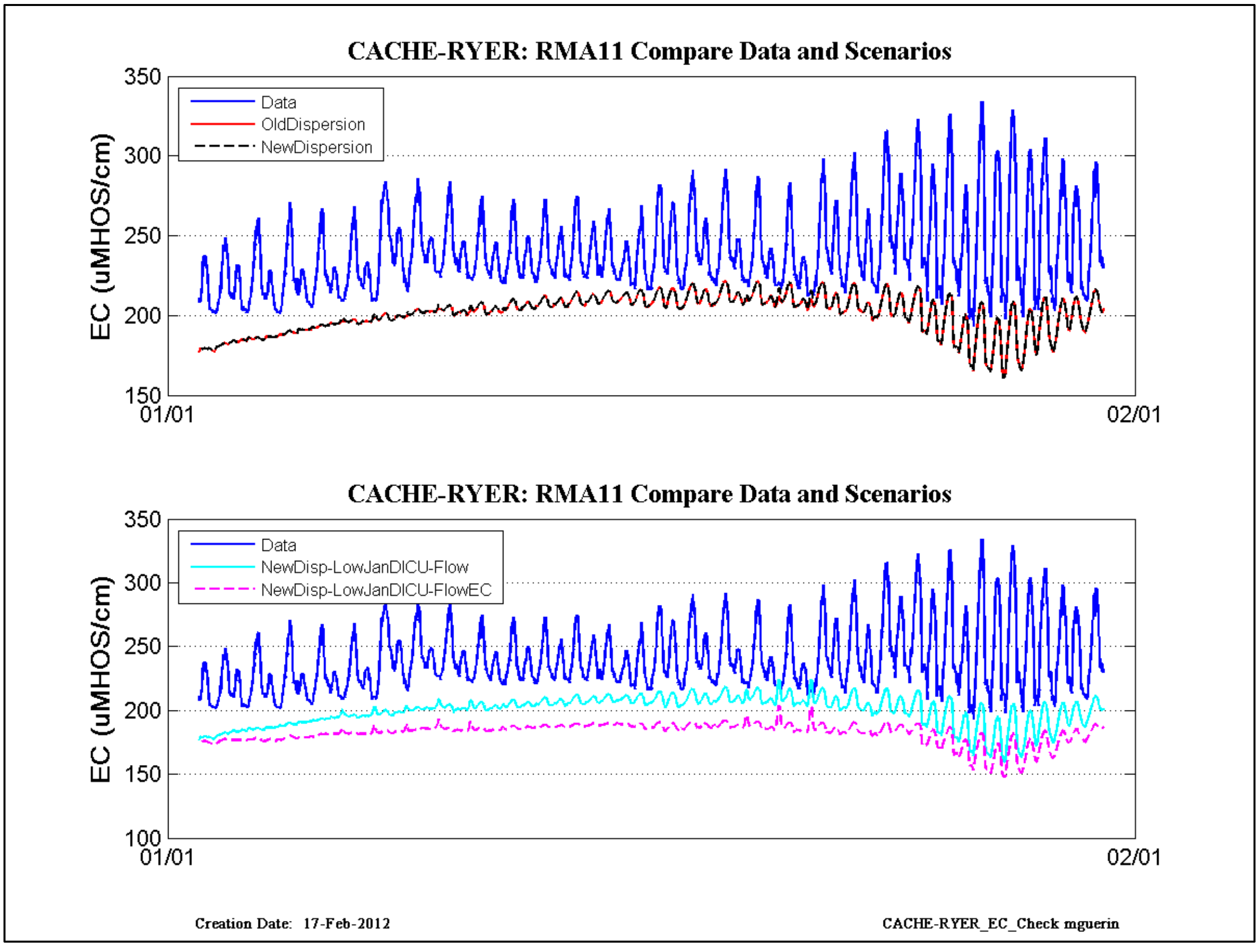

Figure 11-26 The upper plot compares January 2012 data (blue line) at the Cache-Ryer location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot compares data (blue line) at the Cache-Ryer location and model scenarios with new dispersion coefficients and adjusted DICU flow (cyan line) or adjusted DICU flow and EC (pink dash).

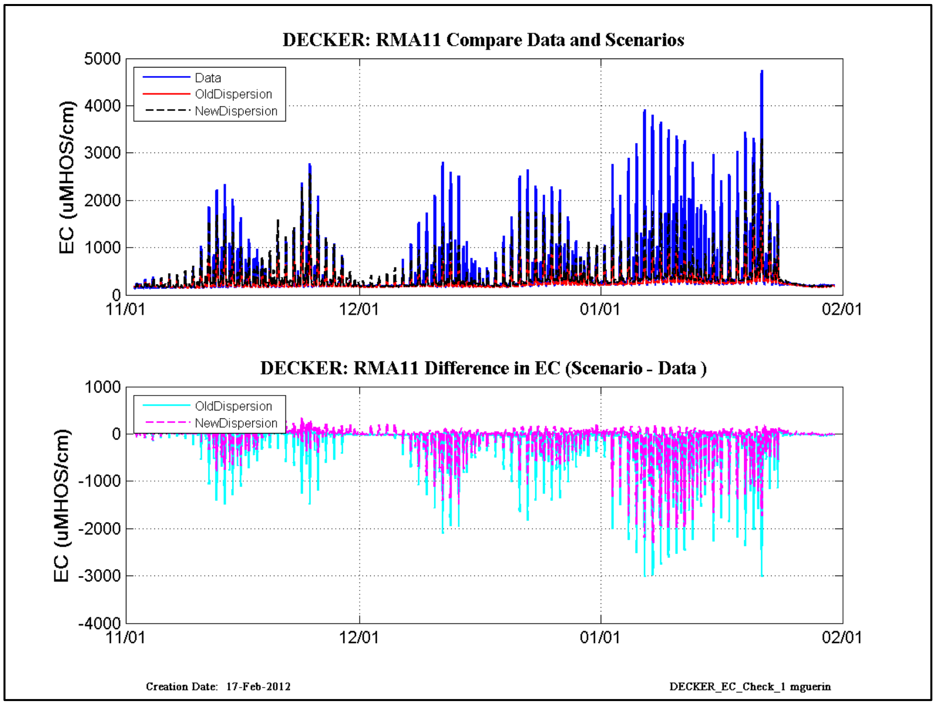

Figure 11-27 The upper plot compares data (blue line) at the Decker Island location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot shows the difference between the model scenario output and the data.

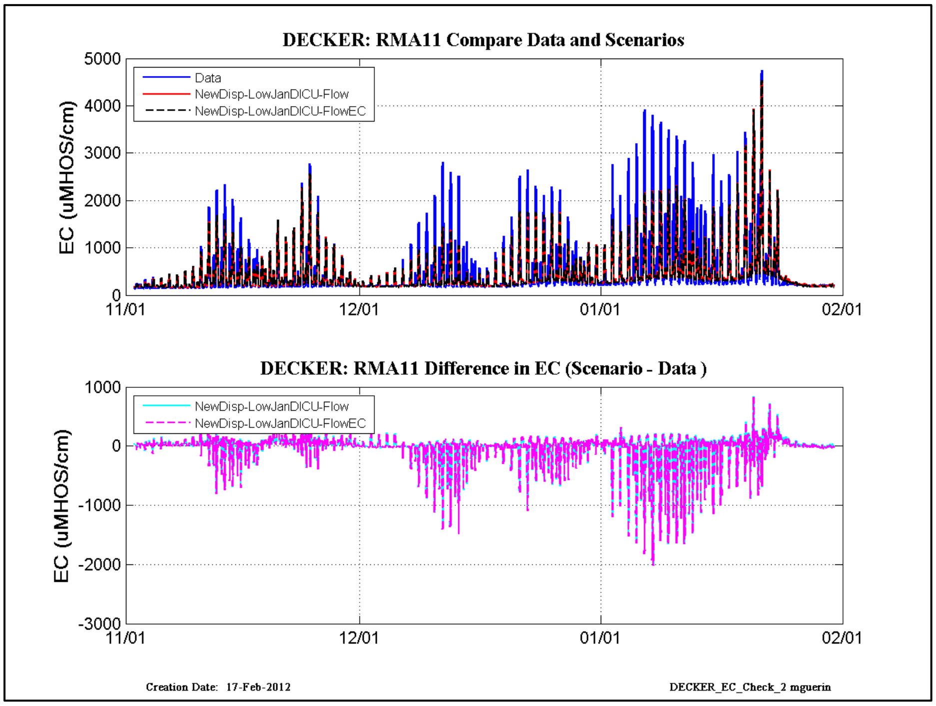

Figure 11-28 The upper plot compares data (blue line) at the Decker Island location and model scenarios with new dispersion coefficients, and adjusted DICU flow (red line) or adjusted DICU flow and EC (black dash). The lower plot shows the difference between the model scenario output and the data.

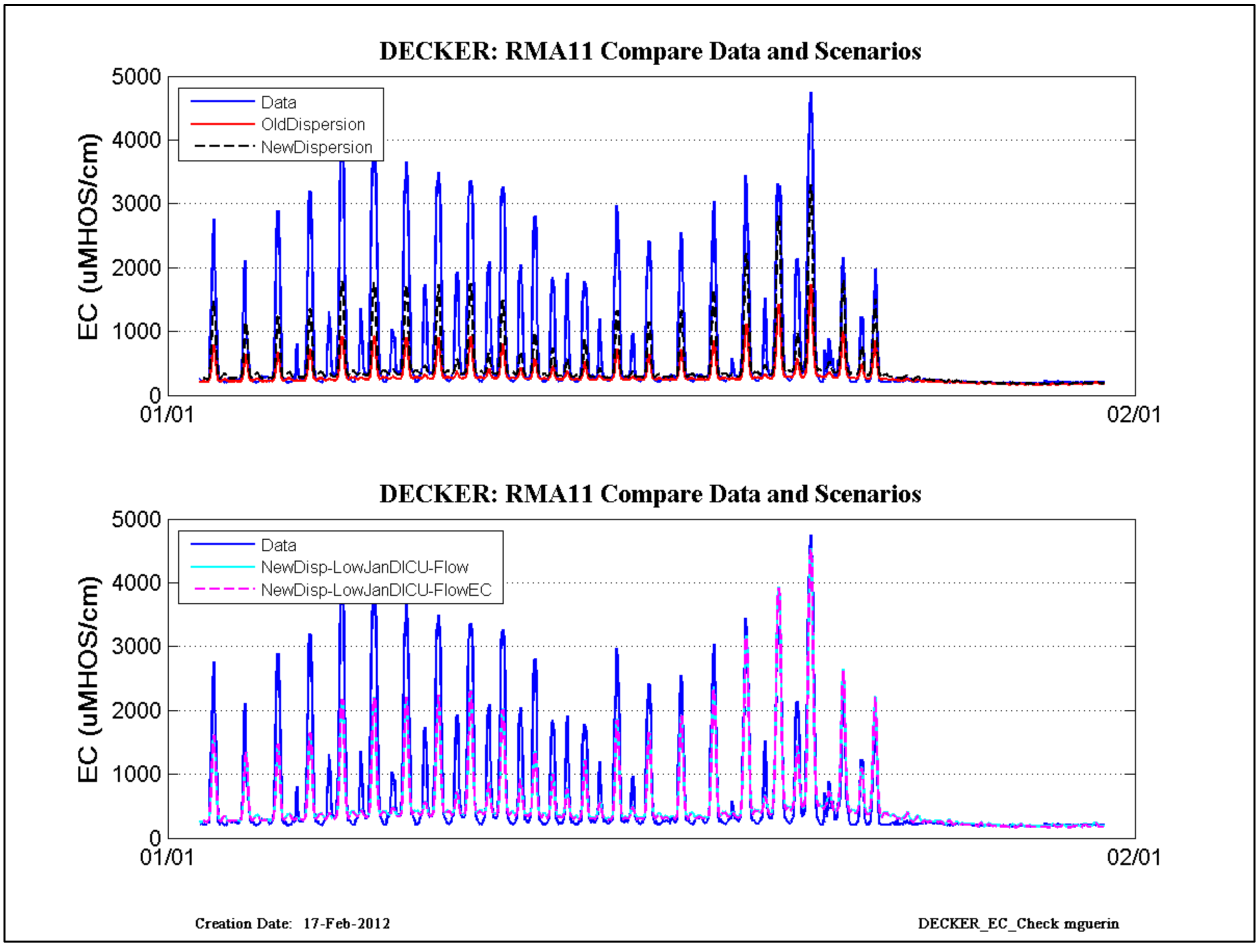

Figure 11-29 The upper plot compares January 2012 data (blue line) at the Decker Island location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot compares data (blue line) at the Decker Island location and model scenarios with new dispersion coefficients and adjusted DICU flow (cyan line) or adjusted DICU flow and EC (pink dash).

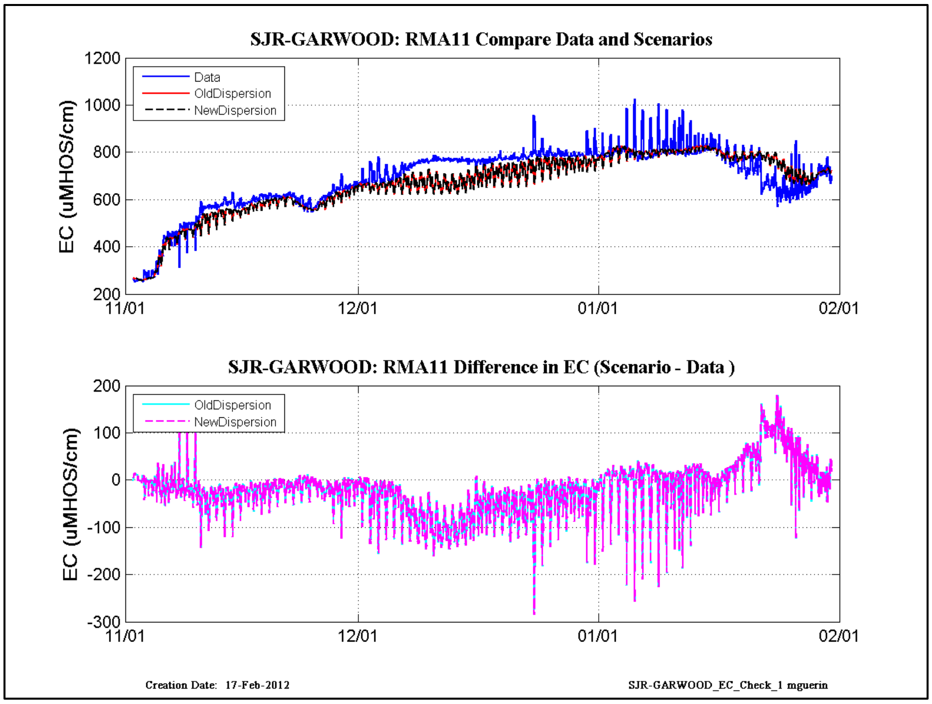

Figure 11-30 The upper plot compares data (blue line) at the SJR-Garwood location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot shows the difference between the model scenario output and the data.

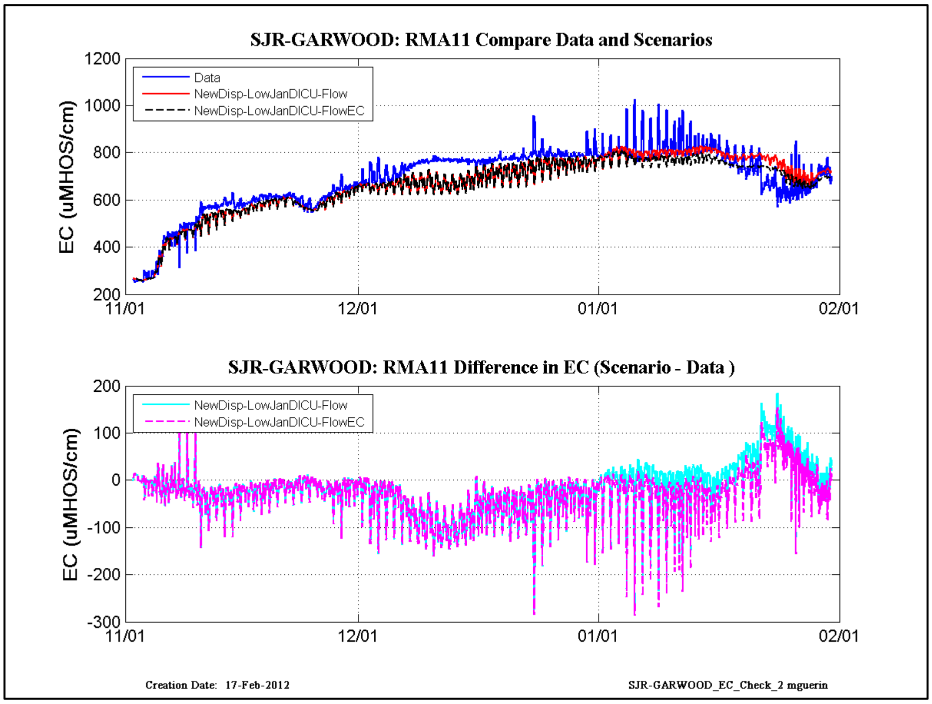

Figure 11-31 The upper plot compares data (blue line) at the SJR-Garwood location and model scenarios with new dispersion coefficients, and adjusted DICU flow (red line) or adjusted DICU flow and EC (black dash). The lower plot shows the difference between the model scenario output and the data.

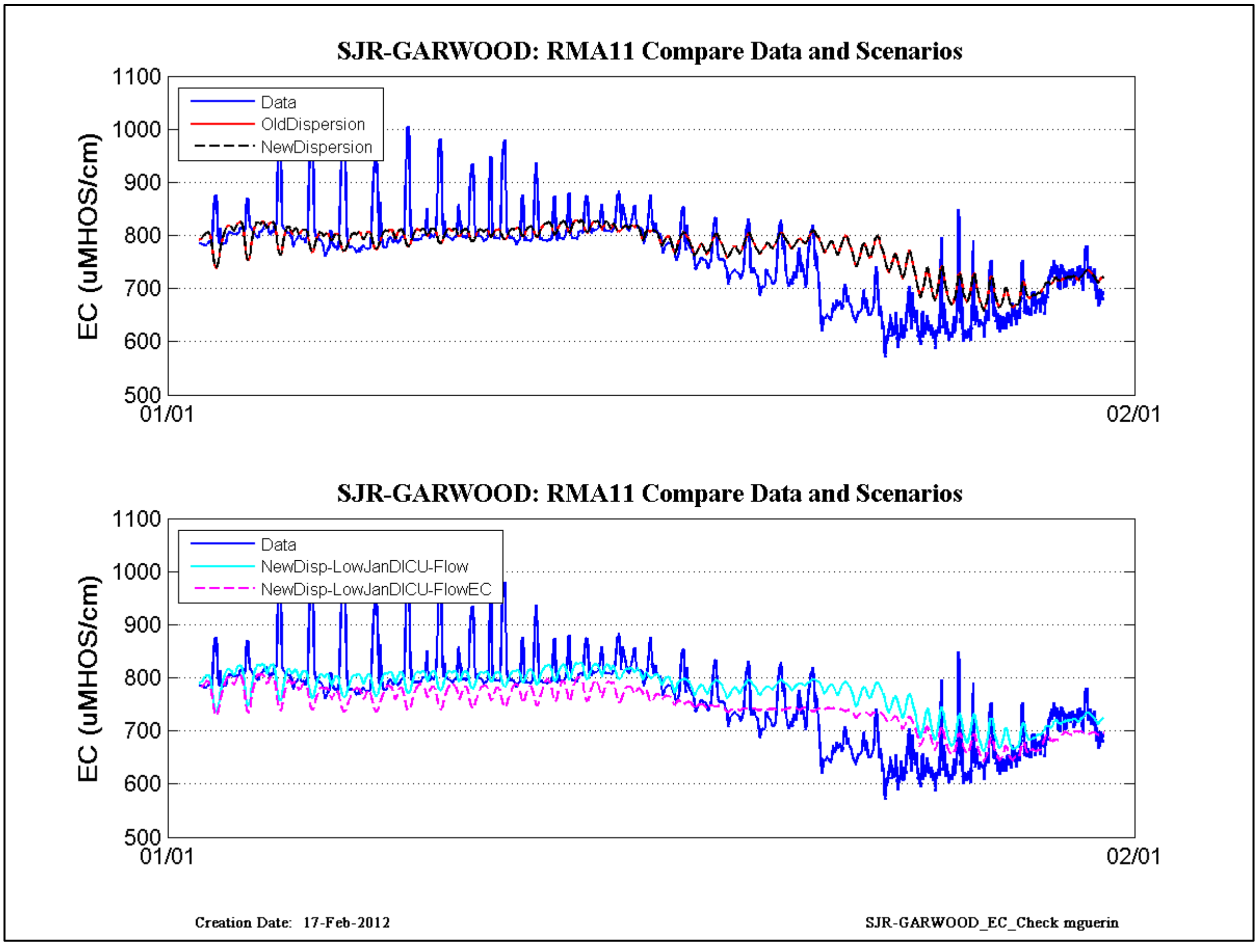

Figure 11-32 The upper plot compares January 2012 data (blue line) at the SJR-Garwood location and model scenario output with old (red line) and new (black dash) dispersion coefficients. The lower plot compares data (blue line) at the SJR-Garwood location and model scenarios with new dispersion coefficients and adjusted DICU flow (cyan line) or adjusted DICU flow and EC (pink dash).

12 Weekly Forecast Documentation Samples

This appendix gives two samples of weekly forecast documentation. The first documentation set (RMA Turbidity and Adult Delta Smelt Behavioral Model Covering the Forecast Period December 15, 2011 to January 3, 2012) gives an example of a forecast made during the dry, low-flow conditions that dominated the WY2012 forecast season. This forecast is additionally informative because it compares model results obtained with and without the use of WARMF boundary conditions. Several figures compare the WARMF boundary conditions generated by Systec against the best judgment boundary condition predictions generated by linear extrapolation or a simple correlation based on DWR predicted flow. Additional figures show the impact of these different boundary condition prescriptions on resulting modeled turbidity.

The second example documentation (RMA Turbidity and Adult Delta Smelt Behavioral Model Covering the Forecast Period January 26, 2012 to February 9, 2012) shows the forecast made several days after the first significant winter storm of WY2012 which generated a turbidity pulse in the Sacramento River. The utility of WARMF in predicting turbidity at Freeport can clearly be seen. This forecast is also informative because of its documentation and use of internal boundary conditions in the turbidity model. These internal boundary conditions were not in use in the previous example forecast.

12.1 RMA Turbidity and Adult Delta Smelt Behavioral Model Covering the Forecast Period December 15, 2011 to January 3, 2012

12.1.1 Summary Assessment

PERIOD: The Delta turbidity and adult delta smelt forecast was produced this week, covering the period December 15, 2011 to January 3, 2012.

PRE_FORECAST SUMMARY: Leading up to the forecast, Delta inflows and turbidity have been low due to dry conditions.

TURBIDITY 3-STATIONS PERFORMANCE & SUMMARY EVALUATION: Turbidity was low throughout the Delta, ranging from about 5 - 25 NTU in the raw data. Turbidity was below compliance values (12 NTU) at two of these three locations. At Holland Cut, the turbidity went above the compliance value for several days in early December, almost certainly due to a wind event. The forecast does not anticipate any storms or significant turbidity events.

SMELT MOVEMENT SUMMARY: As a result, the forecast does not anticipate smelt movement into the south Delta.

12.1.2 Background

This document provides a summary of the second forecast for WY2012 prepared by RMA on December 15, 2011. The forecast was developed using the RMA models for hydrodynamics, salinity, and turbidity and particle tracking using the Adult Delta Smelt Behavioral model. Figures are provided to document the results of the modeling with a focus on turbidity.

Because the funding for this project was delayed for several weeks past the initially agreed-upon start date, there was insufficient time to develop all of the preparatory materials needed for the model forecast simulations. For this reason, the salinity forecast is not presented.

12.1.3 Boundary Condition Development and Simulation Timing

Model boundary conditions for the forecast model were prepared using several sources for historical and forecast conditions including: CNRFC flow data and predictions, CDEC and USGS data, and DWR-supplied model inputs and results from their flow and salinity forecasts.

BC for this forecast period were prepared using these data sources, and using professional judgment where necessary to resolve data discrepancies and to piece the data together for reasonable BC.

The RMA modeled period was November 01, 2011 to January 3, 2012 for flow, salinity and turbidity. DWR Operations and Maintenance (O&M) group provided RMA with BC they used in the DSM2 HYDRO and QUAL/salinity models for a combined historical and forecast period December 02, 2011 through January 03, 2012 – the three week DWR forecast period was December 13 through January 03, 2012. Additional flow, turbidity and EC data was downloaded for the period December 14–15, 2011 from the CDEC, CNRFC and USGS websites to fill-in historical conditions in the RMA forecast models.

Historical and forecast BC for flow, turbidity and salinity were developed from sources as summarized in Table 12-1 through Table 12-3 below. Stage and export BC were compiled solely from DWR O&M sources. Due to low turbidity at the model boundaries, forecast turbidity was modeled as a constant.

Beginning with this second forecast, two “internal” turbidity boundary conditions were applied in the turbidity modeling. The upstream Sacramento River boundary condition typically dominates the computed model turbidity in the western Delta (Sacramento River below Rio Vista). However, Sacramento River flow and turbidities have been low for the current November-December period, with boundary condition turbidities below observed western Delta turbidities. An examination of the set of observed turbidity data indicated the Cache Slough complex and Suisun Bay as potentially significant sources of western Delta turbidity in the first two weeks of November and first week of December. An internal boundary condition was added for the Sacramento River at Mallard Island (CDEC record MAL) to better define the western Delta turbidity contribution from Suisun Bay (Figure 12-1). Similarly, an internal boundary condition was added (but not applied for the forecast period) for the Cache Slough at Ryer Island location (CDEC record RYI) to add the contribution to western Delta turbidity from the Cache Slough-Liberty Island region. A second turbidity simulation was performed without the internal turbidity boundary conditions for comparison. A more detailed discussion on the internal boundary conditions for turbidity modeling is presented in a separate document.

12.1.4 WARMF Model

The WARMF model forecast output was delivered to RMA December 16. The WARMF output boundary conditions included flow, turbidity and EC for the period November 1 through December 29, 2011. A separate set of turbidity, EC and particle tracking simulations were performed using the WARMF turbidity and EC boundary conditions. These simulations maintained the previous set of flow boundary conditions listed in Table 12-1. The WARMF turbidity run included the “internal” boundary condition for the Sacramento River at Mallard Island. The internal boundary condition for the Cache-Ryer location was not applied for the WARMF turbidity run as this would override the WARMF derived Yolo boundary condition.

12.1.5 Flow and Turbidity Model Results

Boundary inflow was low during this period as there have been no recent rain events, and turbidity measurements indicate suspended sediment loading from the watersheds is very low. Depending on time and location within the Delta, measured turbidity was instead partly due to resuspension of sediments due to tidal action and/or wind events. Turbidity was low throughout the Delta, ranging from about 5 - 25 NTU in the raw data. Turbidity data was noisy at many locations, which was particularly evident as turbidity values were so low.

These types of conditions - low boundary inflow and low watershed sediment loading with in-Delta turbidity due to sediment resuspension - are outside the current turbidity model design as turbidity is being modeled not suspended sediment. Additionally, the turbidity model calibration was optimized for high flow conditions with substantial loading from the watersheds, conditions that are hypothesized to lead to movement of delta smelt into the interior of the Delta as they follow flow and turbidity cues.

Flow and turbidity BC are illustrated in Figure 12-2 through Figure 12-8, while Figure 12-9 through Figure 12-12 illustrate export levels and Old+Middle River flows. Using information supplied by O&M for historical and forecast State (SWP) and Federal (CVP) exports, Figure 12-9 illustrates that daily-averaged exports decreased from a maximum of ~13,000 cfs in early November to ~ 2,000 cfs by the end of November, then increased to ~11,000 cfs starting in early December to December 24. On December 24, CVP pumping was reduced to 2,500 cfs for the remaining forecast period. Banks pumping was reduced to 2,500 cfs beginning January 1, 2012 leading to reduced Clifton Court Forebay inflows near the end of the forecast period. Figure 12-10 and Figure 12-11 are plots of Old River and Middle River flows and daily-averaged flows, respectively, while Figure 12-12 illustrates the combined Old+Middle River flow criterion (3-day center-weighted average) compared with CDEC data.

Figure 12-13 is a comparison of model output and data at the three compliance locations, and Figure 12-14 is a similar plot in the SWP export area. Note that Figure 12-64 is a comparison of data inside Clifton Court Forebay with model output at the entrance to the Forebay. For these two figures, data were cleaned (noisy values removed) and missing data filled with linear approximation. The cleaned and filled data were also daily averaged for comparison with daily-averaged model output.

Turbidity was below compliance values (12 NTU) at two of these three locations. At Holland Cut, the turbidity went above the compliance value for several days in early December, almost certainly due to a wind event (see previous forecast report).

Figure 12-15 and Figure 12-16 illustrate the progression of the main turbidity boundary conditions at Freeport and Vernalis down the Sacramento and San Joaquin Rivers, respectively. Figure 12-17 through Figure 12-23 are plots of model output compared with raw CDEC turbidity data at several in-Delta locations - these locations can be found on a map of the Delta in Figure 12-24. The turbidity model captured the very low measured turbidity in the south and central Delta (see, for example Figure 12-22 and Figure 12-23).

The use of the internal boundary conditions at Mallard Island and Cache Slough at Ryer Island greatly improves the model vs. CDEC data turbidity along the Sacramento River mainstem at Rio Vista and downstream at Decker Island (Figure 12-18 and Figure 12-19, respectively). The turbidity peaks at Decker Island in the CDEC data occur during the flood tide period indicating a downstream source. These peaks are also present in the computed result though generally underestimated.

A separate turbidity model run was performed using the WARMF turbidity boundary conditions. The WARMF turbidity boundary conditions are shown plotted with the CDEC data derived boundary conditions in used in the above results in Figure 12-25 to Figure 12-30. Model turbidity results for the compliance locations and the SWP export area are shown in Figure 12-31 and Figure 12-32 respectively. Figure 12-33 through Figure 12-39 present model turbidity at the six Delta locations for the WARMF turbidity boundary condition run.

12.1.6 Adult Delta Smelt Particle Tracking Model Results

Figure 12-41 through Figure 12-44 present the turbidity contour plots and particle tracking model results for the runs using the data derived turbidity and EC boundary conditions listed Table 12-2 and Table 12-3. The Delta Smelt behavioral model was run November 01, 2011 to January 03, 2012 - 50,000 particles were inserted on November 01. Figure 12-41 through Figure 12-44 show contour plots of RMA-modeled turbidity (left plot) with particle tracking model results (right plot). These plots illustrate that just prior to and during the forecast period, modeled turbidity in the Delta was very low. The delta smelt behavioral model results illustrate that the distribution of the particles is centered along the Sacramento River and the region at the confluence with the San Joaquin River. A few particles stray into the central Delta after Jan 01. However, no particles reached the export locations by the end of the simulation.

A similar set of turbidity contour plots and particle tracking are shown in Figure 12-45 through Figure 12-47 for the model runs using the WARMF turbidity and EC boundary conditions. The WARMF forecast period ended Dec 29, thus no plot is presented for the Jan 03, 2012 date.

12.1.7 MWD Training

Model input files and results were provided to Dr. Chuching Wang for remote access on the RMA intranet.

12.1.8 List of Acronyms:

WY ~ Water Year
SWP ~ State Water Project
CCFB ~ Clifton Court Forebay
CNRFC ~ California-Nevada River Forecasting Center
CDEC ~ California Data Exchange Center
CIMIS ~ California Irrigation Management System

CDEC Stations:
FPT ~ Freeport
MAL~ Sacramento River at Mallard Island
RYI ~ Cache Sl. at Ryer Island
SMR ~ South Fork Mokelumne River
MRZ ~ Martinez
VNS ~ Vernalis
DSM2 Boundary Locations:
RMKL070 ~ Mokelumne River
RCSM075 ~ Cosumnes River
RCAL009 ~ Calaveras River
RSAN112 ~ San Joaquin River
BYOLO040 ~ Yolo Bypass
RSAC054 ~ Martinez

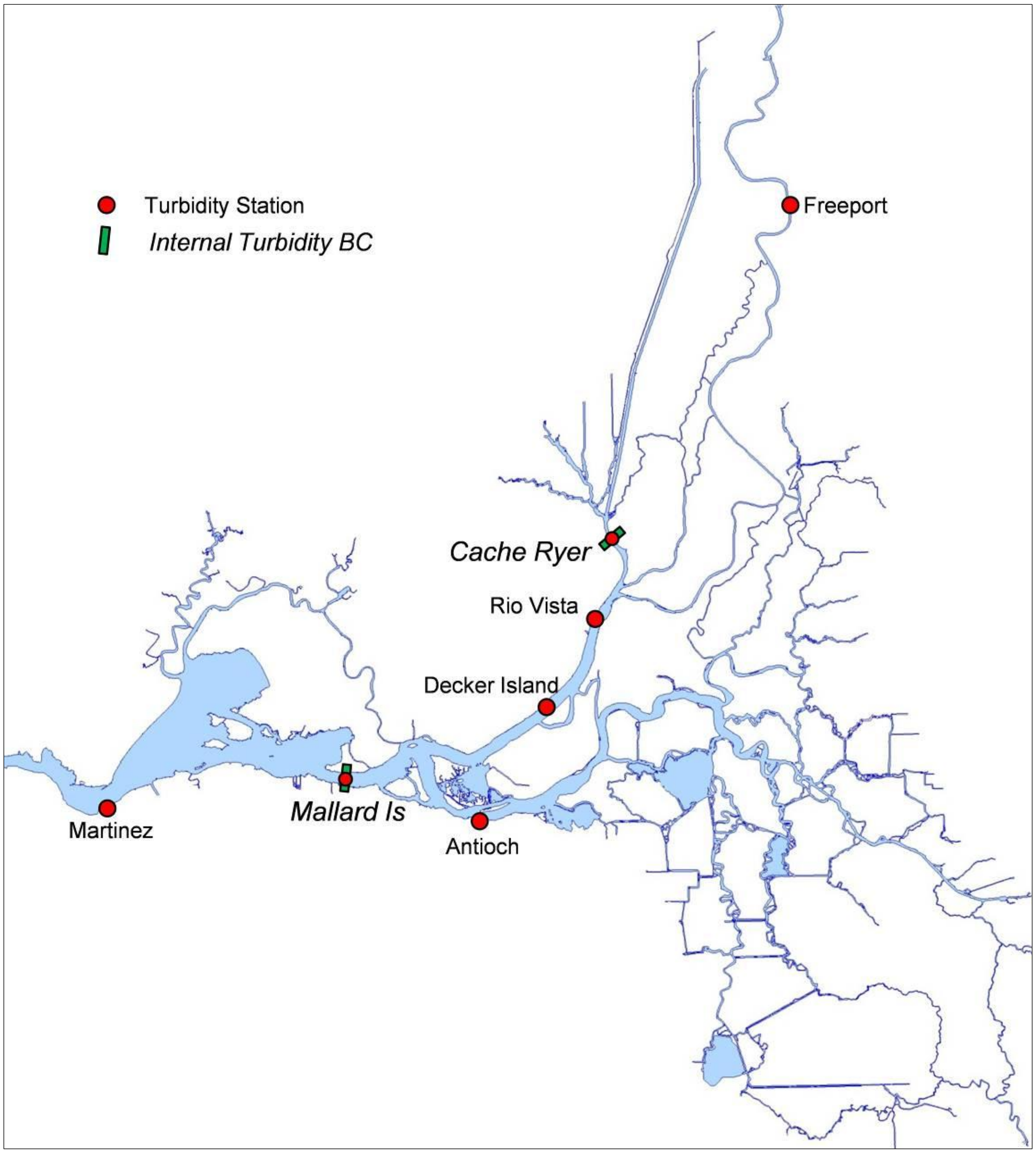

Figure 12-1 Locations of the internal turbidity boundary conditions added in the current turbidity forecast model run. The internal boundary conditions are located at the Sacramento River at Mallard Island and Cache Slough at Ryer Island.

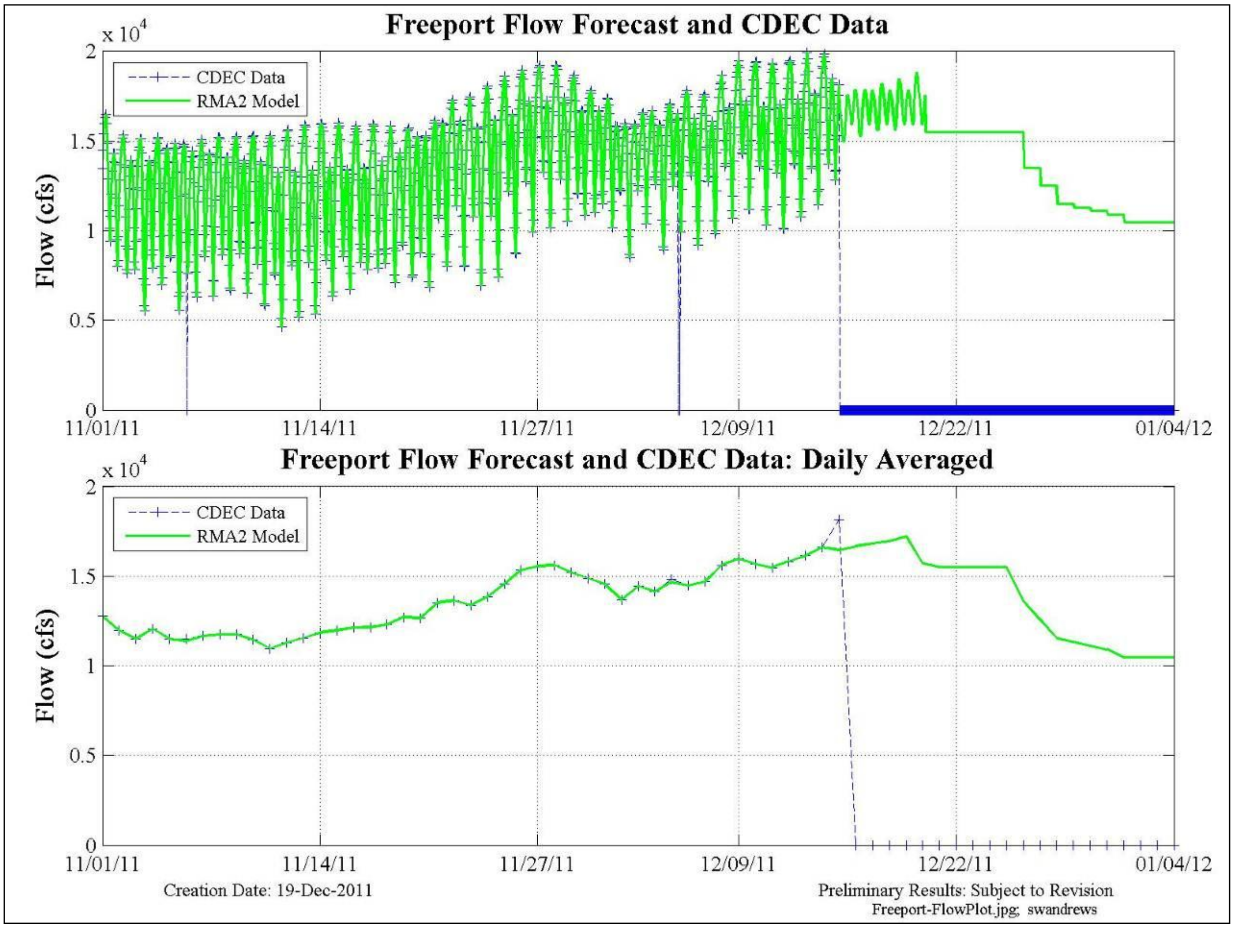

Figure 12-2 Freeport flow BC was compiled using CDEC data, CNRFC forecast and then extended as a constant. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue).

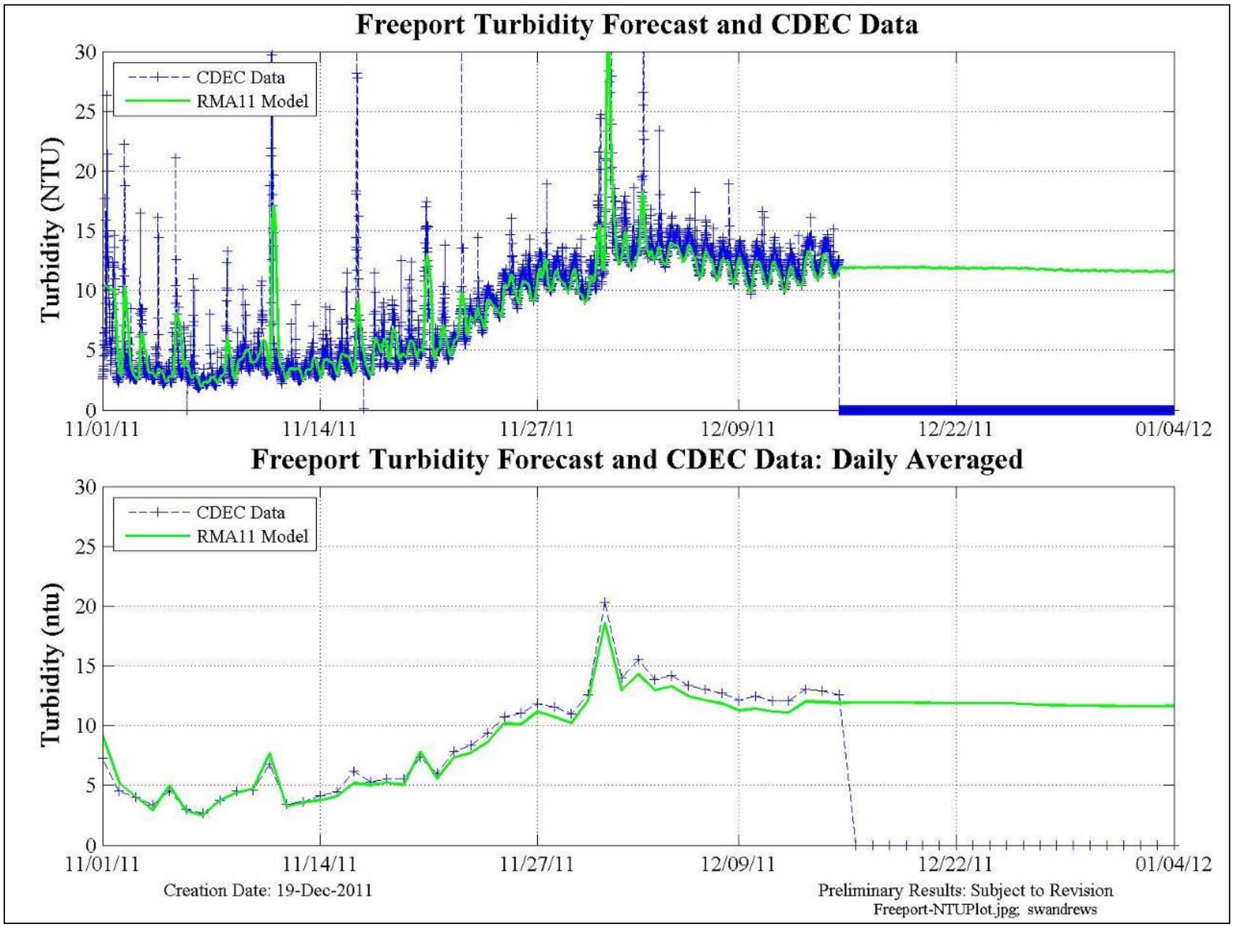

Figure 12-3 Freeport turbidity BC was compiled using CDEC data, and then extended as a constant. Zero values indicate the end of data (blue).

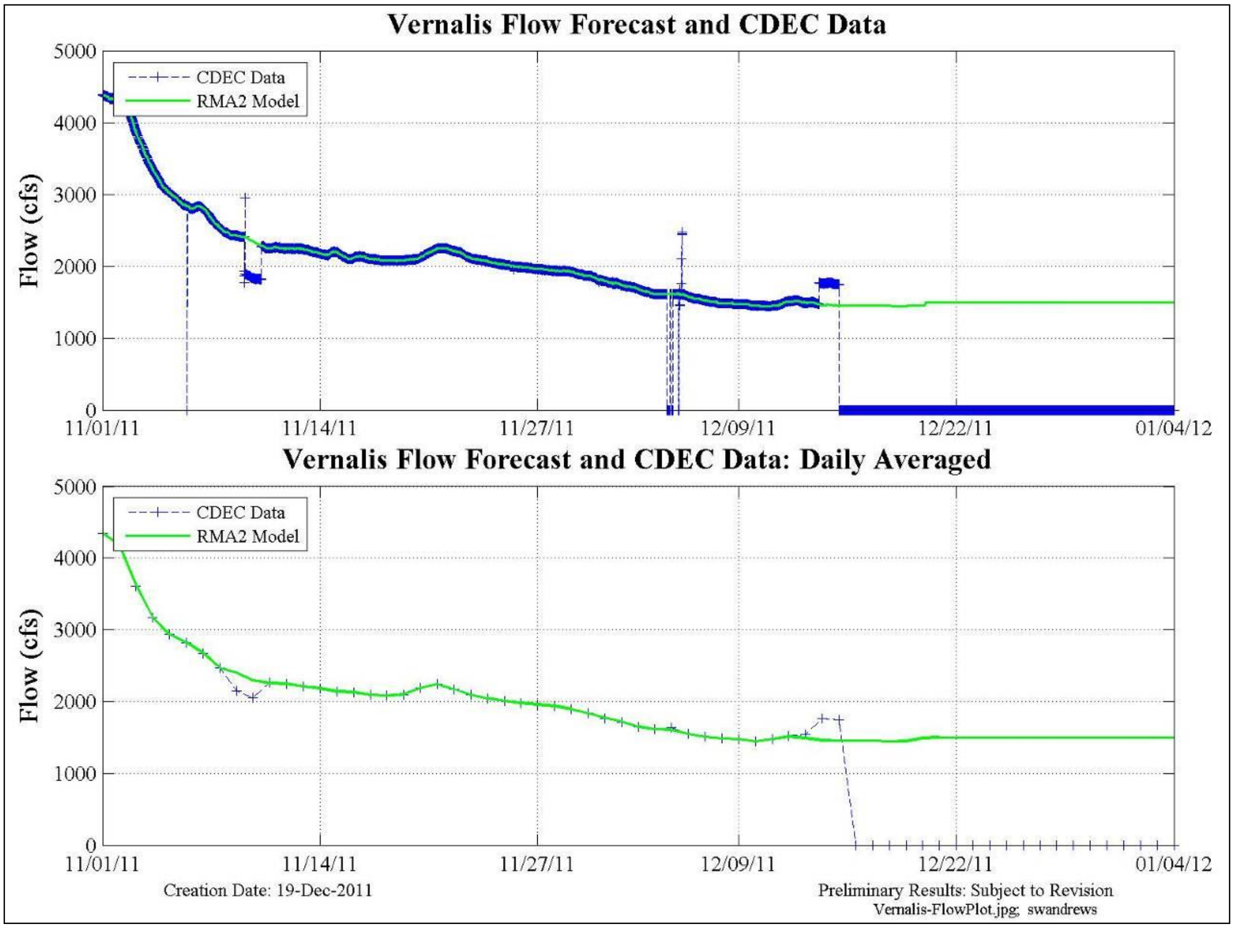

Figure 12-4 Vernalis flow BC was compiled using CDEC data and DWR forecast flow. Zero values indicate the end of data (blue).

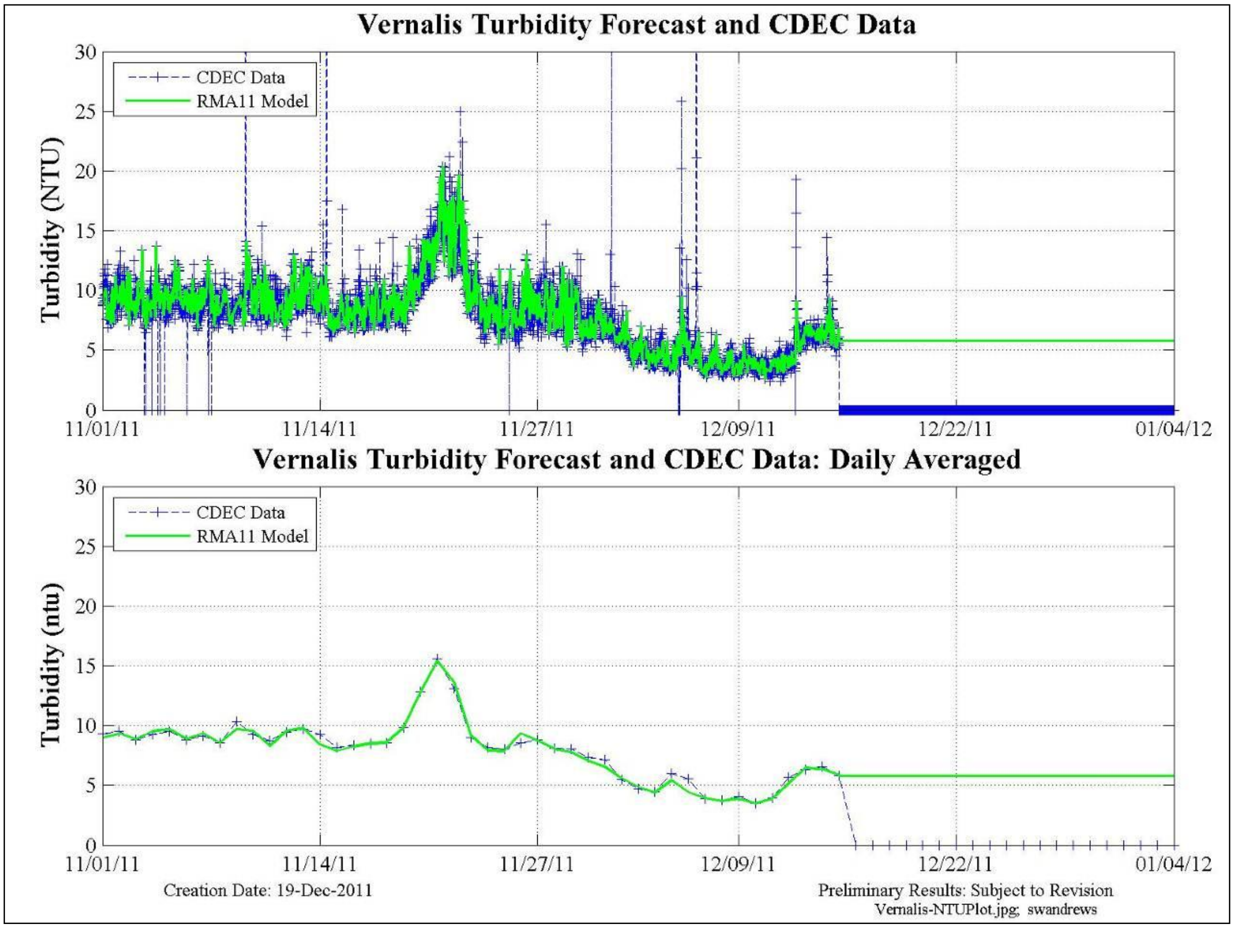

Figure 12-5 Vernalis turbidity BC was compiled using CDEC data, then extended as a constant. Zero values indicate the end of data (blue).

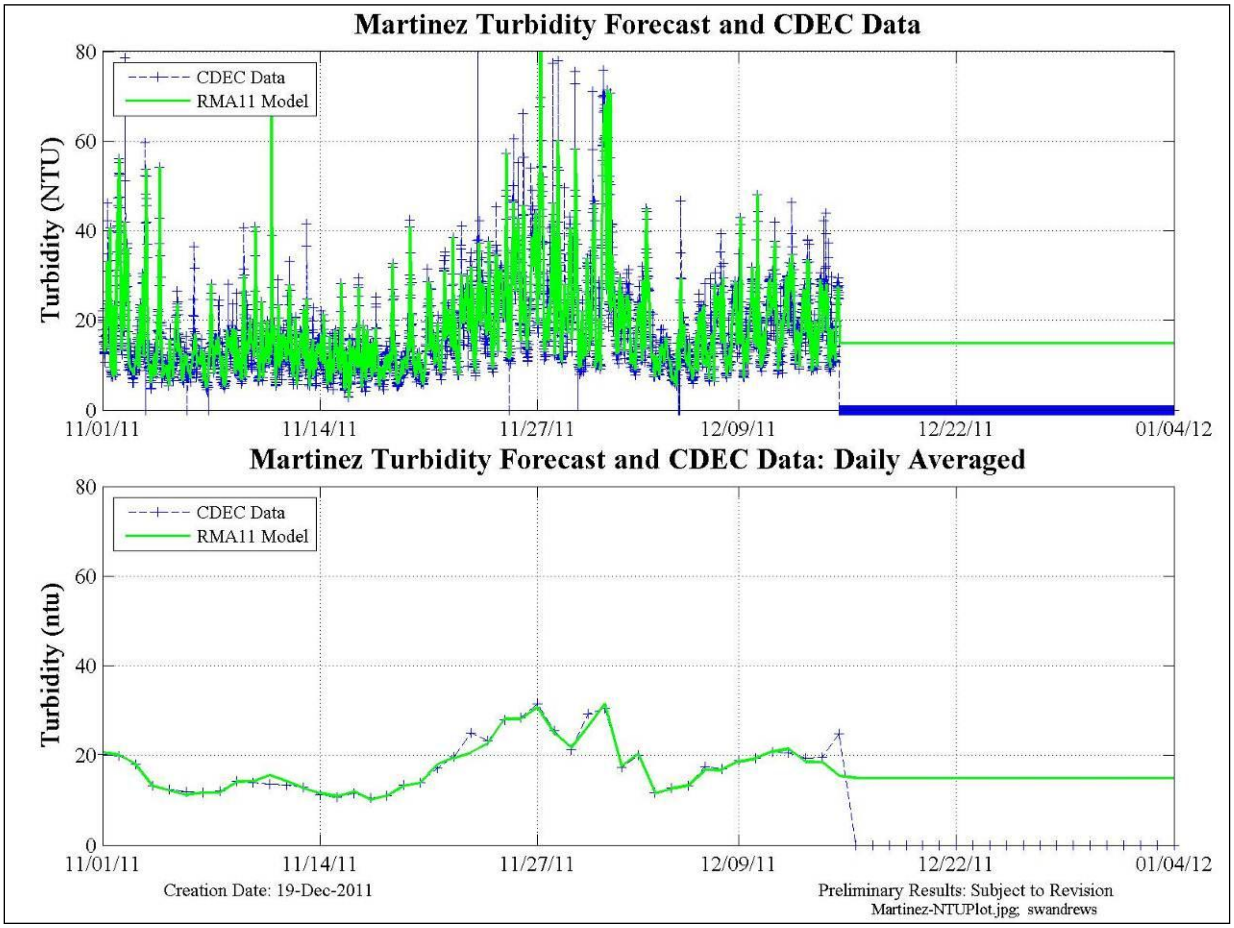

Figure 12-6 Martinez turbidity BC was compiled from CDEC data then extended linearly to a value of 15 NTU. Zero values indicate the end of data (blue).

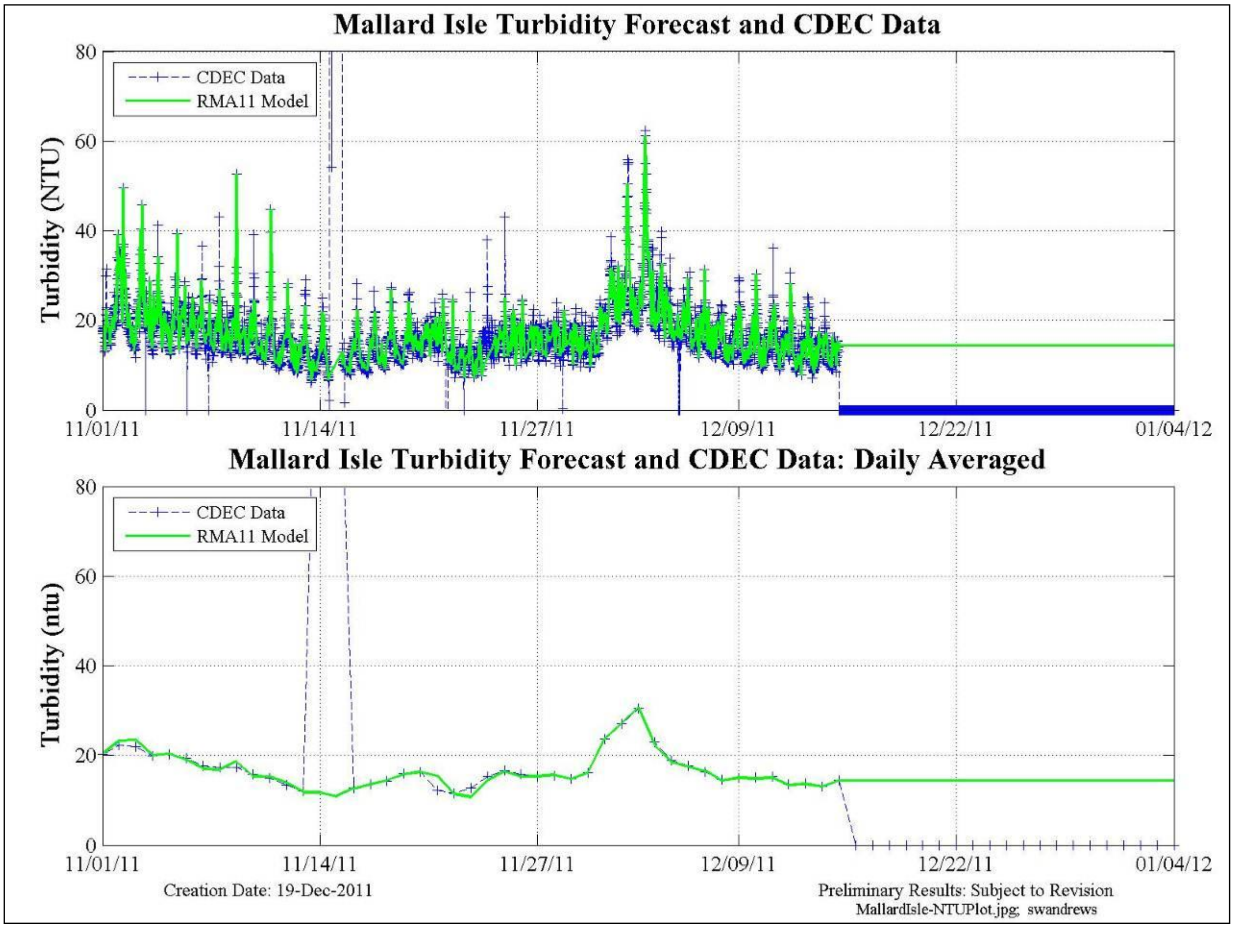

Figure 12-7 The Sacramento River at Mallard Island internal turbidity BC compiled from CDEC data then extended linearly to a value of 14.4 NTU. Zero values indicate the end of data (blue).

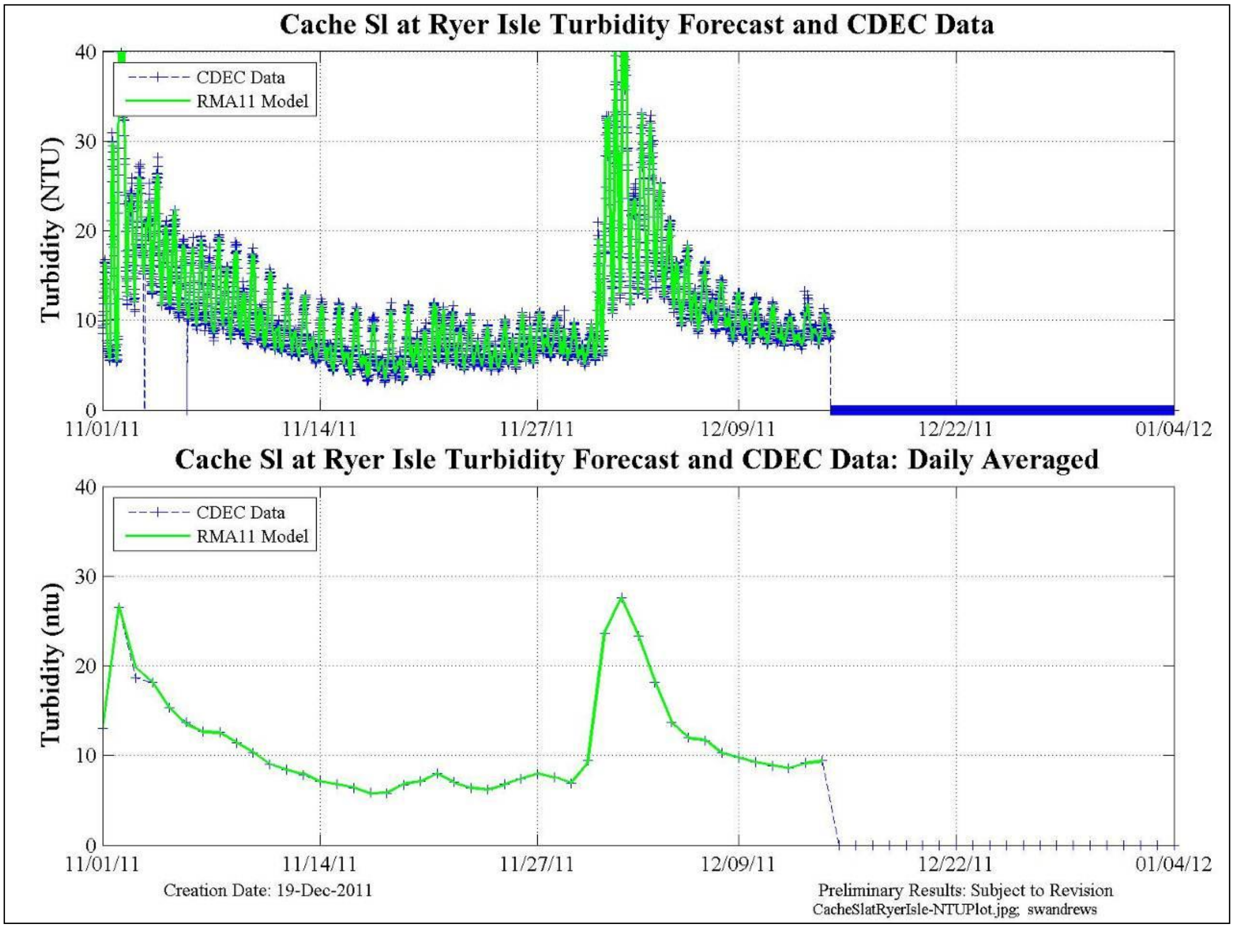

Figure 12-8 The Cache Slough at Ryer Island internal turbidity BC compiled from CDEC data. The boundary condition was not applied beyond the end time of the observed data. Zero values indicate the end of data (blue).

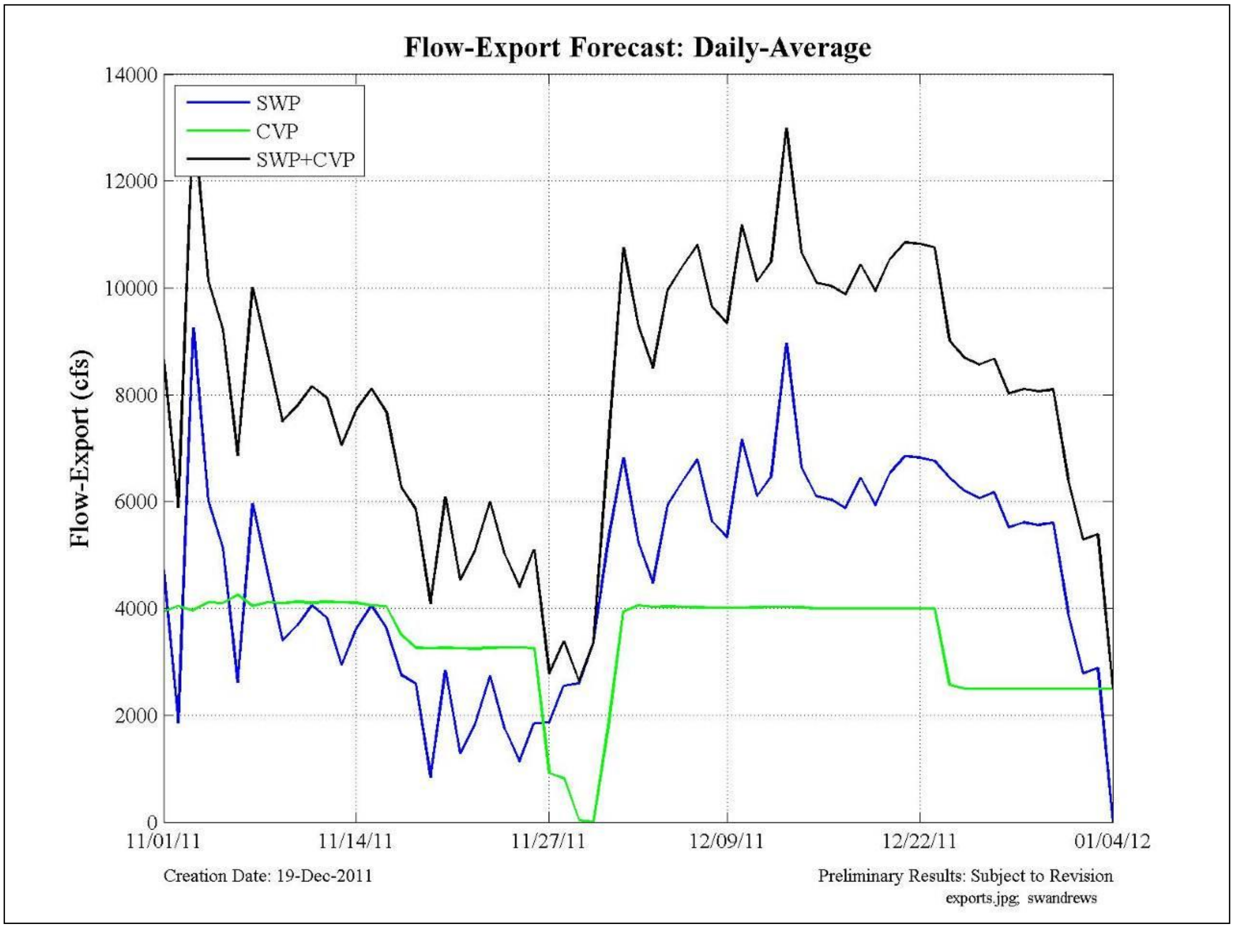

Figure 12-9 The plot illustrate modeled daily-averaged exports at the SWP and CVP) export locations, and the combined SWP+CVP exports.

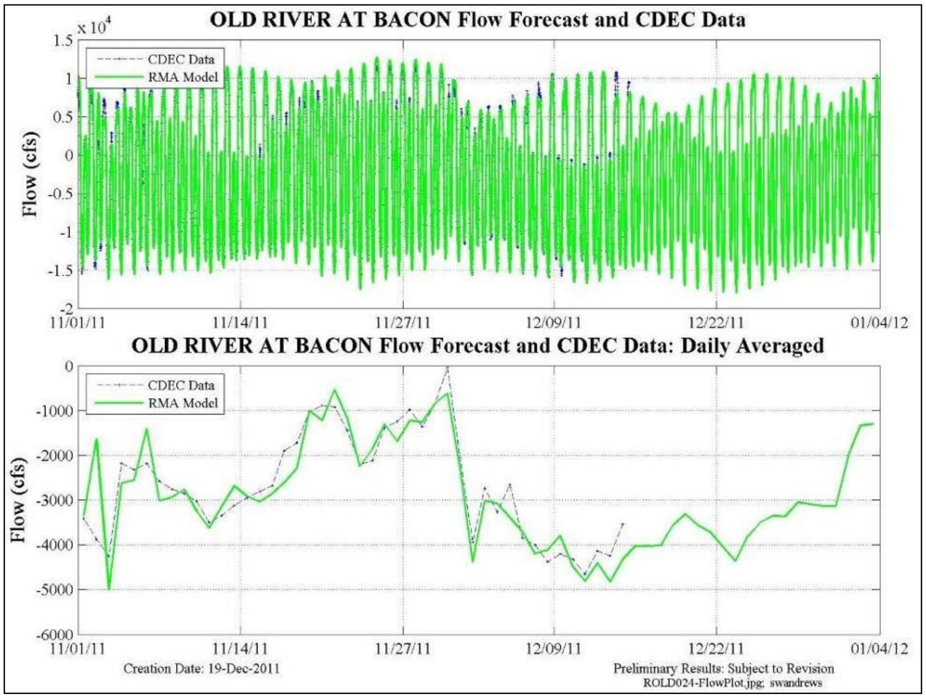

Figure 12-10 Model flow forecast output and raw CDEC data at Old River at Bacon (ROLD024) location. Both 15-min (upper) and daily averaged (lower) plots are shown.

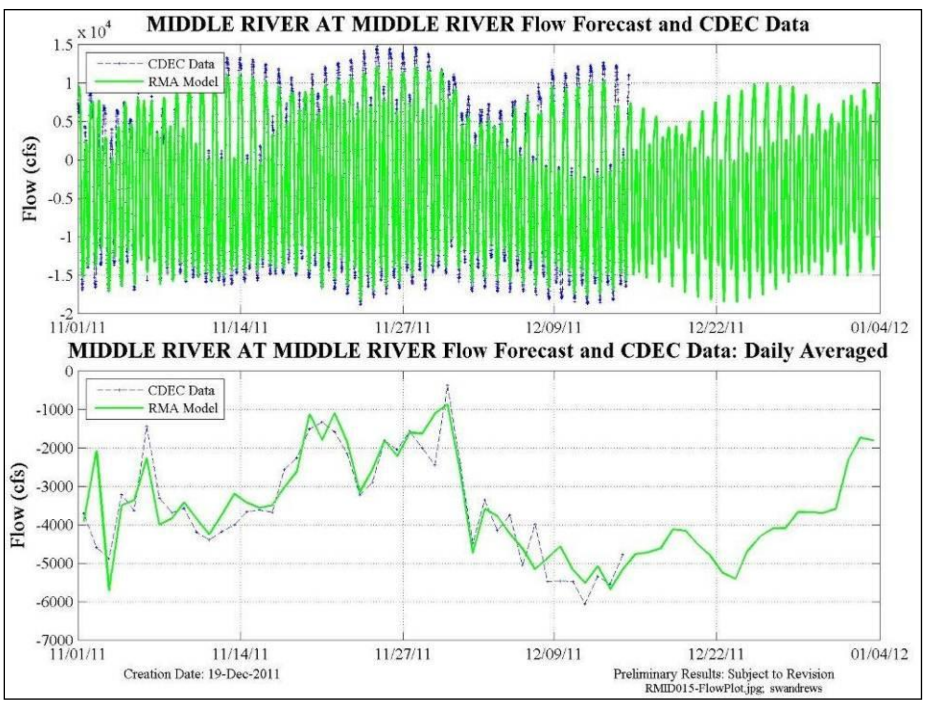

Figure 12-11 Model flow forecast output and raw CDEC data the Middle River-at-Middle (RMID015) location. Both 15-min (upper) and daily averaged (lower) plots are shown.

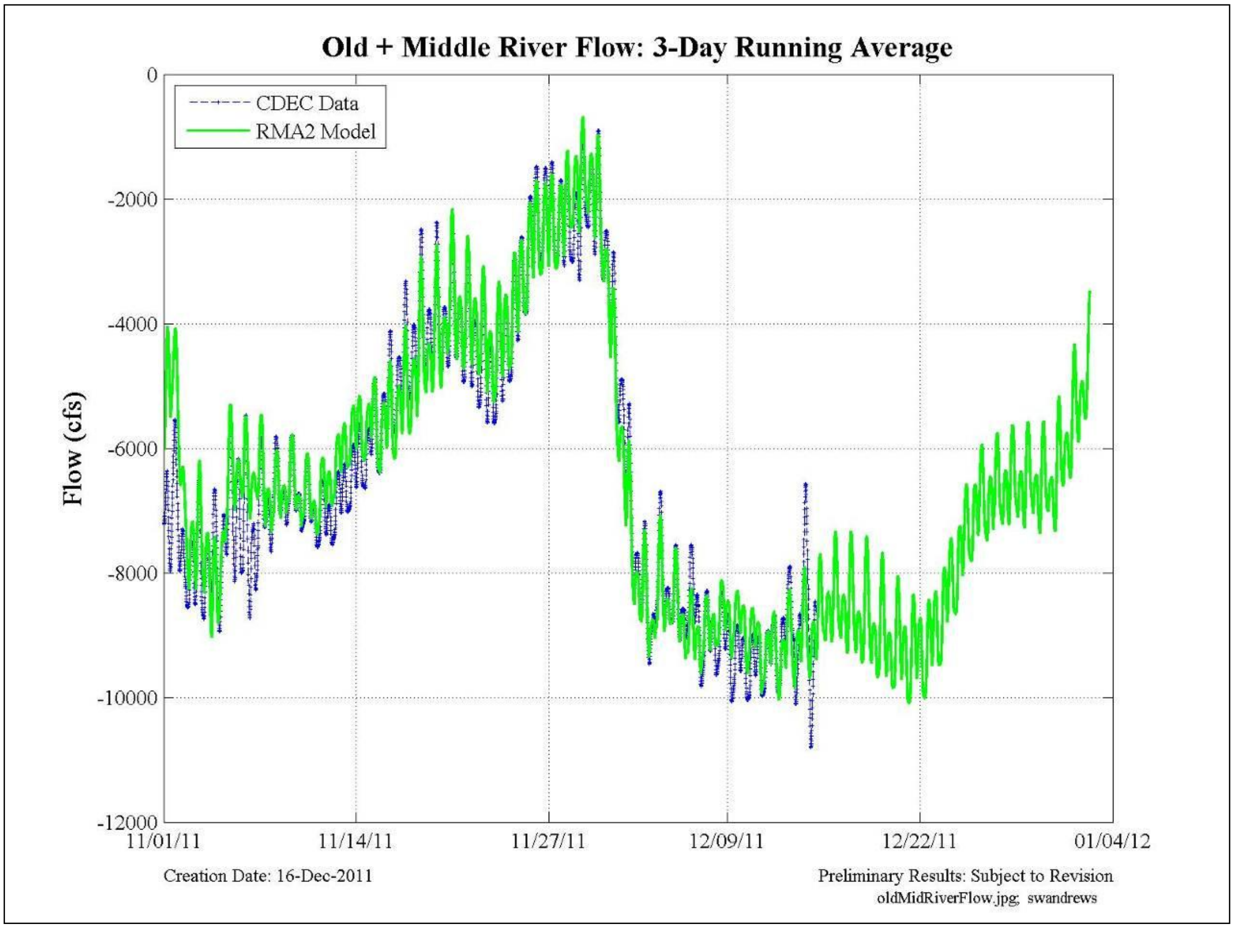

Figure 12-12 Model flow forecast output and raw CDEC data for the Old+Middle River flow criterion for three-day running-average flow.

Table 12-1 Boundary condition development for flow for this forecast period.

December 15, 2011	Historical DWR BC	Definition Historical Flow	Definition Forecast Flow	Comment
BC Location				
Yolo Bypass	Not used	Hourly CDEC LIS stage, cleaned+filled, converted flow	Hourly CNRFC forecast (Yolo at Lisbon) for 5 days, Daily DSM2 BYOLO040 after	Stage-discharge rating table from CNRFC
Sacramento River at Freeport	Not used	Hourly CDEC FPT, cleaned+filled	Hourly CNRFC forecast (Sac R at I St.) for 5 days, Daily DSM2 RSAC155 after	
Mokelumne River	Daily DSM2 RMKL070, converted to hourly	Not used	Daily DSM2 RMKL070, converted to hourly	
Cosumnes River	Not used	Hourly CNRFC Cosumnes-McConnell, cleaned+filled	Hourly CNRFC forecast (Cosumnes R at McCon) for 5 days, Daily DSM2 RCSM075 after	
Calaveras River	Not used	Hourly CDEC MRS, cleaned+filled	Daily DSM2 RCAL009, converted to hourly	
San Joaquin River at Vernalis	Not used	Hourly CDEC VNS, cleaned+filled	Hourly CNRFC forecast (SJ R at Vernalis) for 5 days, Daily DSM2 RSAN112 after	
Stage - Martinez	Not used	15min CDEC MRZ, cleaned+filled	15min DSM2 RSAC054 (hydro.dss)	

Table 12-2 Boundary condition development for turbidity for this forecast period.

December 15, 2011	Definition Historical NTU	Definition Forecast NTU	Comment
BC Location			
Yolo Bypass	15min CDEC RYI, cleaned+filled, hourly averaged	extend as constant	
Cache Slough at Ryer internal bc	15min CDEC RYI, cleaned+filled, hourly averaged	not applied	
Sacramento River at Freeport	15min CDEC FPT, cleaned+filled, hourly averaged	extend as constant	Shifted 15hrs back in time (optimal shift for low Sac flow)
Mokelumne River	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	extend as constant	Daily-avg to remove tidal variation
Cosumnes River	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	extend as constant	Daily-avg to remove tidal variation
Calaveras River	15min CDEC RRI, cleaned+filled, hourly averaged	extend as constant	
San Joaquin River at Vernalis	15min CDEC SJR, cleaned+filled, hourly averaged	extend as constant	
Sacramento River at Mallard Island internal bc	15min CDEC MAL, cleaned+filled, hourly averaged	extend as constant	
Martinez	15min CDEC MRZ, cleaned+filled, hourly averaged	extend as constant	

Table 12-3 Boundary condition development for EC for this forecast period.

December 8, 2011	Historical DWR BC	Definition Historical EC	Definition Forecast EC	Comment
BC Location				
Yolo Bypass	Not used	15min CDEC RYI, cleaned+filled, hourly averaged	extend as constant	
Sacramento River at Freeport	Not used	15min CDEC FPT, cleaned+filled, hourly averaged	extend as constant	Shift back 15 hrs
Mokelumne River	Not used	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	extend as constant	Daily-avg to remove tidal variation
Cosumnes River	Not used	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	extend as constant	Daily-avg to remove tidal variation
Calaveras River	Not used	15min CDEC RRI, cleaned+filled, hourly averaged	extend as constant	tidal variation not removed
San Joaquin River at Vernalis	Not used	15min CDEC SJR, cleaned+filled, hourly averaged	extend as constant	
Martinez	Not used	15min CDEC MRZ, cleaned+filled, hourly averaged	DWR forecast (quality.dss)	

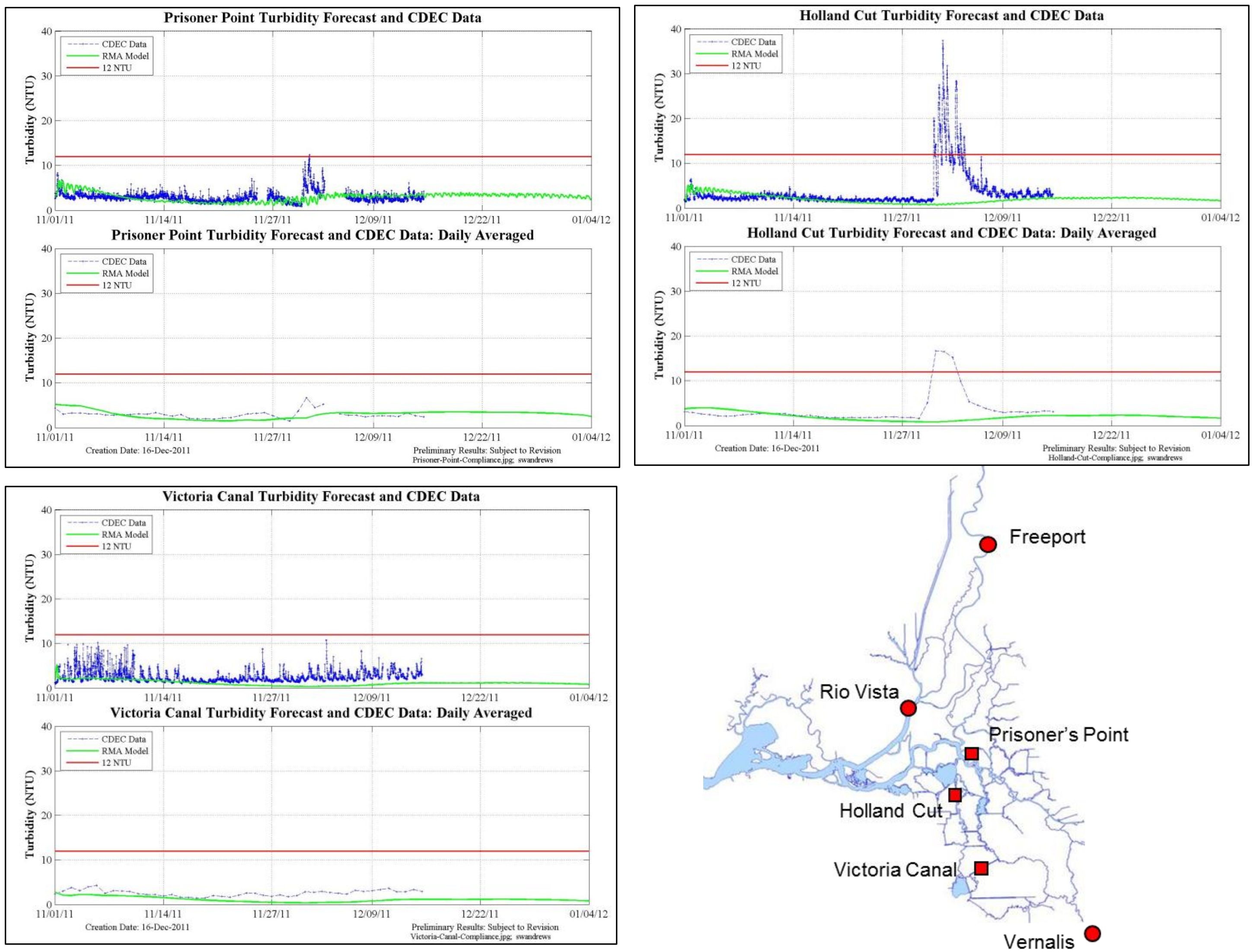

Figure 12-13 Modeled turbidity and data (cleaned and filled) at the three compliance locations. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value.

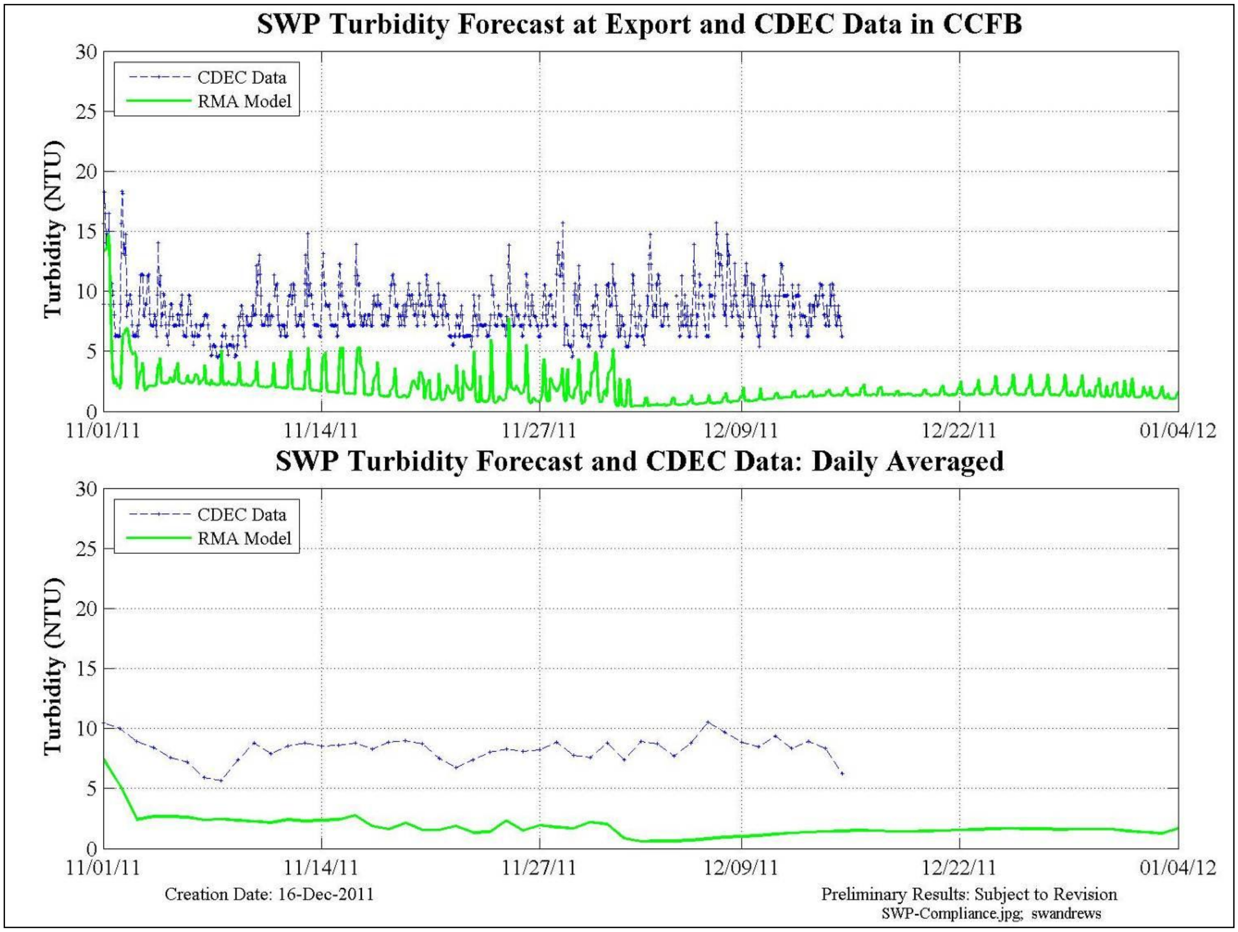

Figure 12-14 Plots compare model output at the SWP export location with data gathered inside Clifton Court Forebay. Both 15-min model output and daily averaged plots are shown.

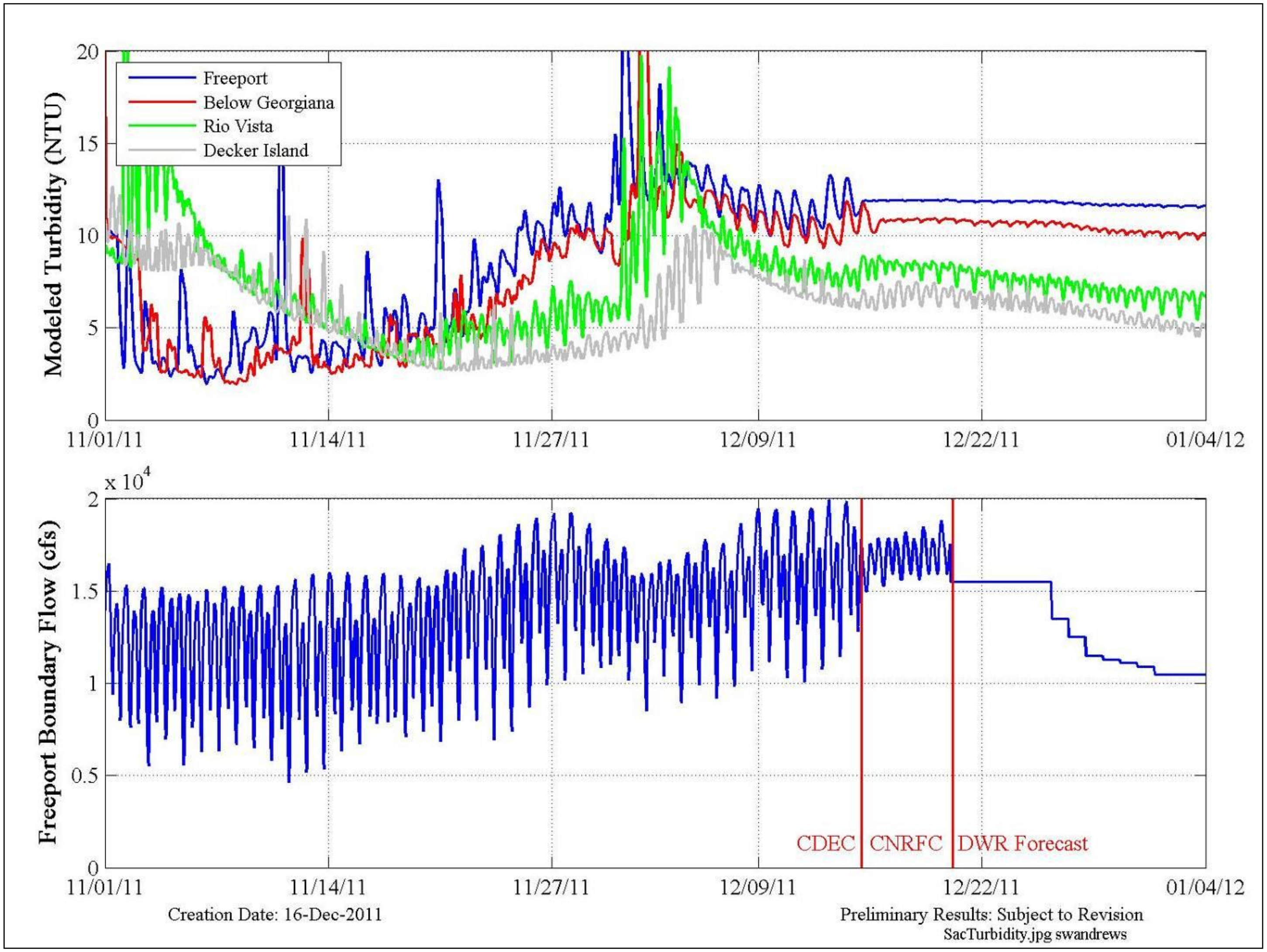

Figure 12-15 Freeport turbidity boundary condition progression down the Sacramento R. (upper plot) along with the flow boundary (lower plot) used during the historical and forecast periods. Forecast began on Dec. 08, 2011.

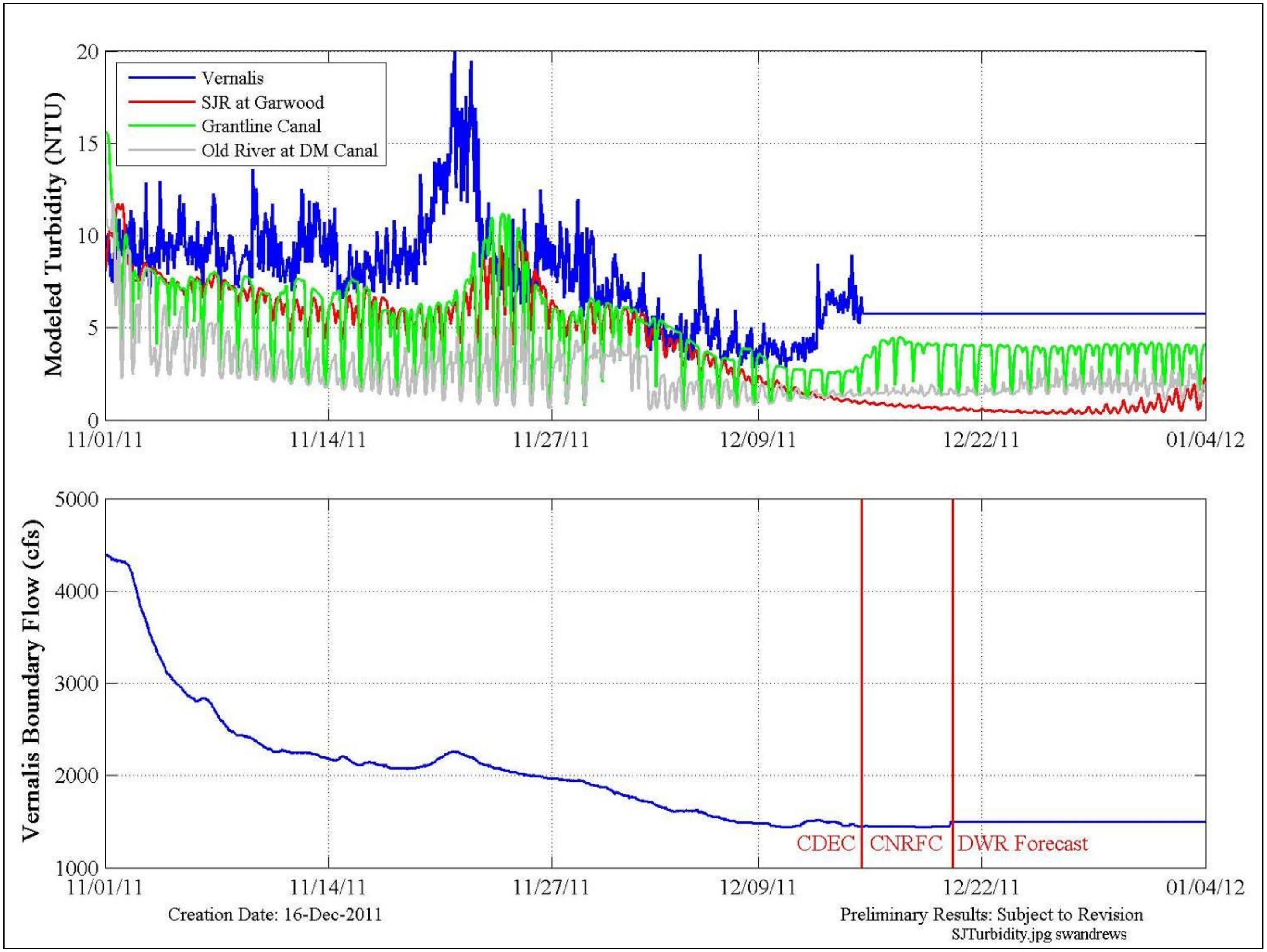

Figure 12-16 Progression of the turbidity boundary condition from Vernalis down the San Joaquin R to Garwood, and down Old River. Vernalis flow forecast periods indicated by red lines (upper plot). Flow boundary conditions at Vernalis are shown in the lower plot.

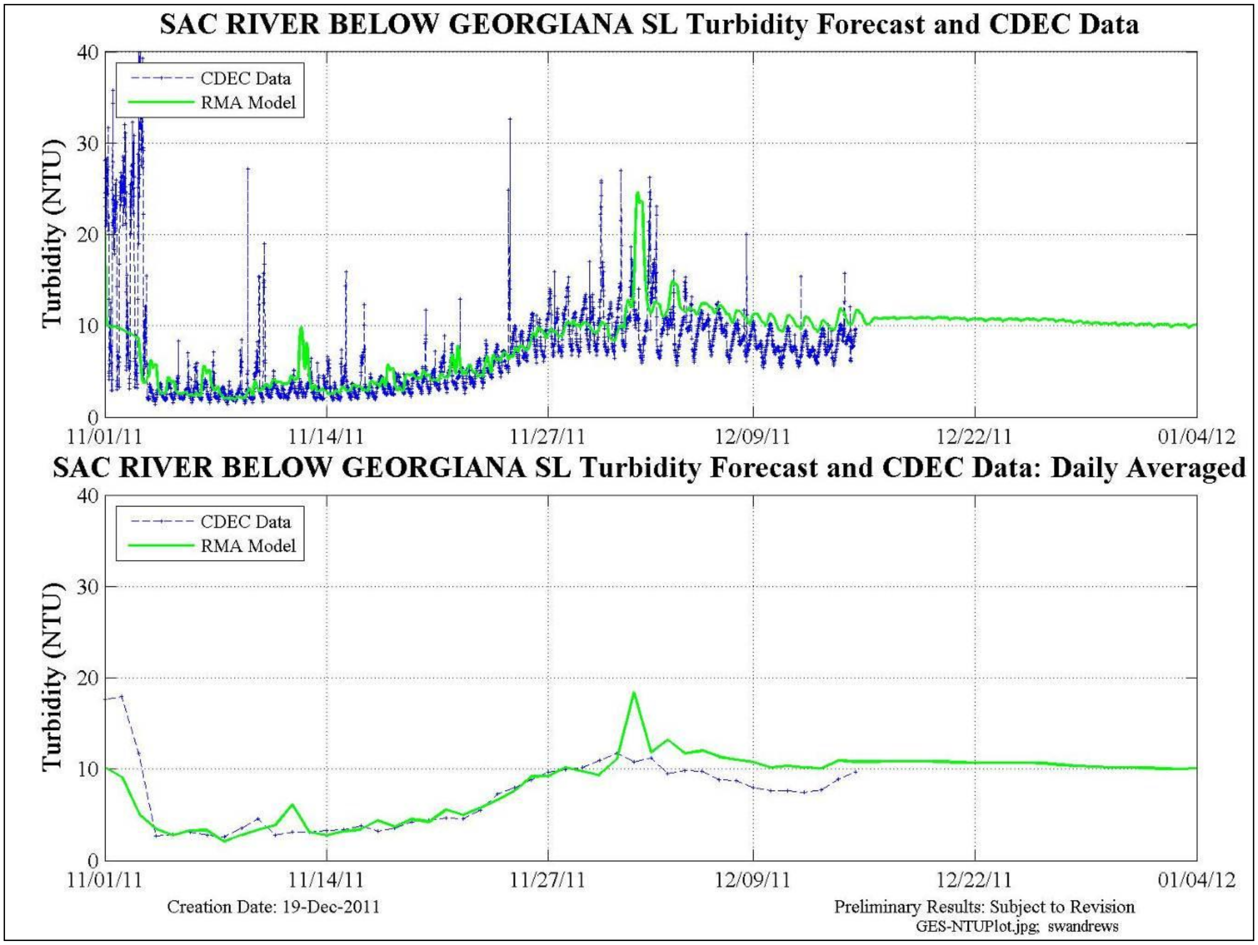

Figure 12-17 Model forecast and raw CDEC data at Sac. River Below Georgiana Sl. Both 15-min (upper) and daily averaged (lower) plots are shown.

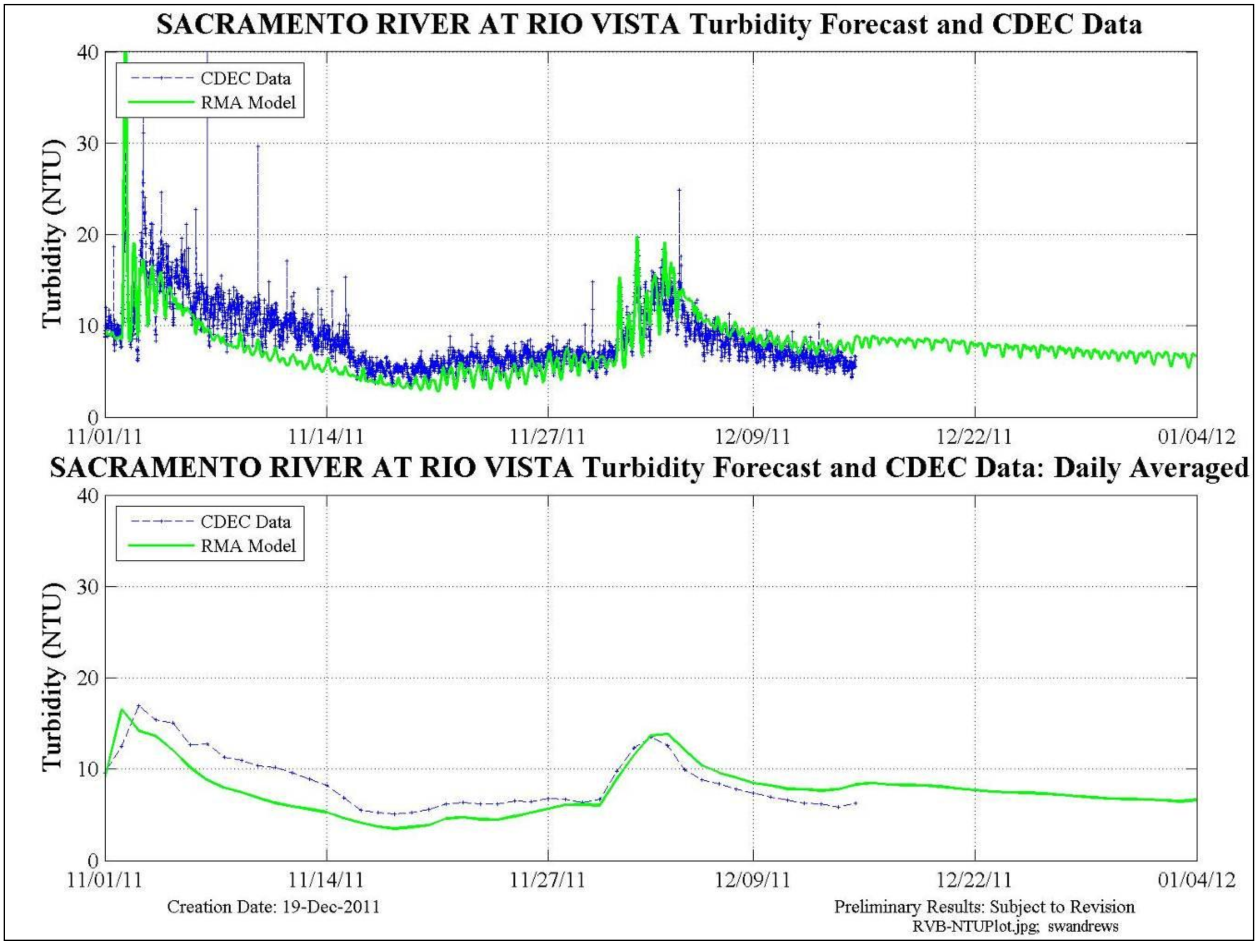

Figure 12-18 Model forecast and raw CDEC data at Rio Vista. Both 15-min (upper) and daily averaged (lower) plots are shown.

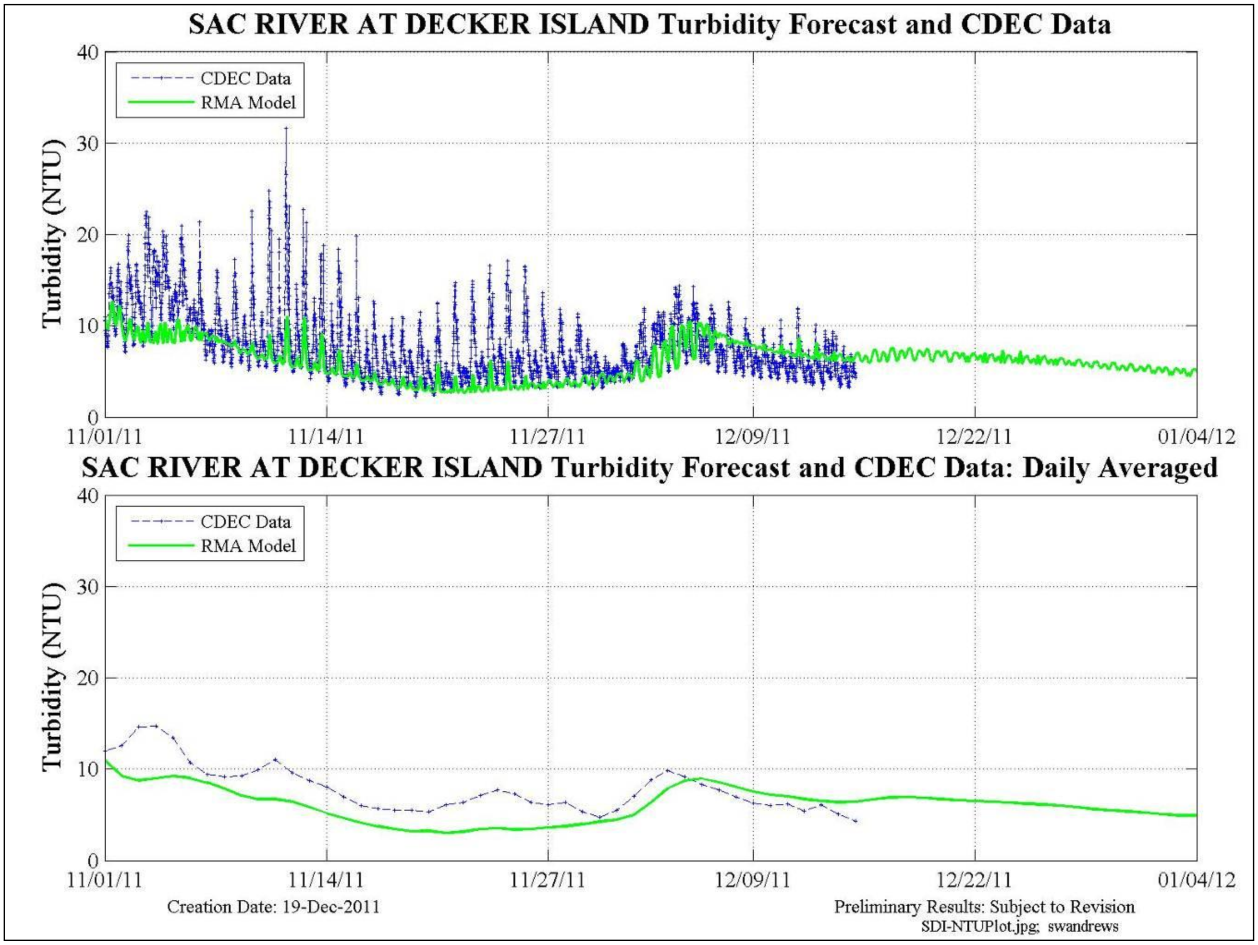

Figure 12-19 Model forecast and raw CDEC data at Decker Island. Both 15-min (upper) and daily averaged (lower) plots are shown.

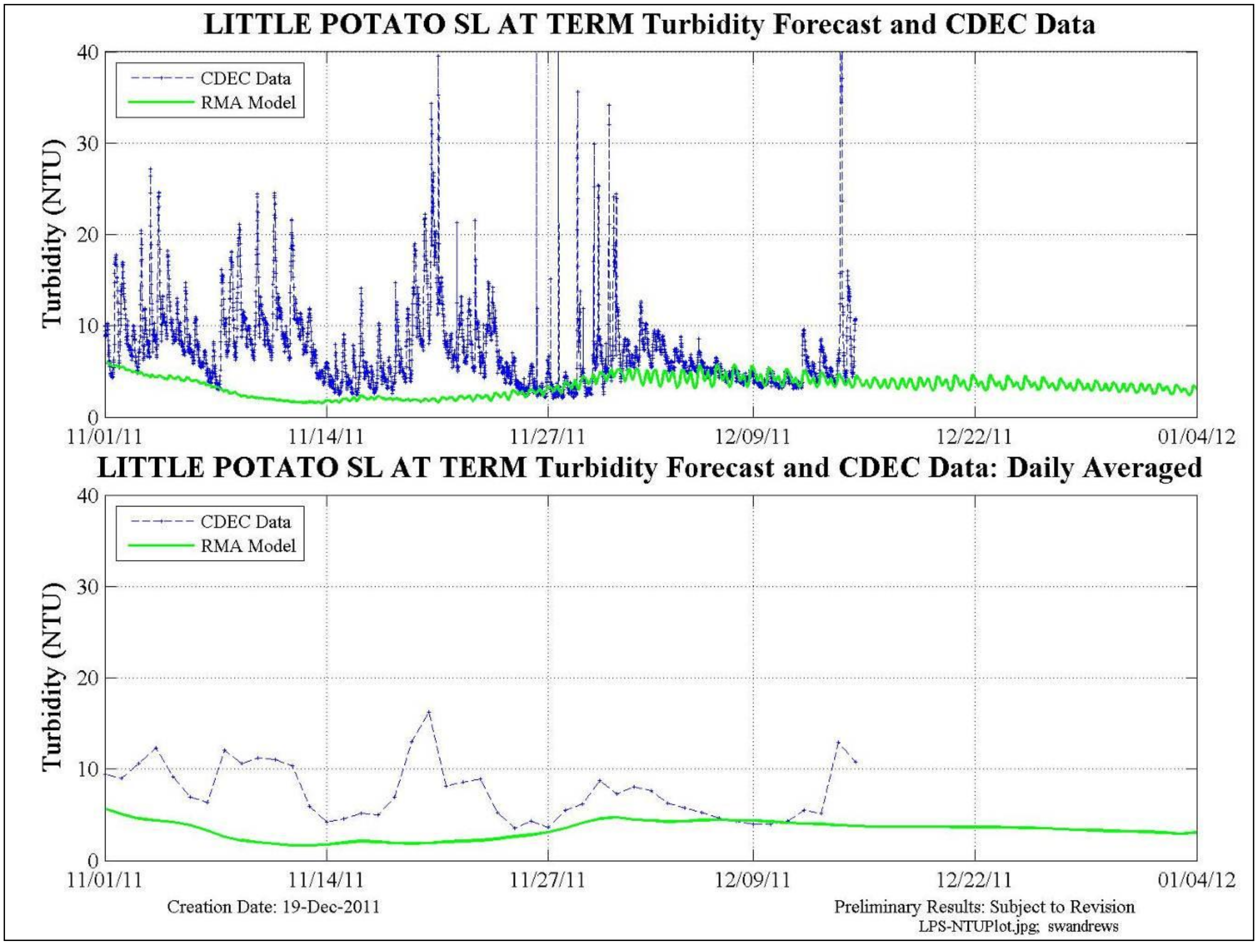

Figure 12-20 Model forecast and raw CDEC data at Little Potato Slough at Terminous. Both 15-min (upper) and daily averaged (lower) plots are shown.

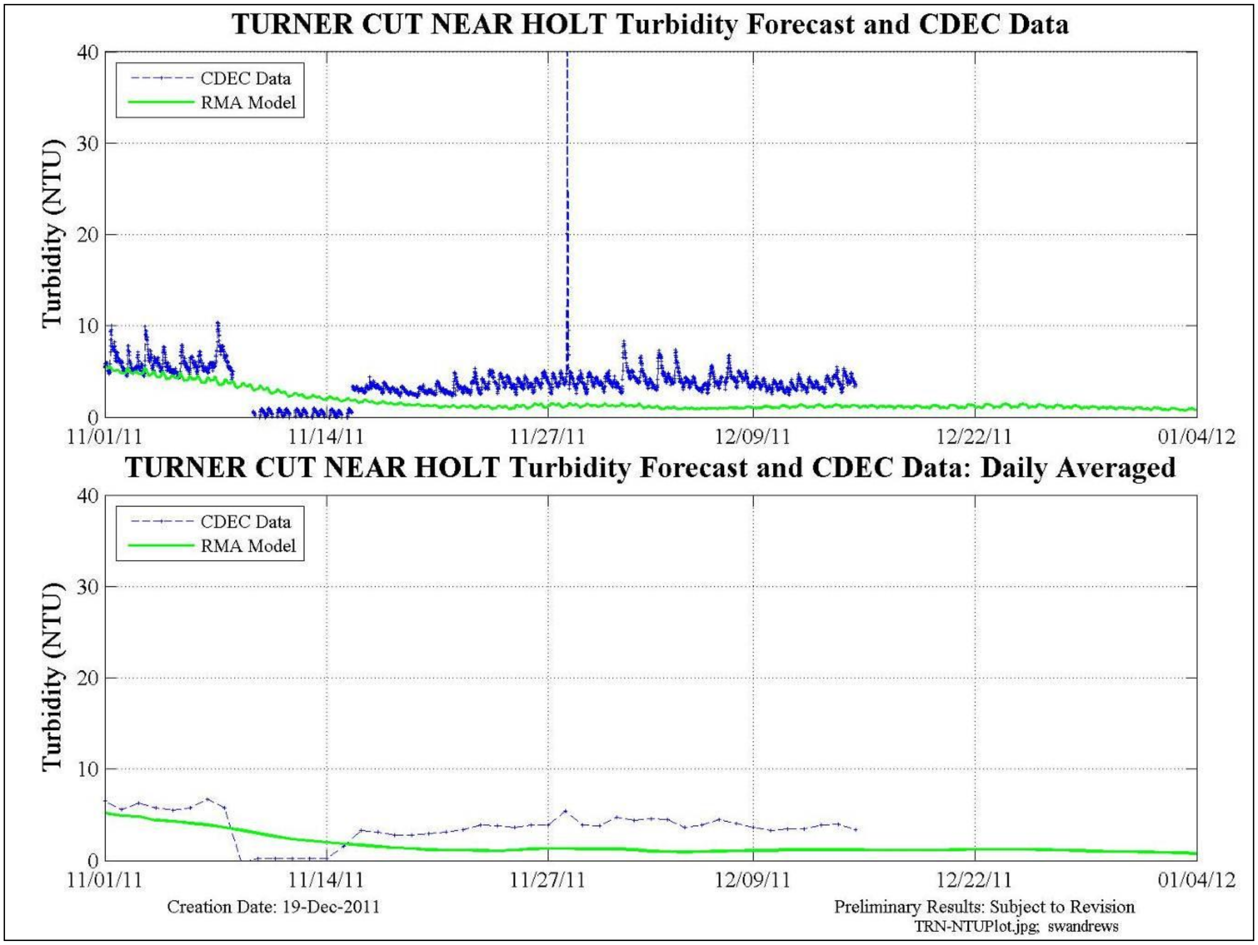

Figure 12-21 Model forecast and raw CDEC data at Turner Cut near Holt. Both 15-min (upper) and daily averaged (lower) plots are shown.

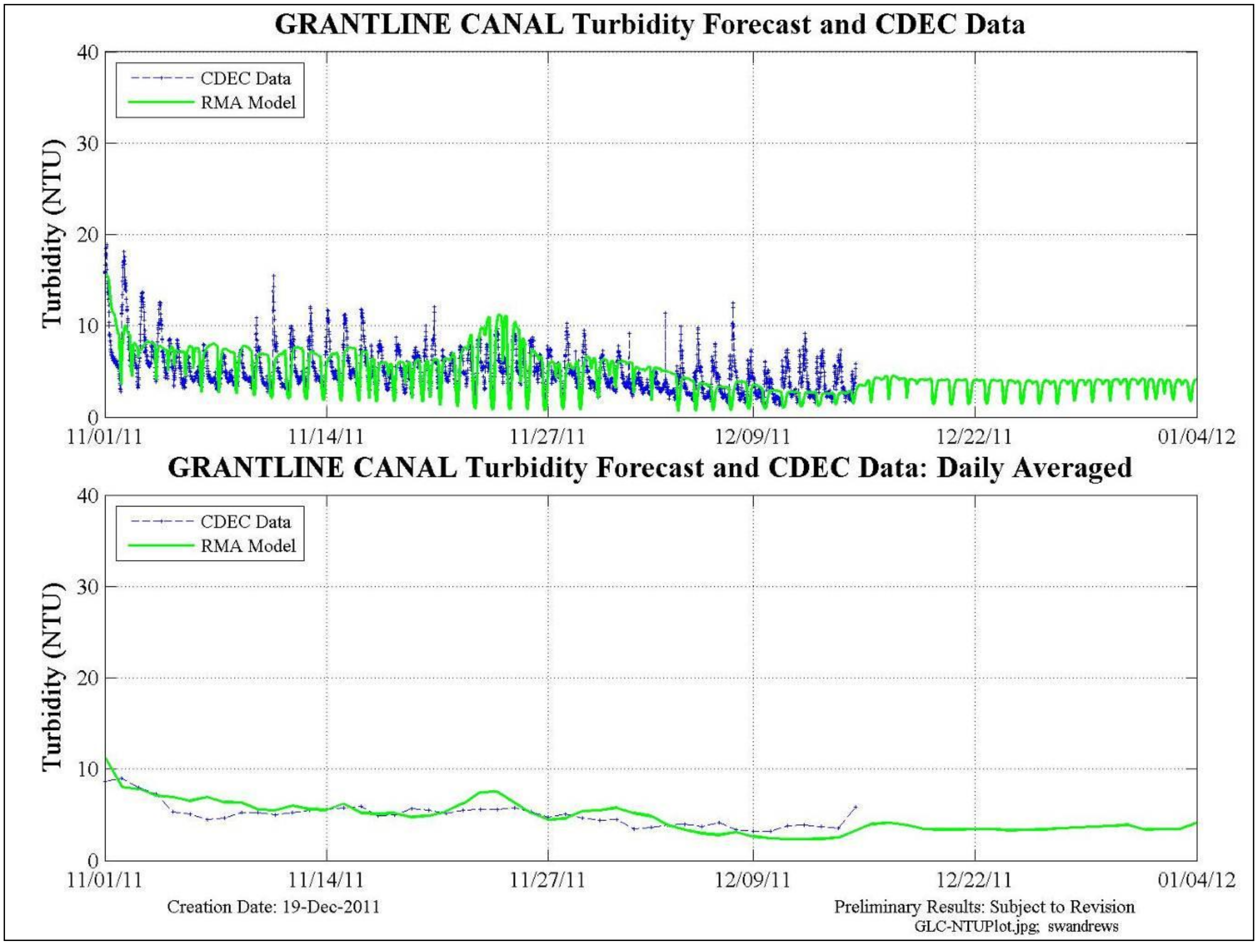

Figure 12-22 Model forecast and raw CDEC data at Grant Line. Both 15-min (upper) and daily averaged (lower) plots are shown.

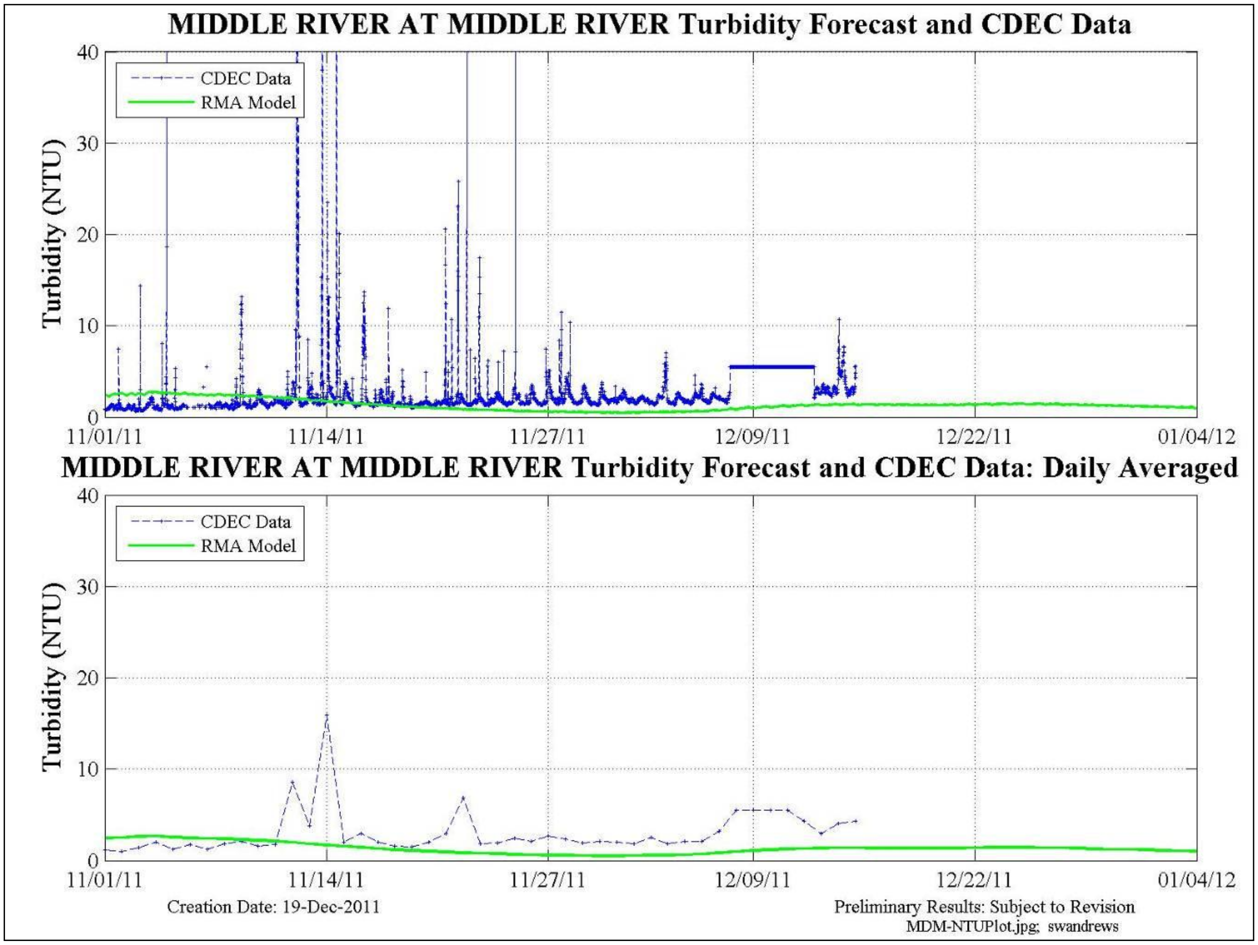

Figure 12-23 Model forecast and raw CDEC data at Middle R. at Middle R. Both 15-min (upper) and daily averaged (lower) plots are shown.

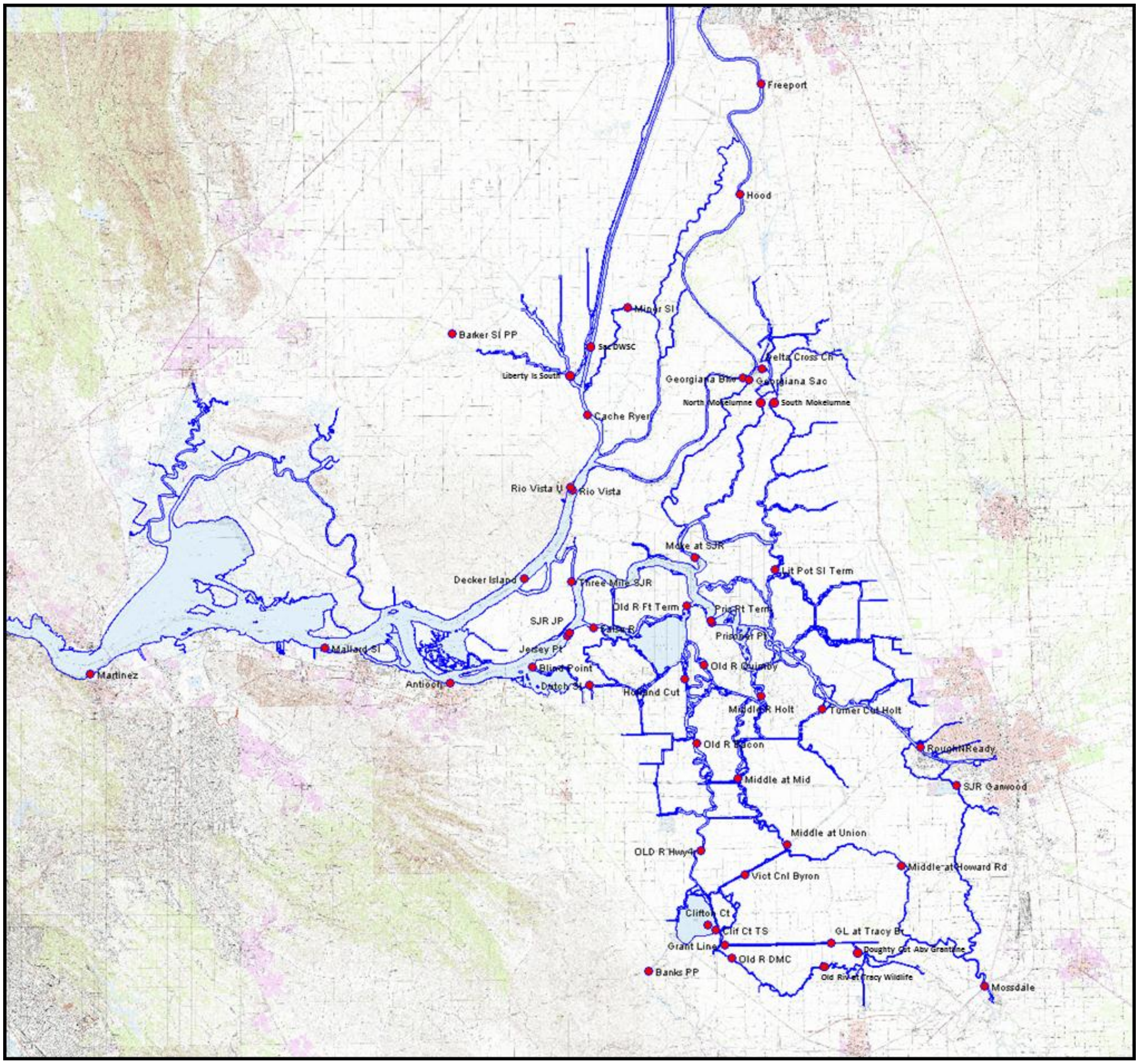

Figure 12-24 Figure illustrating model output and data collection locations.

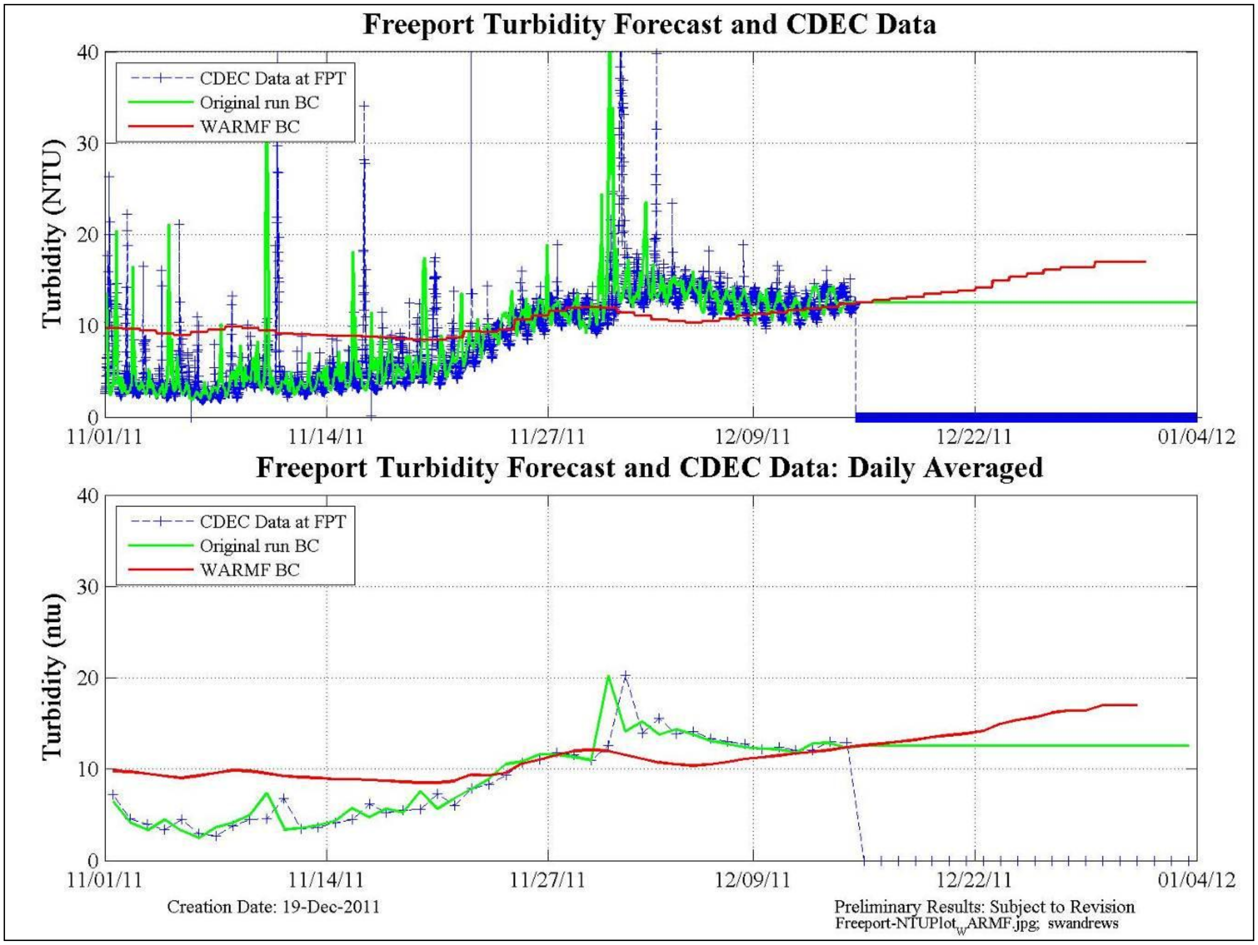

Figure 12-25 WARMF turbidity BC for the Sacramento River at I Street shown with the CDEC data derived RMA BC used for the Sacramento River. Zero values indicate the end of data (blue).

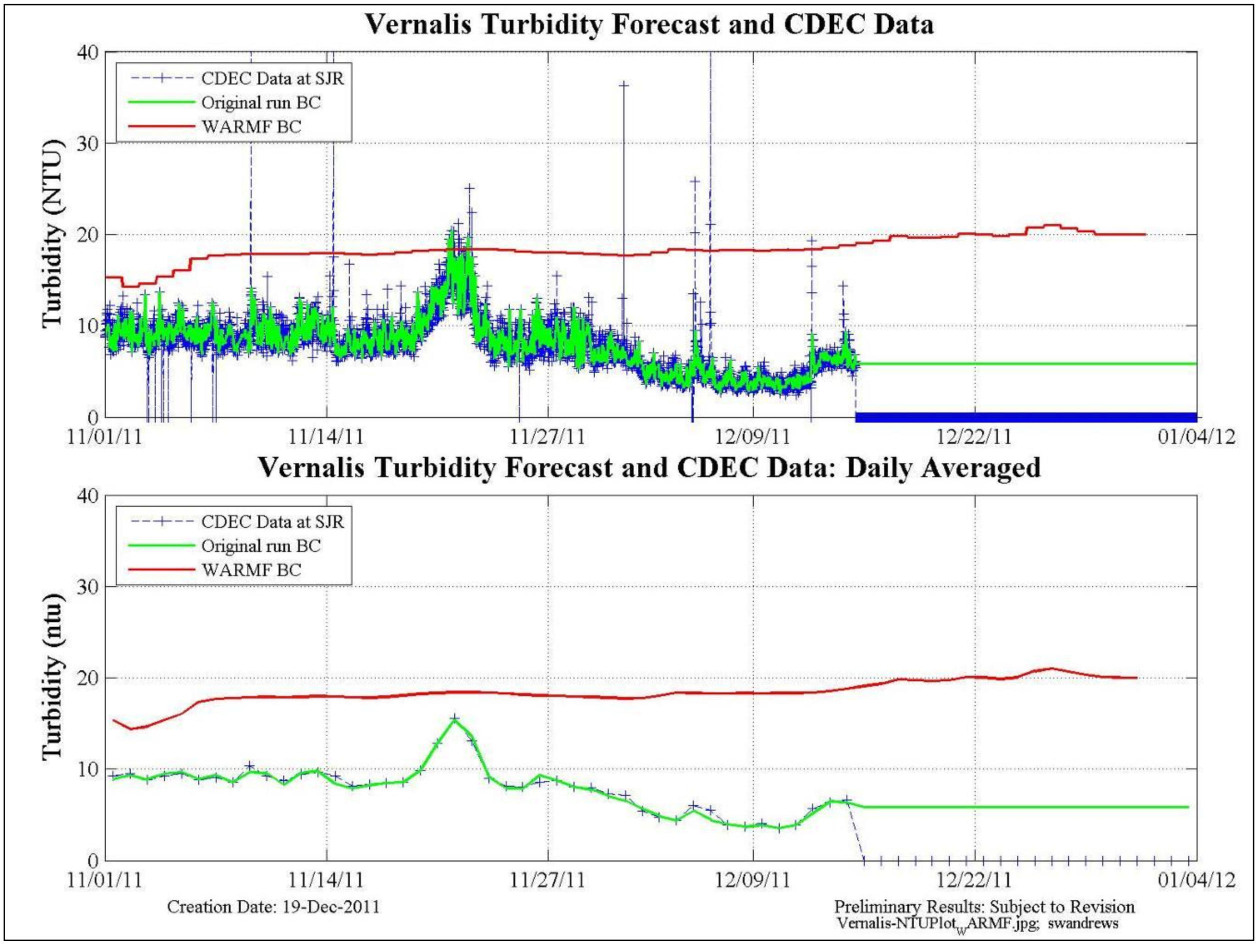

Figure 12-26 WARMF turbidity BC for the San Joaquin River at Vernalis shown with the CDEC data derived RMA BC. Zero values indicate the end of data (blue).

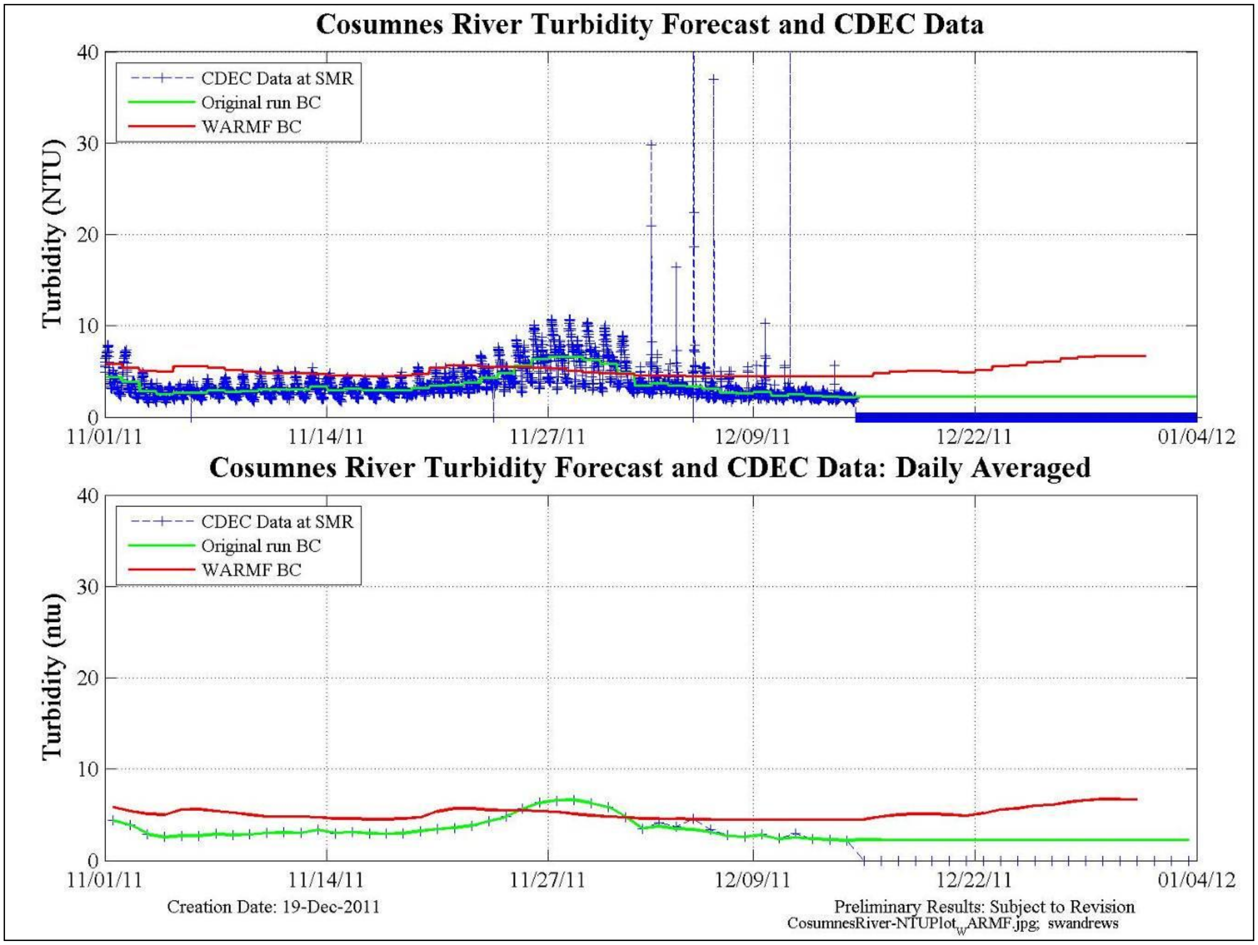

Figure 12-27 WARMF turbidity BC for the Cosumnes River shown with the CDEC data (South Fork Mokelumne River) derived RMA BC. Zero values indicate the end of data (blue).

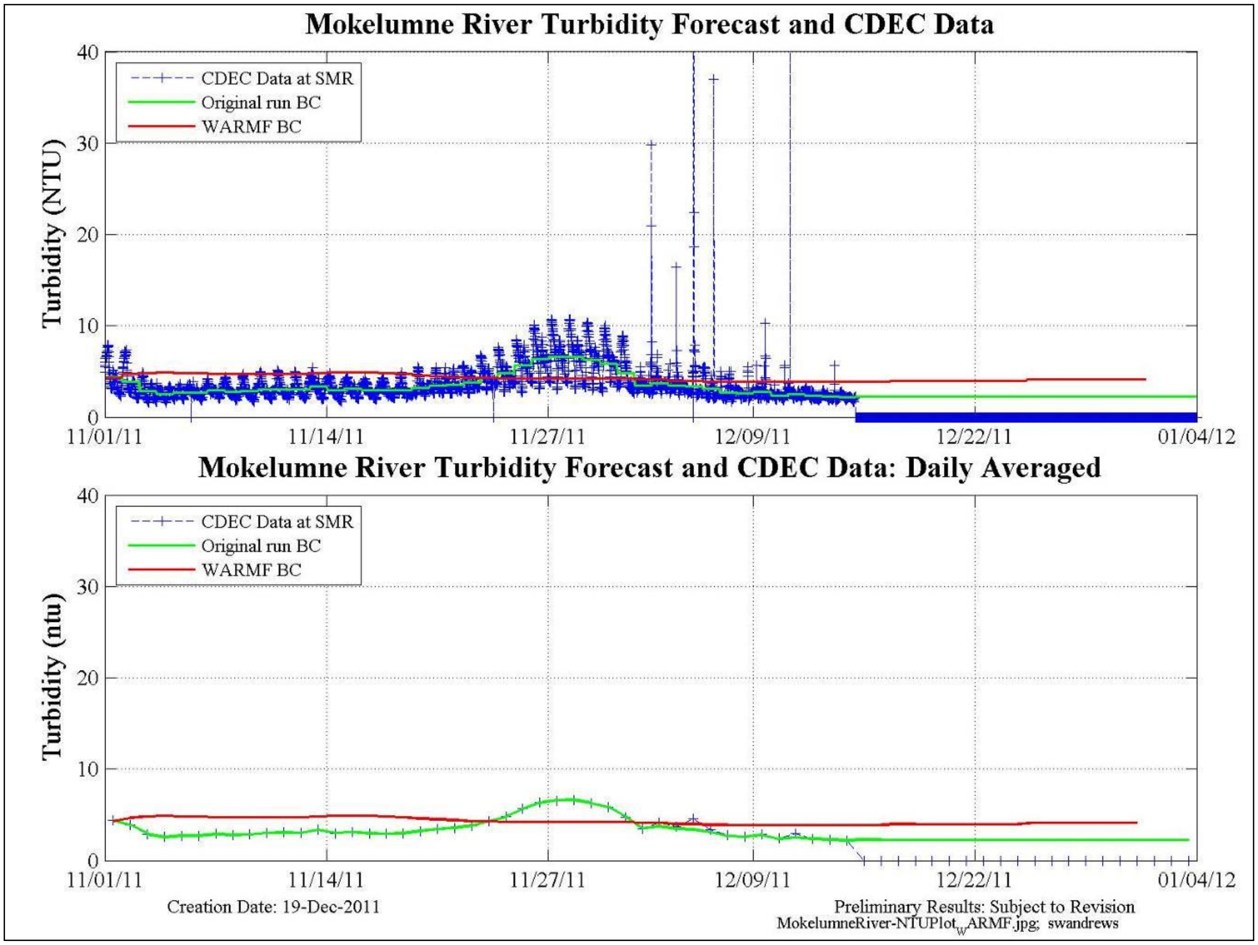

Figure 12-28 WARMF turbidity BC for the Mokelumne River shown with the CDEC data (South Fork Mokelumne River) derived RMA BC. Zero values indicate the end of data (blue).

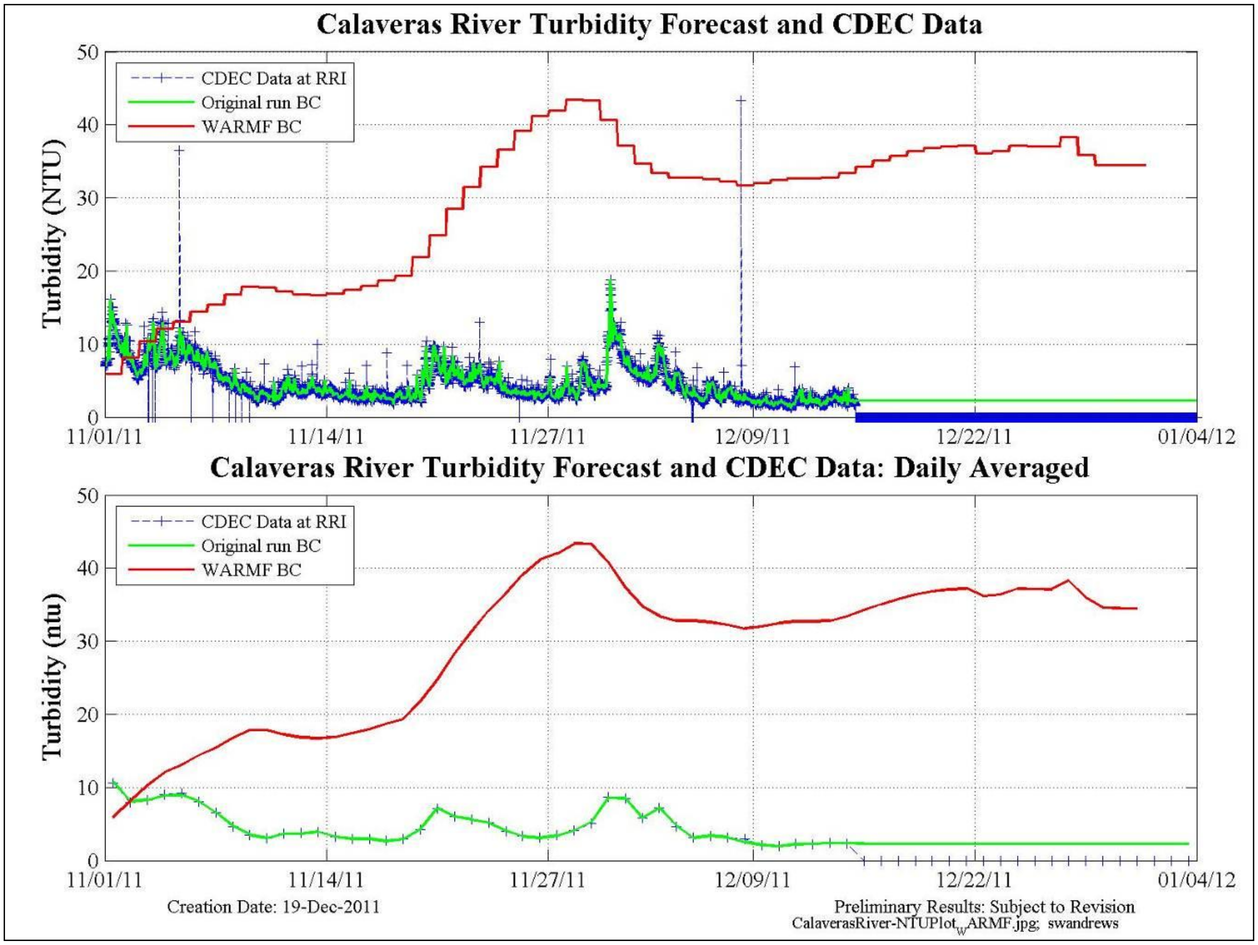

Figure 12-29 WARMF turbidity BC for the Calaveras River – Mormon Slough shown with the CDEC data (Rough and Ready Island) derived RMA BC. Zero values indicate the end of data (blue).

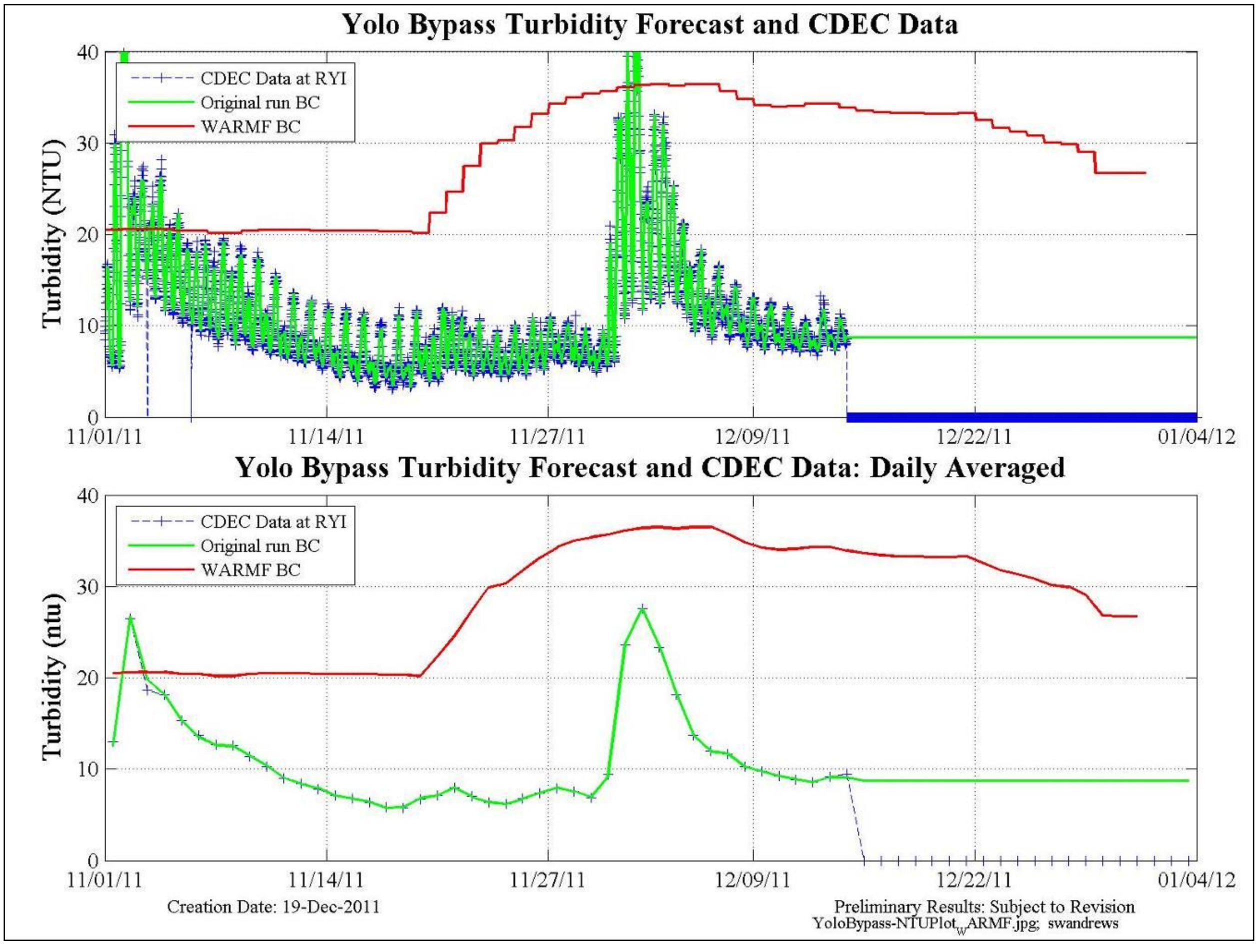

Figure 12-30 WARMF turbidity BC for the Yolo Bypass shown with the CDEC data (Cache Slough at Ryer Island) derived RMA BC. Zero values indicate the end of data (blue).

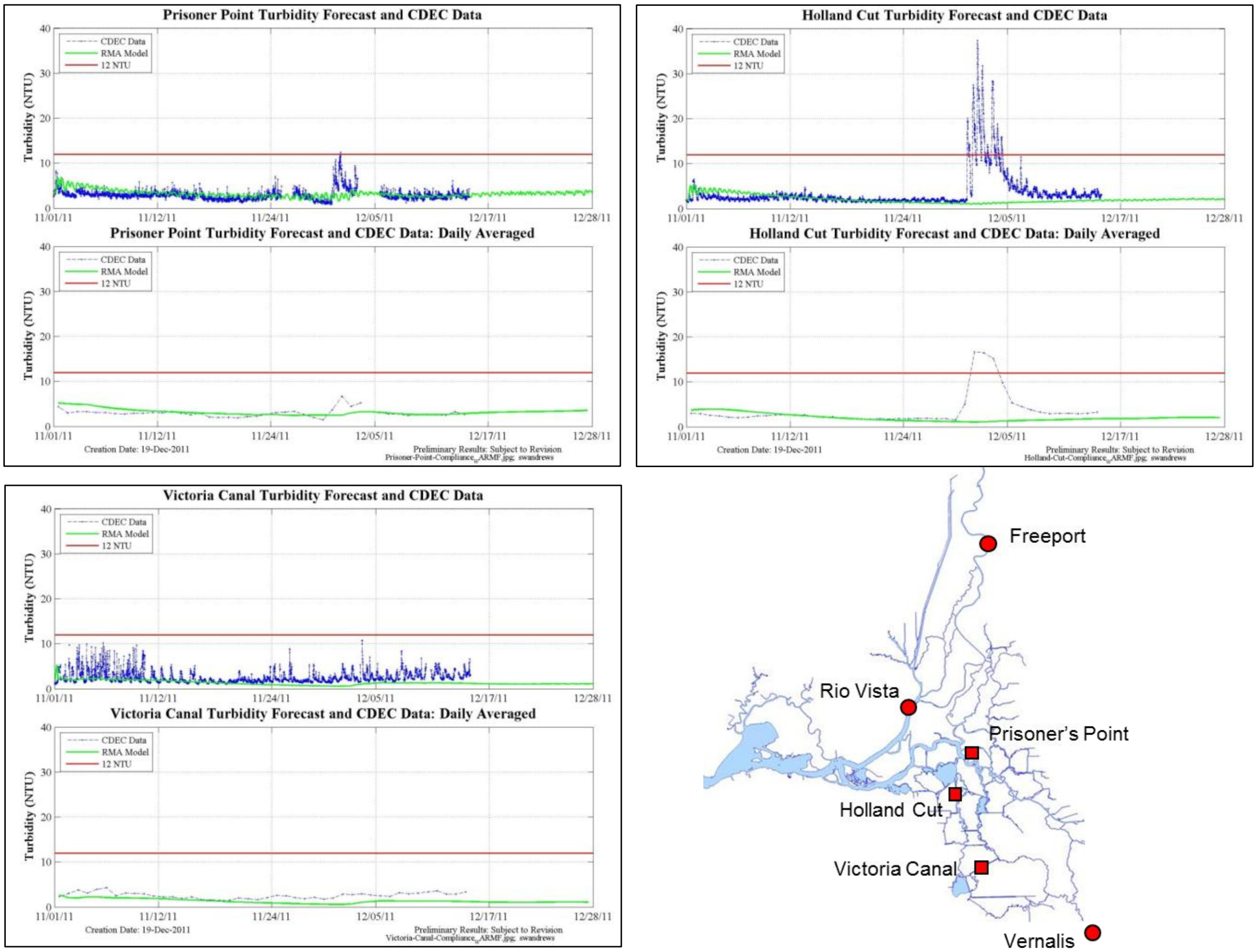

Figure 12-31 Modeled turbidity using the WARMF turbidity boundary conditions and data (cleaned and filled) at the three compliance locations. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value.

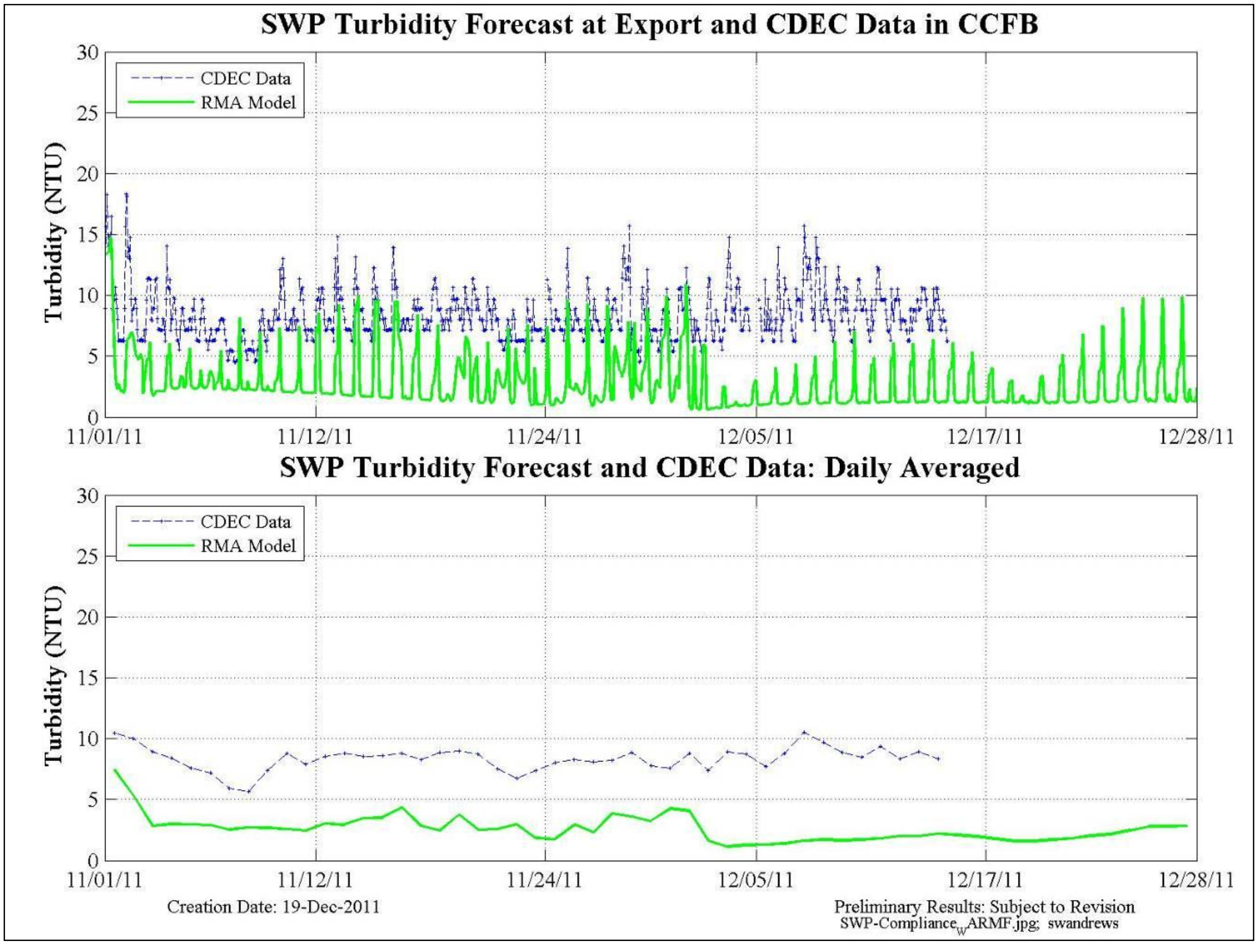

Figure 12-32 Modeled turbidity using the WARMF turbidity boundary conditions. Plots compare modeled turbidity at the SWP export location with data gathered inside Clifton Court Forebay. Both 15-min model output and daily averaged plots are shown.

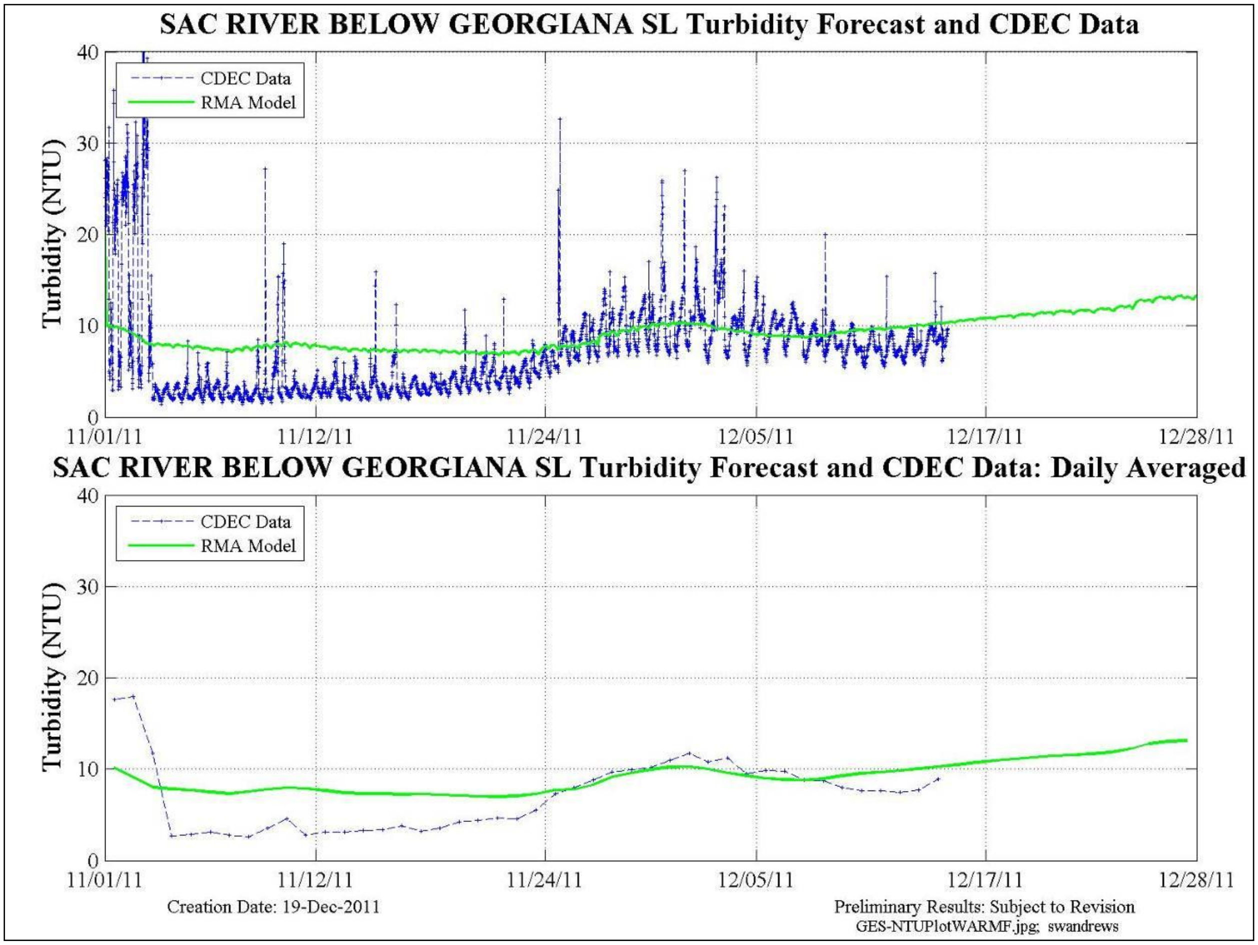

Figure 12-33 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Sac. River Below Georgiana Sl. Both 15-min (upper) and daily averaged (lower) plots are shown.

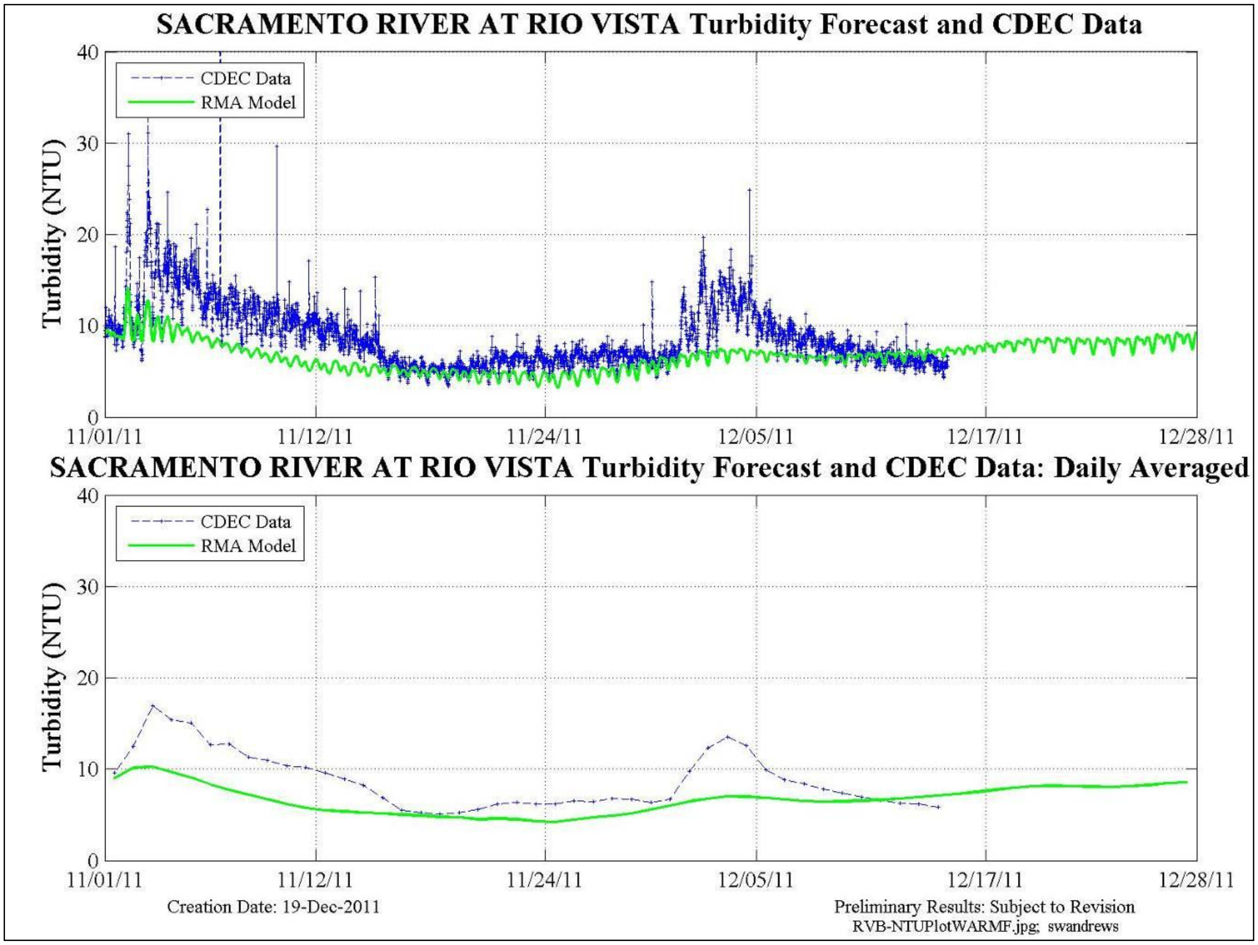

Figure 12-34 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Rio Vista. Both 15-min (upper) and daily averaged (lower) plots are shown.

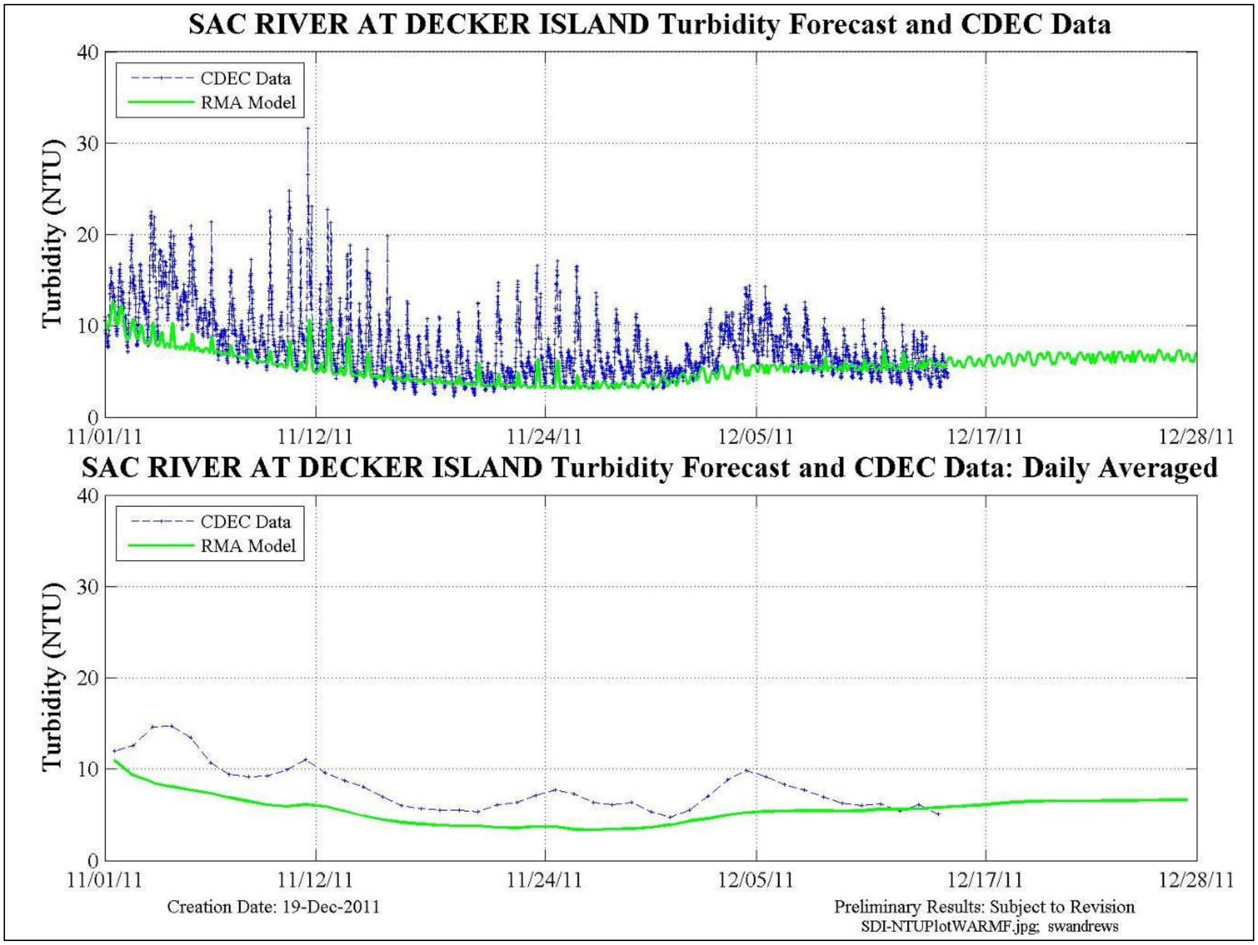

Figure 12-35 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Decker Island. Both 15-min (upper) and daily averaged (lower) plots are shown.

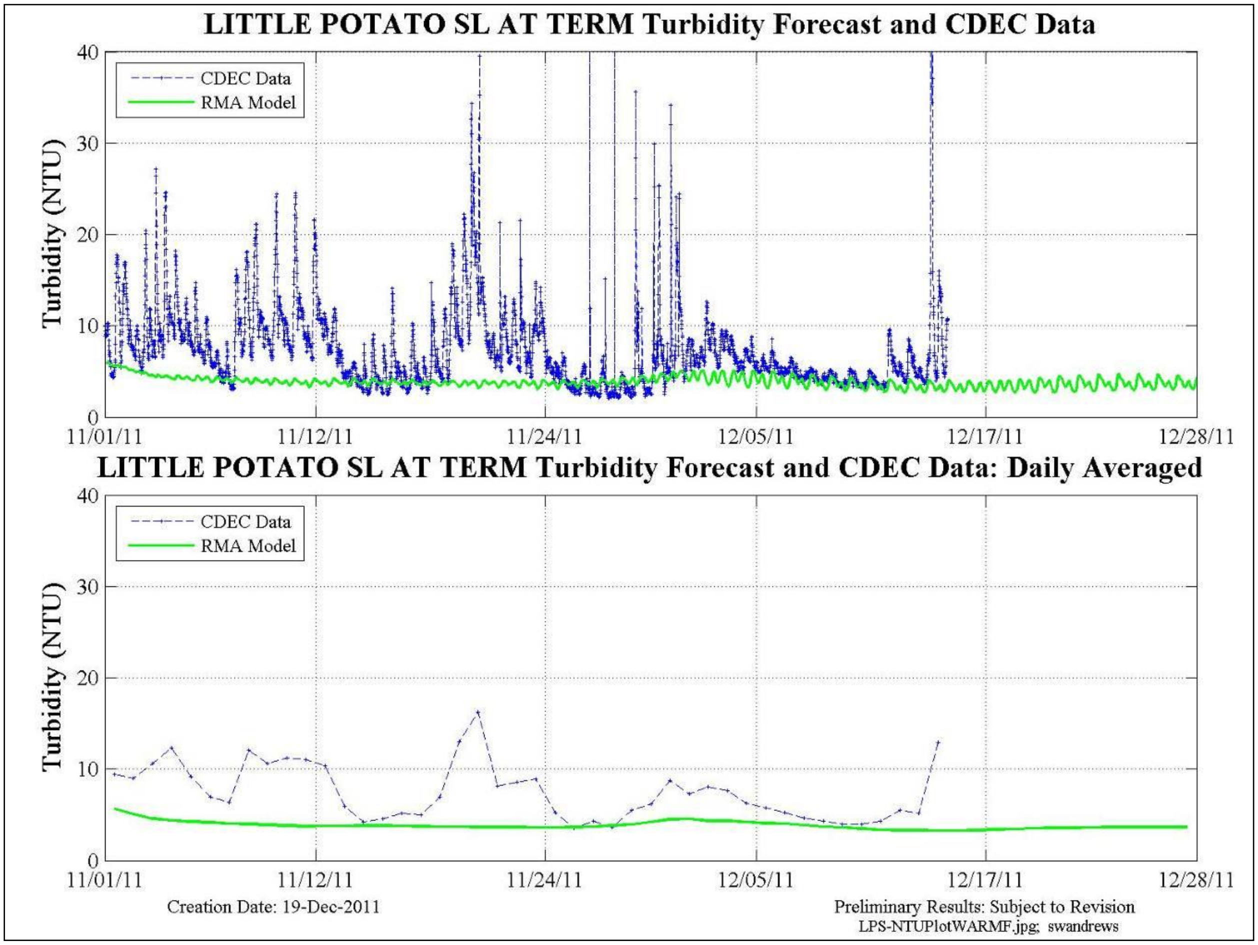

Figure 12-36 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Little Potato Slough at Terminous. Both 15-min (upper) and daily averaged (lower) plots are shown.

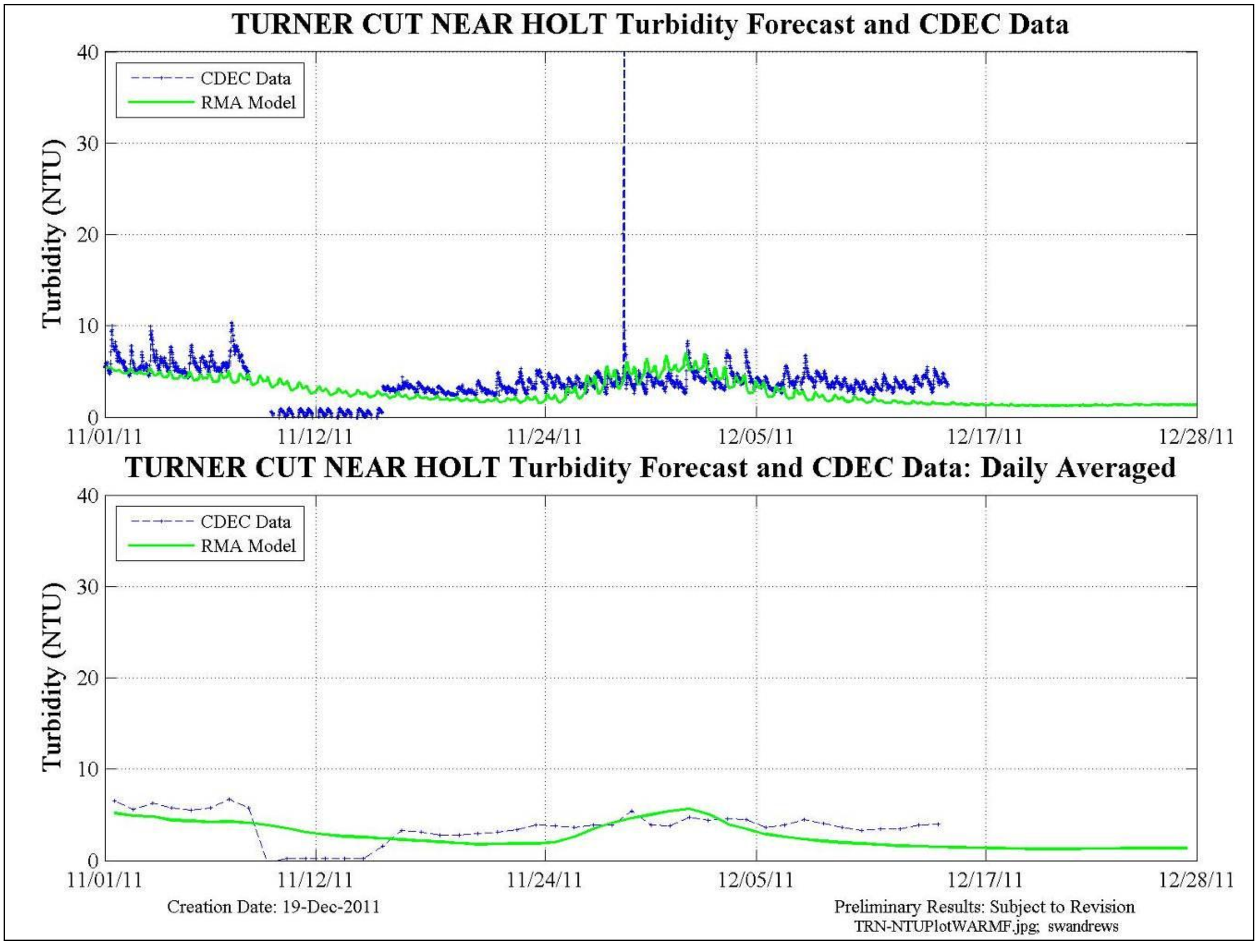

Figure 12-37 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Turner Cut near Holt. Both 15-min (upper) and daily averaged (lower) plots are shown.

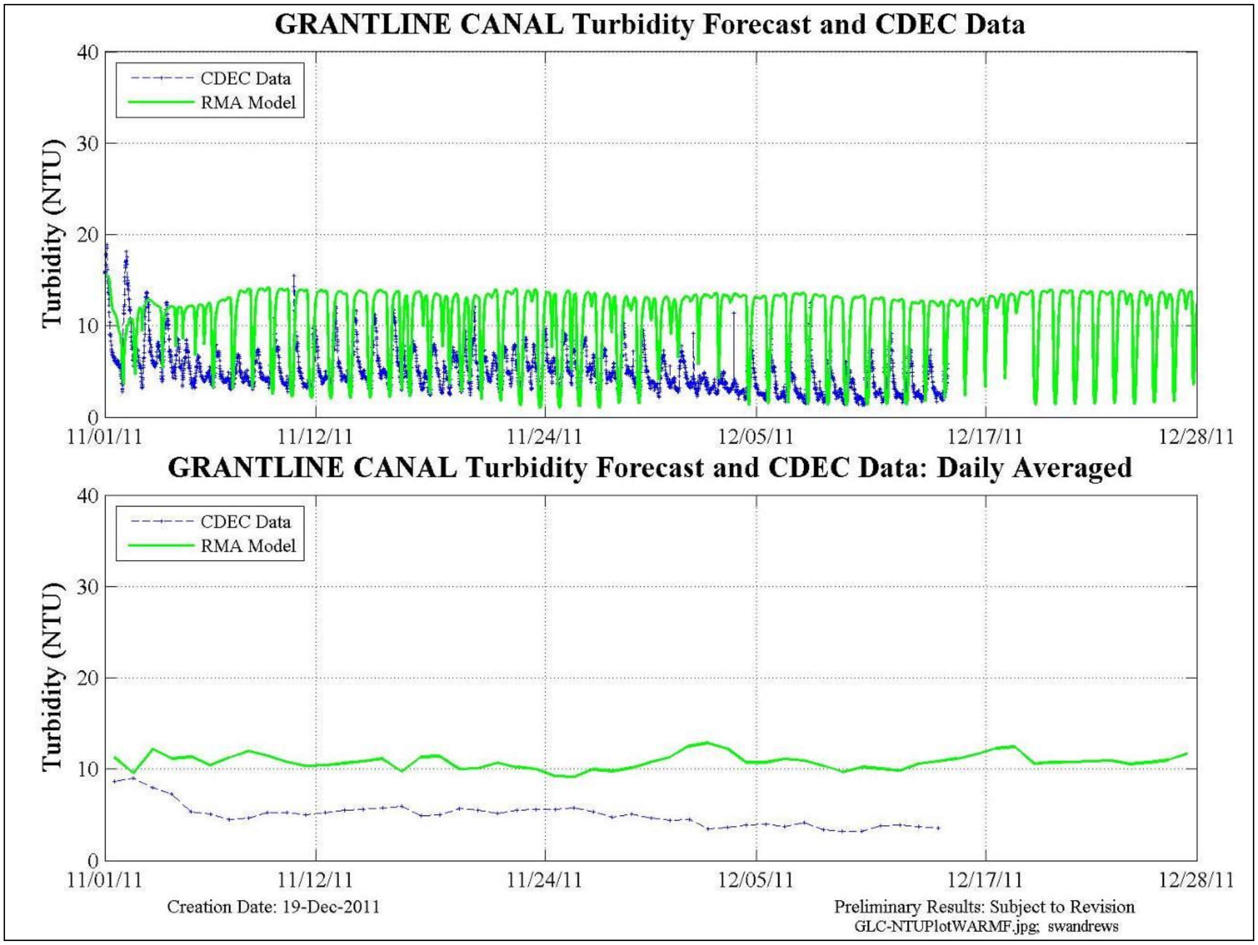

Figure 12-38Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Grant Line. Both 15-min (upper) and daily averaged (lower) plots are shown.

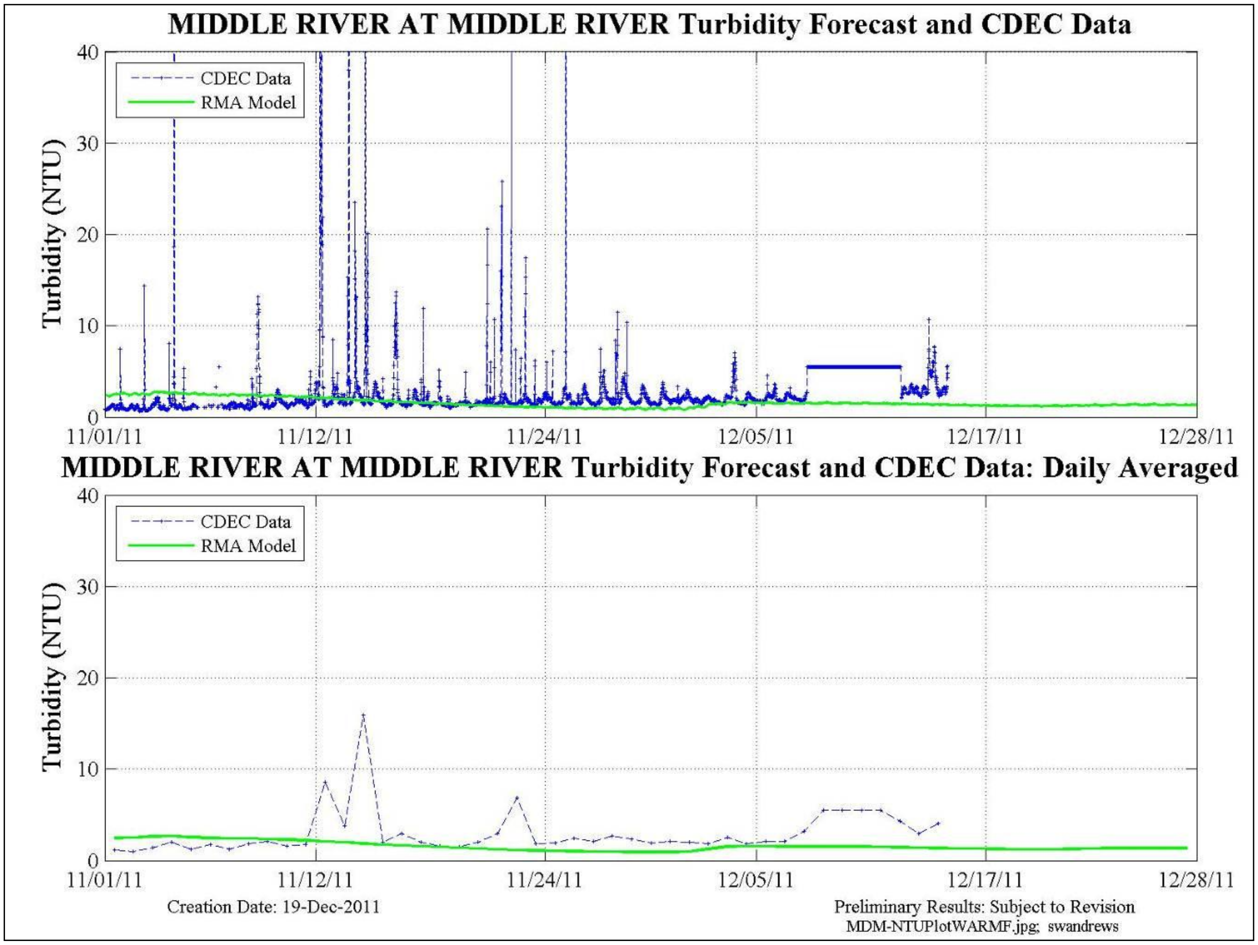

Figure 12-39 Model turbidity using the WARMF turbidity boundary conditions, and raw CDEC data at Middle R. at Middle R. Both 15-min (upper) and daily averaged (lower) plots are shown.

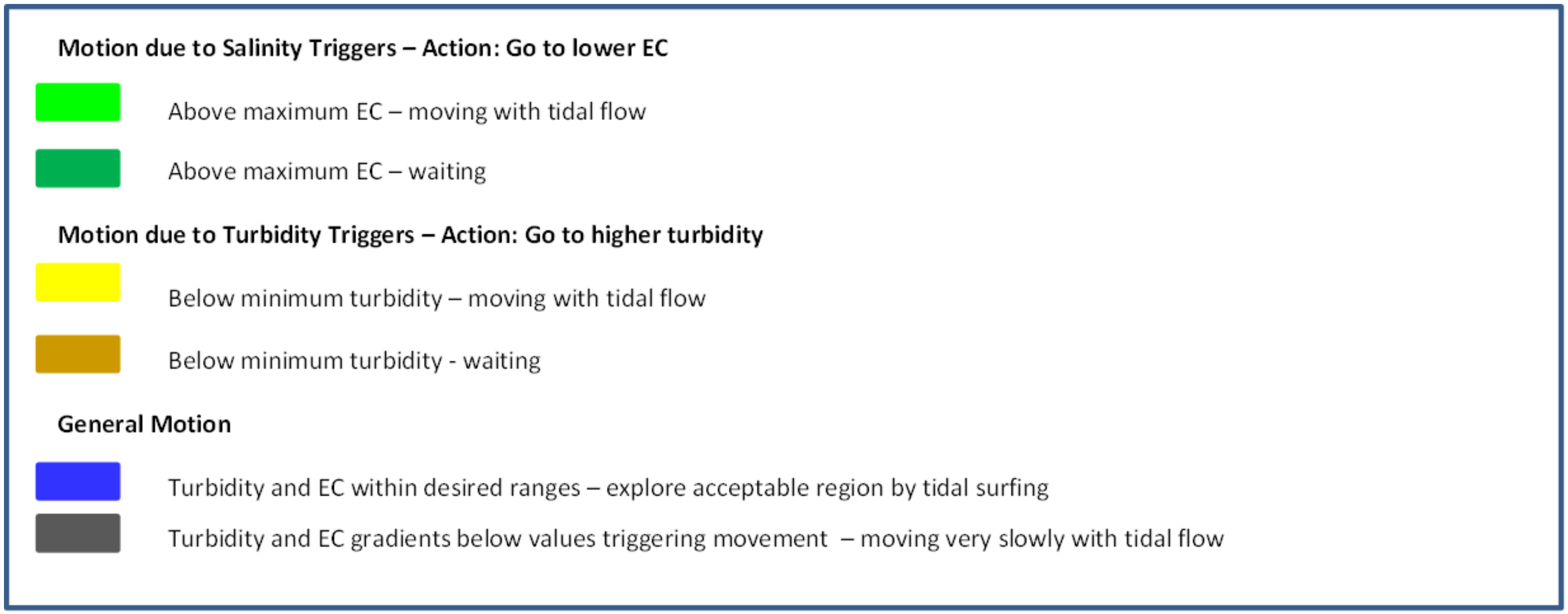

Figure 12-40 Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the next three figures.

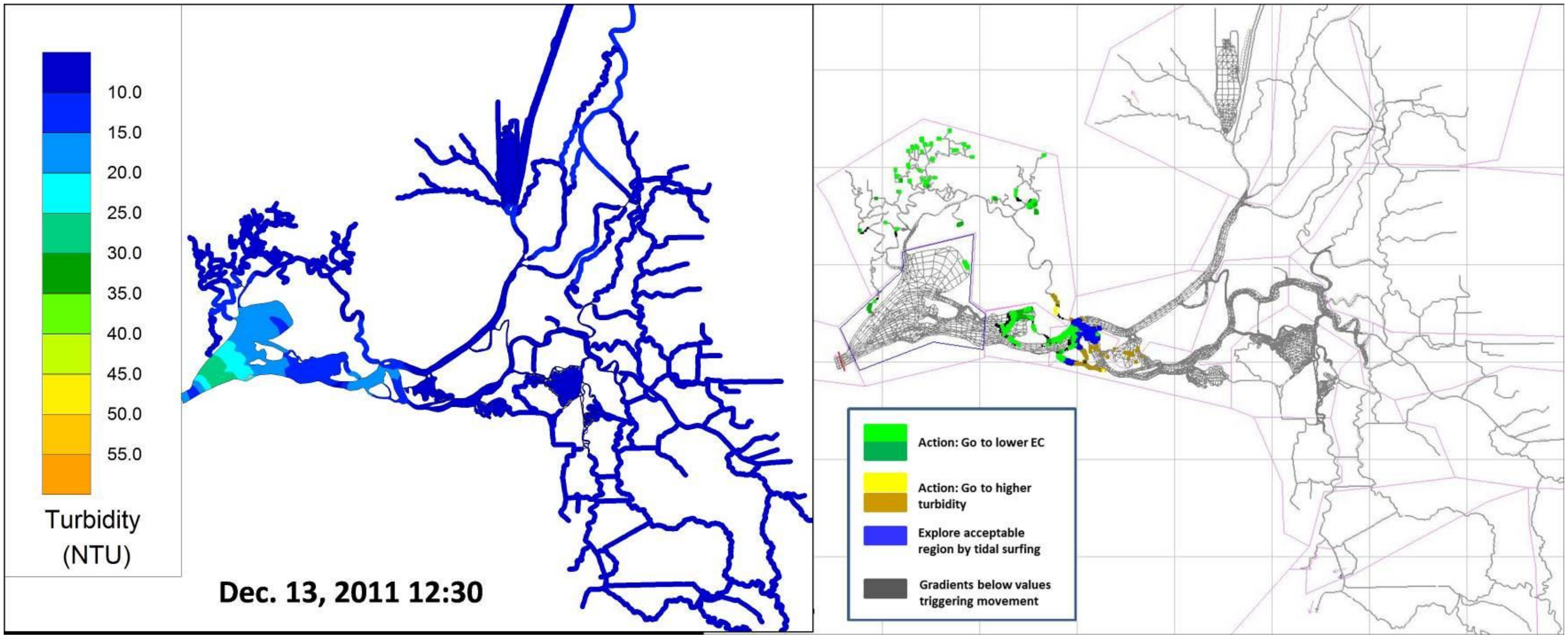

Figure 12-41 Turbidity contours and particle location in the RMA model grid on Dec. 13, 2011.

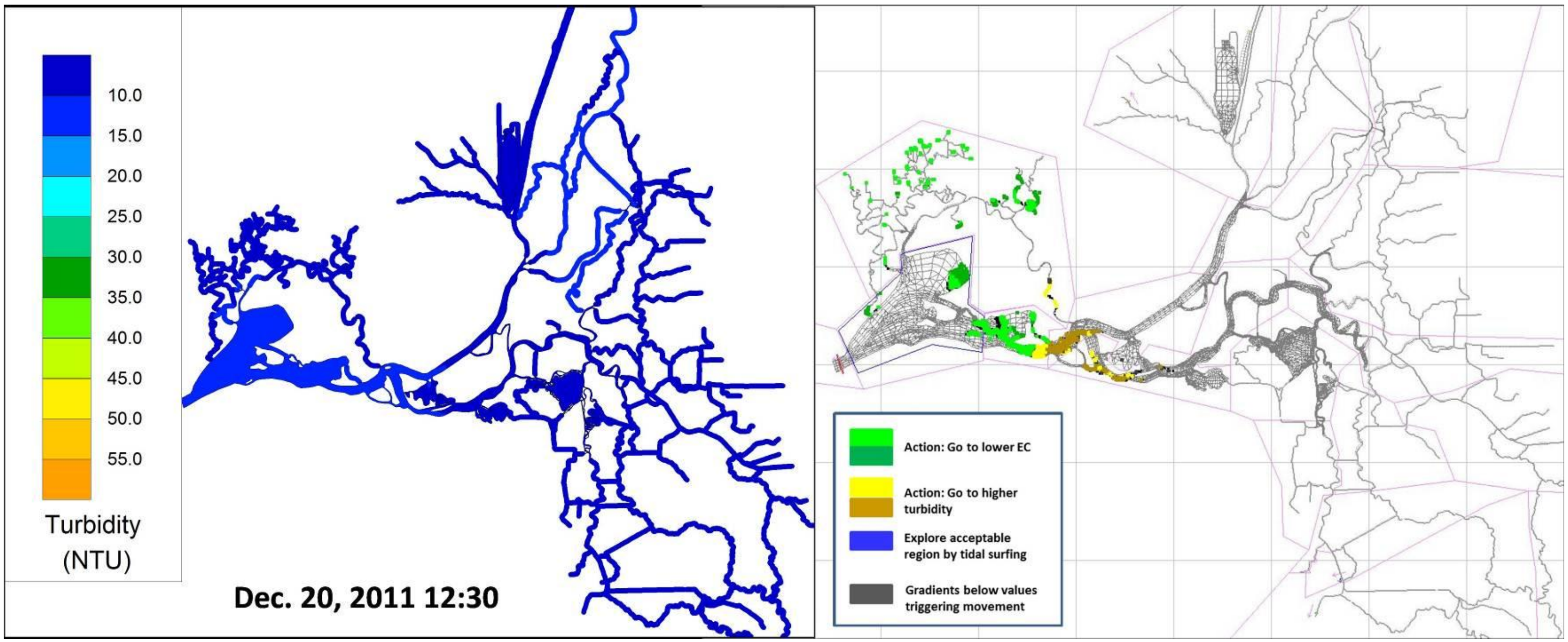

Figure 12-42 Turbidity contours and particle location in the RMA model grid on Dec. 20, 2011.

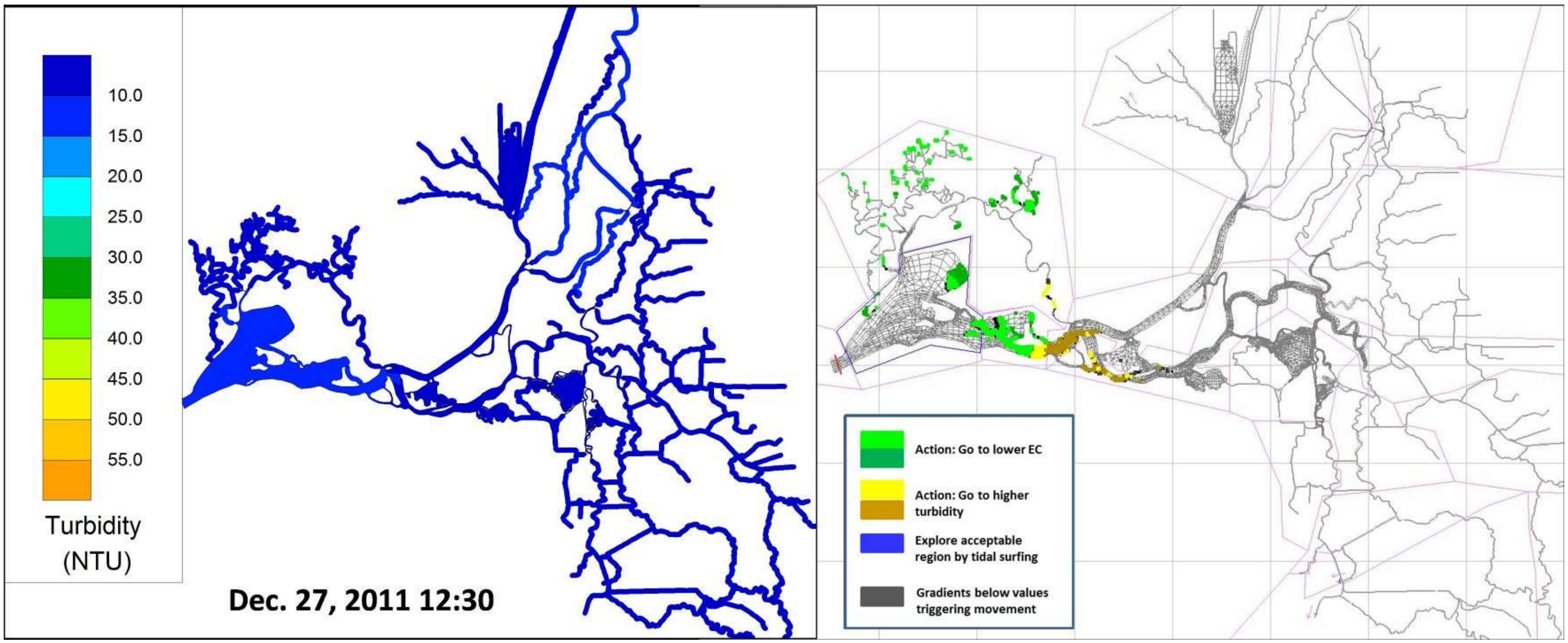

Figure 12-43 Turbidity contours and particle location in the RMA model grid on Dec. 27, 2011.

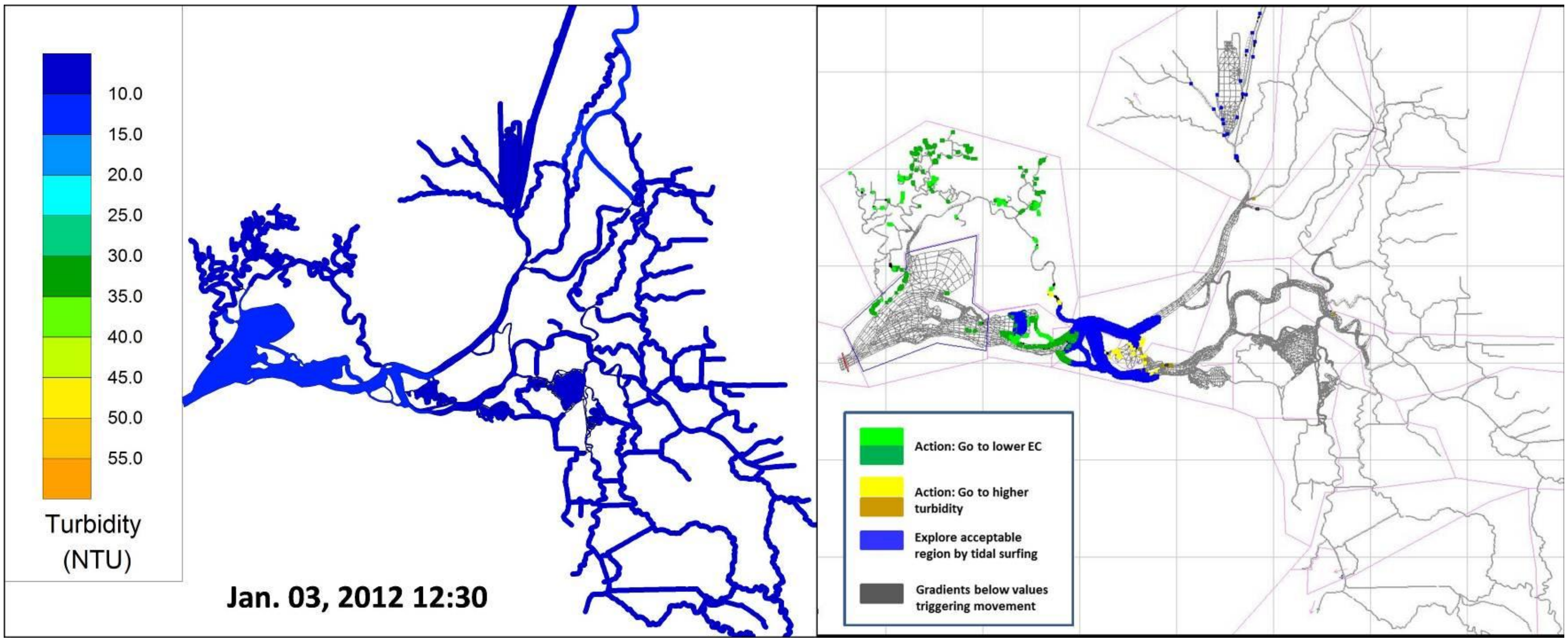

Figure 12-44 Turbidity contours and particle location in the RMA model grid on Jan 03, 2012.

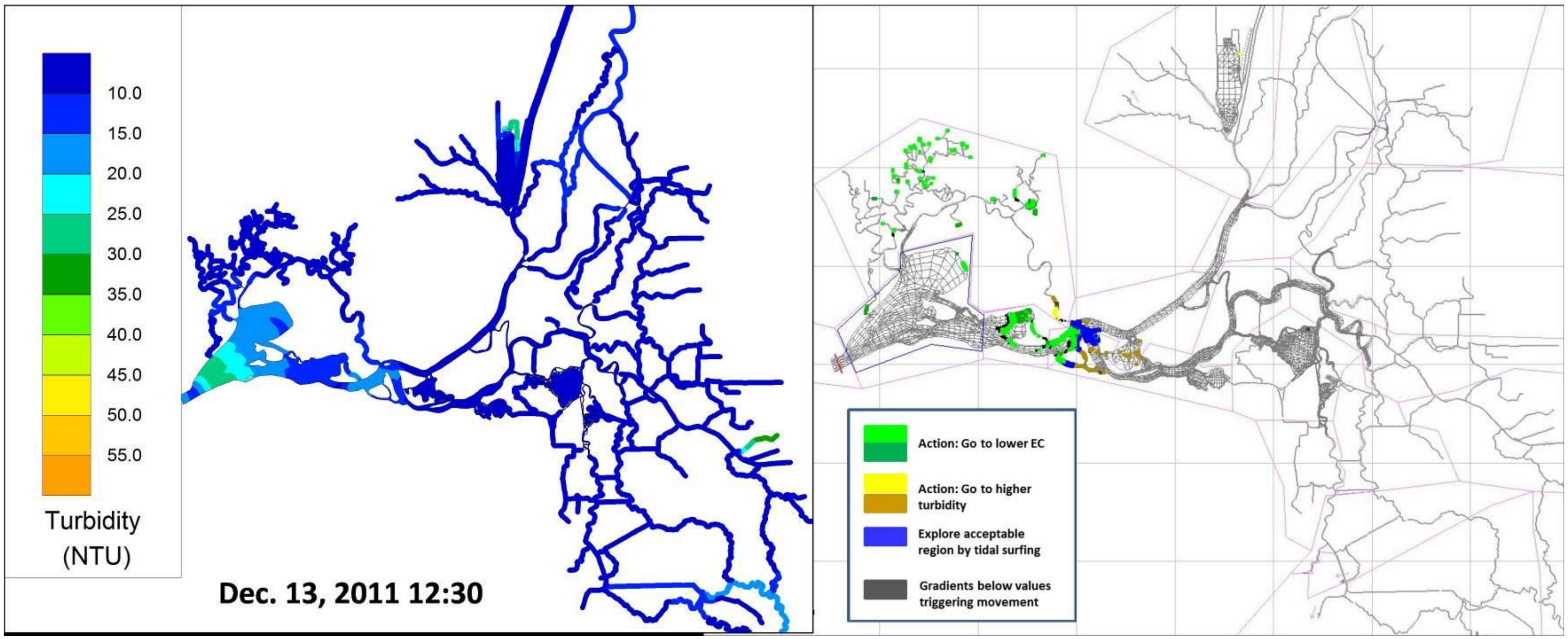

Figure 12-45 WARMF boundary conditions model results. Turbidity contours and particle location in the RMA model grid on Dec 13, 2011.

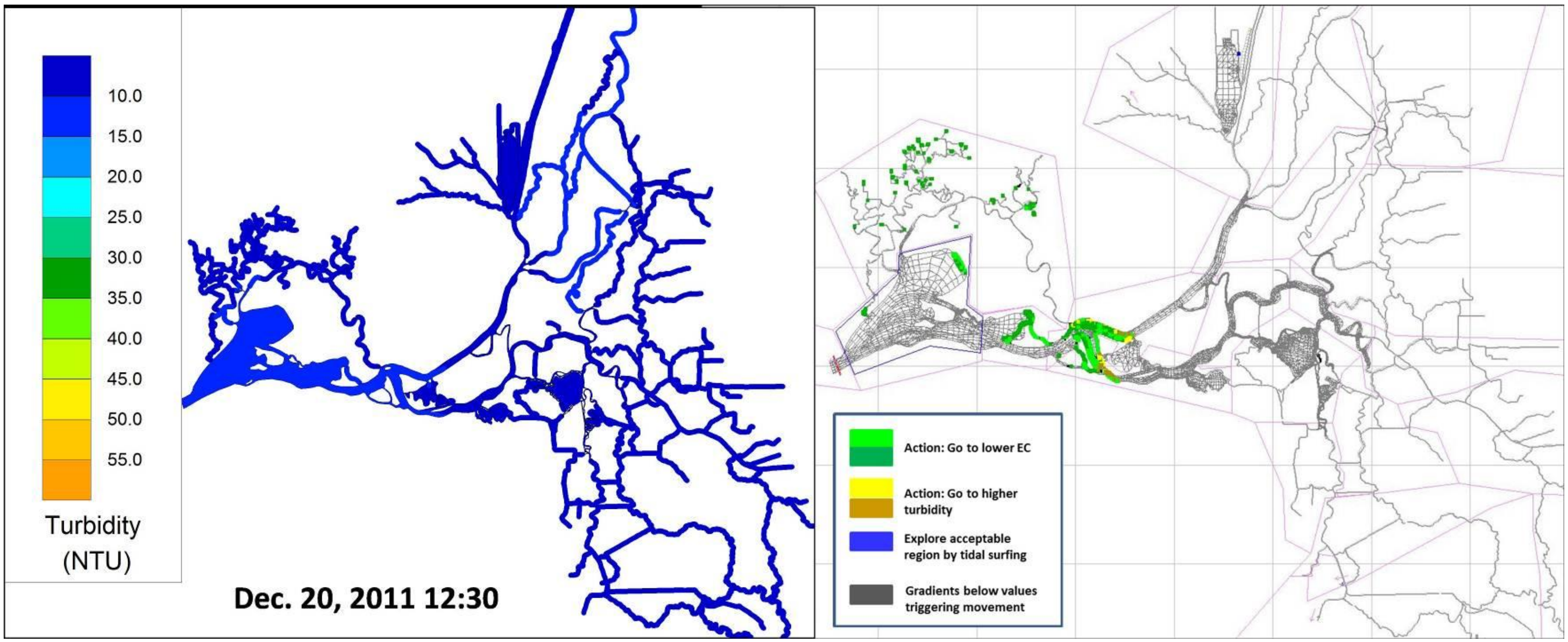

Figure 12-46 WARMF boundary conditions model results. Turbidity contours and particle location in the RMA model grid on Dec 20, 2011.

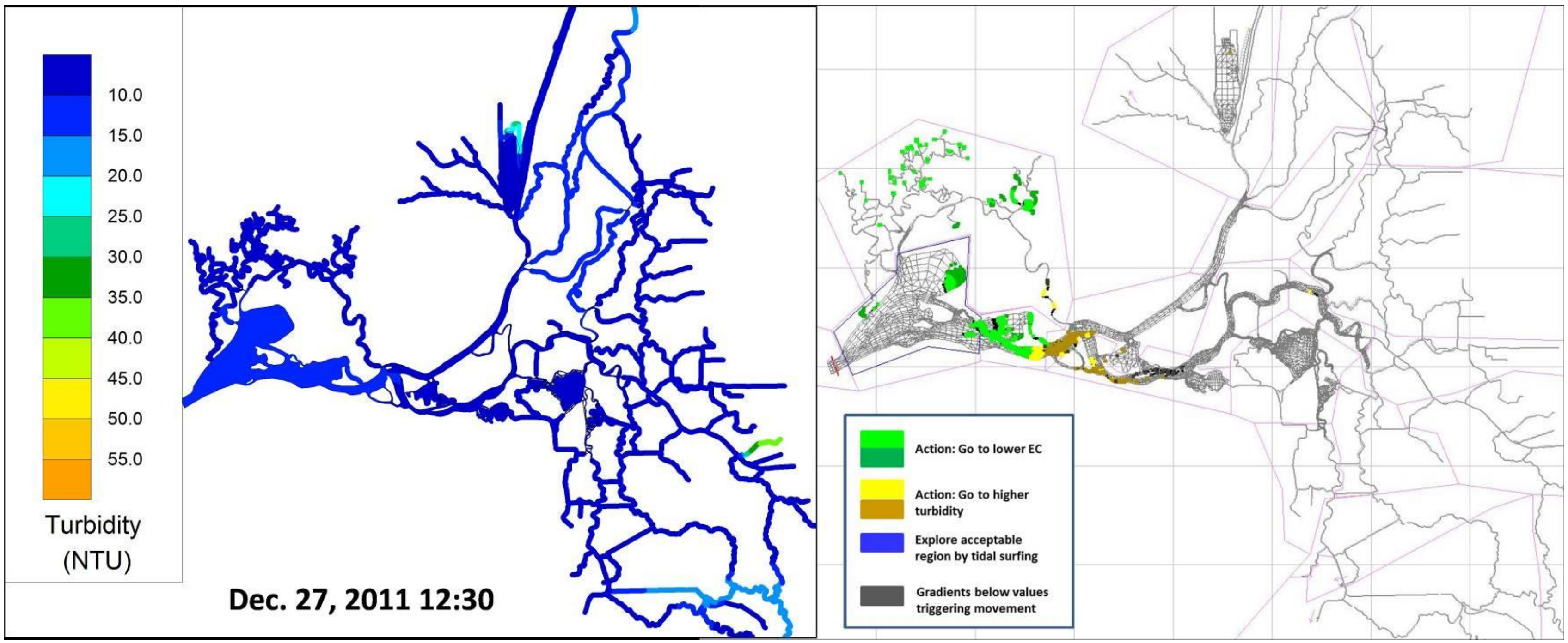

Figure 12-47 WARMF boundary conditions model results. Turbidity contours and particle location in the RMA model grid on Dec 27, 2011.

12.2 RMA Turbidity and Adult Delta Smelt Behavioral Model Covering the Forecast Period January 26, 2012 to February 9, 2012

12.2.1 Summary Assessment

PERIOD: The Delta turbidity and adult delta smelt forecast was produced this week, and this documentation covers the forecast period January 26, 2012 to February 9, 2012 plus a period of historical conditions.

PRE-FORECAST SUMMARY: A pulse of turbid water (peak ~90 NTU) and high flow conditions from the previous week storms in the Sacramento River basin is just beginning to enter the Delta at the start of the forecast period. Prior to that, turbidity was low throughout the Delta, ranging from about 5 - 40 NTU in the raw data at nearly all locations.

TURBIDITY 3-STATIONS PERFORMANCE & SUMMARY EVALUATION: During the historical period, turbidity was below compliance values (12 NTU) at two of the three compliance locations: at Holland Cut, the turbidity went above the compliance value periodically in December and January almost certainly due to wind events. Turbidity is forecasted to remain below compliance values at Holland Cut and Victoria Canal. Turbid water from the Sacramento River is predicted to affect Prisoner Point, the northernmost compliance location, increasing it above compliance values for several days in late January and early February.

SMELT MOVEMENT SUMMARY: As a result of the significant Sacramento turbidity pulse, smelt movement is anticipated up the Sacramento River and into the Northern and Central Delta.

12.2.2 Background

This document provides a summary of the sixth forecast for WY2012 prepared by RMA on January 26, 2012. The forecast was developed using the RMA models for hydrodynamics, salinity, and turbidity and particle tracking using the Adult Delta Smelt Behavioral model. Figures are provided to document the results of the modeling with a focus on turbidity.

Additional documentation can be found on the Bay-Delta Live website: http://www.baydeltalive.com/

12.2.3 Boundary Condition Development and Simulation Timing

Boundary conditions for the forecast models were developed using several sources for historical and forecast conditions including: CNRFC flow data and predictions, CDEC and USGS data, DWR-supplied model inputs and results from their flow and salinity forecasts, and WARMF modeled salinity, and turbidity forecasts, provided by Systec Water Resources, Inc. Boundary conditions were prepared using these data sources and using professional judgment where necessary to resolve data discrepancies and to piece the data together for reasonable Boundary conditions.

The RMA modeled period was November 01, 2011 to February 14, 2012 for flow, salinity and turbidity, and this document presents results for the period December 01, 2011 through February 9, 2012, which include two weeks of forecast period. DWR Operations and Maintenance (O&M) group provided RMA with Boundary conditions they used in the DSM2 HYDRO and QUAL/salinity models for a combined historical and forecast period January 13, 2012 through February 14, 2012 – the three week DWR forecast period was January 24 through February 14, 2012. WARMF model results were provided for the period November 01, 2011 to February 14, 2012.

Additional flow, turbidity and EC data was downloaded for the period January 24–25, 2012 from the CDEC, CNRFC, and USGS websites to fill-in historical conditions in the RMA forecast models.

Historical and forecast BC for flow, turbidity and salinity were developed from sources as summarized in Table 12-4 through Table 12-6 below. Stage and export BC were compiled solely from DWR O&M sources. Flow Boundary conditions were developed using DWR flow predictions for this forecast, which were qualitatively similar to WARMF predictions. WARMF water quality forecasts were used at the Sacramento at Freeport and Cosumnes and Mokelumne River Boundary conditions. Forecasts at the other model boundaries were extended as constants, due to poor agreement of WARMF predictions with historical observed data.

Examination of the CDEC and USGS flow time series for the San Joaquin River at Vernalis showed a shift in the flow rating on December 13, 2011 of about +240 cfs. The new flow time series was used for the Vernalis flow BC for the "historical" period. The downloaded CNRFC "observed" and "forecast" flows incorporate the shift in the flow rating. A similar shift was found to occur in the Calaveras flow time series in early December and was treated similarly.

As with the previous forecast, internal turbidity boundary conditions were applied in the turbidity model (Figure 12-48) at both the Sacramento River at Mallard Island and Cache Slough at Ryer Island (from previous forecasts) and in the central Delta (Old River at Quimby, Mokelumne River at the San Joaquin River confluence, and the San Joaquin River at Jersey Point; as described in the Jan 19, 2012 forecast) to improve model fit during the modeled historical time period. With the exception of Mallard Island (where forecast data was extended as a constant), these internal boundary conditions were not applied during the forecast period.

12.2.4 WARMF Model Information

WARMF simulations in forecast mode require the best available real-time and forecast time series data to drive the simulation. There are five types of time series data used as inputs to the WARMF model: meteorology, air & rain chemistry, point sources, reservoir releases, and diversions. Data up to real-time is collected for those model inputs for which it is available—reservoir releases and many meteorology stations. All remaining time series inputs except meteorology are filled in by extrapolation using average values for each day of the year based on the historical record.

There are seven meteorology parameters used by WARMF: precipitation, minimum temperature, maximum temperature, cloud cover, dewpoint temperature, air pressure, and wind speed. The 6-day forecast meteorology is collected from the National Weather Service and entered into the WARMF database. Missing past and future meteorology data is filled in by comparing stations with missing data to nearby stations which have more complete data. Meteorology beyond the 6-day forecast window is filled in by extrapolation. All but precipitation are extrapolated by calculating the average value for each day of the year from historical data and then applying that average in the extrapolation. Extrapolated precipitation is defaulted to zero.

Forecast reservoir releases are acquired from the California Data Exchange Center and entered into the WARMF time series database. Reservoir releases beyond the scheduled period are extrapolated by continuing the last scheduled release flow through the forecast period. WARMF is first run for at least one year prior to the forecast time period to establish good initial conditions for the forecast. Then the forecast is run using the updated time series inputs.

12.2.5 Flow and Turbidity Model Results

Boundary inflow during most of the historical portion of the simulation was low, resulting from a lack of recent rain events. Turbidity measurements for this time span indicate suspended sediment loading from the watersheds was also very low. Depending on time and location within the Delta, measured turbidity was instead partly due to resuspension of sediments due to tidal action and/or wind events. Turbidity was low throughout the Delta, ranging from about 5–40 NTU in the raw data at nearly all locations. Turbidity data was noisy at many locations, which was particularly evident as turbidity values were so low.

These types of conditions—low boundary inflow and low watershed sediment loading with in-Delta turbidity due to sediment resuspension—are outside the current turbidity model design as turbidity is being modeled not suspended sediment. Additionally, the turbidity model calibration was optimized for high flow conditions with substantial loading from the watersheds, conditions that are hypothesized to lead to movement of delta smelt into the interior of the Delta as they follow flow and turbidity cues.

A weather system brought significant precipitation to the Sacramento watershed January 18–23, 2012. This resulted in a significant increase in flows and turbidity on the Sacramento River at Freeport (see Figures 2 and 3), the Yolo Bypass, and the Cosumnes River. These turbidity pulses caused local increases in turbidity as they made their way through the Delta, but, because of low-to-moderate export levels, stayed north of the south Delta region.

Flow and turbidity BC are illustrated in Figure 12-49 through Figure 12-58, while Figure 12-59 through Figure 12-62 illustrate export levels and Old+Middle River flows. Using information supplied by O&M for historical and forecast State (SWP) and Federal (CVP) exports, Figure 12-59 illustrates that daily-averaged exports decreased from a maximum of ~10,000 cfs in early December to ~ 6,000 cfs by January. Figure 12-60 and Figure 12-61 are plots of Old River and Middle River flows and daily-averaged flows, respectively, while Figure 12-62 illustrates the combined Old+Middle River flow criterion (3-day center-weighted average) compared with CDEC data.

Figure 12-63 is a comparison of model output and data at the three compliance locations, and Figure 12-64 is a similar plot in the SWP export area. Note that Figure 12-64 is a comparison of data inside Clifton Court Forebay with model output at the entrance to the Forebay. For these two figures, data were cleaned (noisy values removed) and missing data filled with linear approximation. The cleaned and filled data were also daily averaged for comparison with daily-averaged model output.

Turbidity was consistently below compliance values (12 NTU) at only one of these three compliance locations. At Holland Cut, the turbidity exceeded the compliance value for several days periodically throughout December and January, in response sediment resuspended during wind events. The northernmost compliance location, at Prisoner's Point, is forecasted to exceed compliance turbidity for several days in late January–early February, in response to the pulse of turbid Sacramento River water traveling into the Central Delta.

Figure 12-65 and Figure 12-66 illustrate the progression of the main turbidity boundary conditions at Freeport and Vernalis down the Sacramento and San Joaquin Rivers, respectively. Figure 12-67 through Figure 12-73 are plots of model output compared with raw CDEC turbidity data at several in-Delta locations - these locations can be found on a map of the Delta in Figure 12-74. The turbidity model captured the transport of the turbidity pulse through the north and central Delta, and the generally low turbidity in the south.

12.2.6 Adult Delta Smelt Particle Tracking Model Results

Figure 12-75 through Figure 12-78 present the turbidity contour plots and particle tracking model results for the runs using the data-derived turbidity and EC boundary conditions listed in Table 12-5 and Table 12-6— RMA-modeled turbidity is in left plot and particle tracking model results are in the right plot. The Delta Smelt behavioral model was run November 01, 2011 to February 9, 2012; 50,000 particles were inserted on November 01. These plots illustrate that just prior to the forecast period, turbidity was increasing throughout the north Delta. This turbidity spread throughout the north and central Delta, but generally stayed away from the south Delta, and had dissipated by the end of the 2-week forecast period (Figure 12-78). None of the modeled particles reached the export locations during the simulation; however a small number of delta smelt were reported by DFG as being salvaged at the CVP pump locations on January 18, 24, and 25 (Figure 12-79).

12.2.7 MWD Training

Model input files and results were provided to Dr. Chuching Wang for remote access on the RMA intranet.

12.2.8 List of Acronyms

WY ~ Water Year
SWP ~ State Water Project
CVP ~ Central Valley Project
CCFB ~ Clifton Court Forebay
CNRFC ~ California-Nevada River Forecasting Center
CDEC ~ California Data Exchange Center
CIMIS ~ California Irrigation Management System
DWR ~ California Department of Water Resources
USGS ~ United States Geological Survey

RMA ~ Resource Management Associates
WARMF ~ Watershed Analysis Risk Management Framework
DFG ~ California Department of Fish and Game

CDEC Stations:
FPT ~ Freeport
MAL~ Sacramento River at Mallard Island
RYI ~ Cache Sl. at Ryer Island
SMR ~ South Fork Mokelumne River
MRZ ~ Martinez
VNS ~ Vernalis

DSM2 Boundary Locations:
RMKL070 ~ Mokelumne River
RCSM075 ~ Cosumnes River
RCAL009 ~ Calaveras River
RSAN112 ~ San Joaquin River
BYOLO040 ~ Yolo Bypass
RSAC054 ~ Martinez

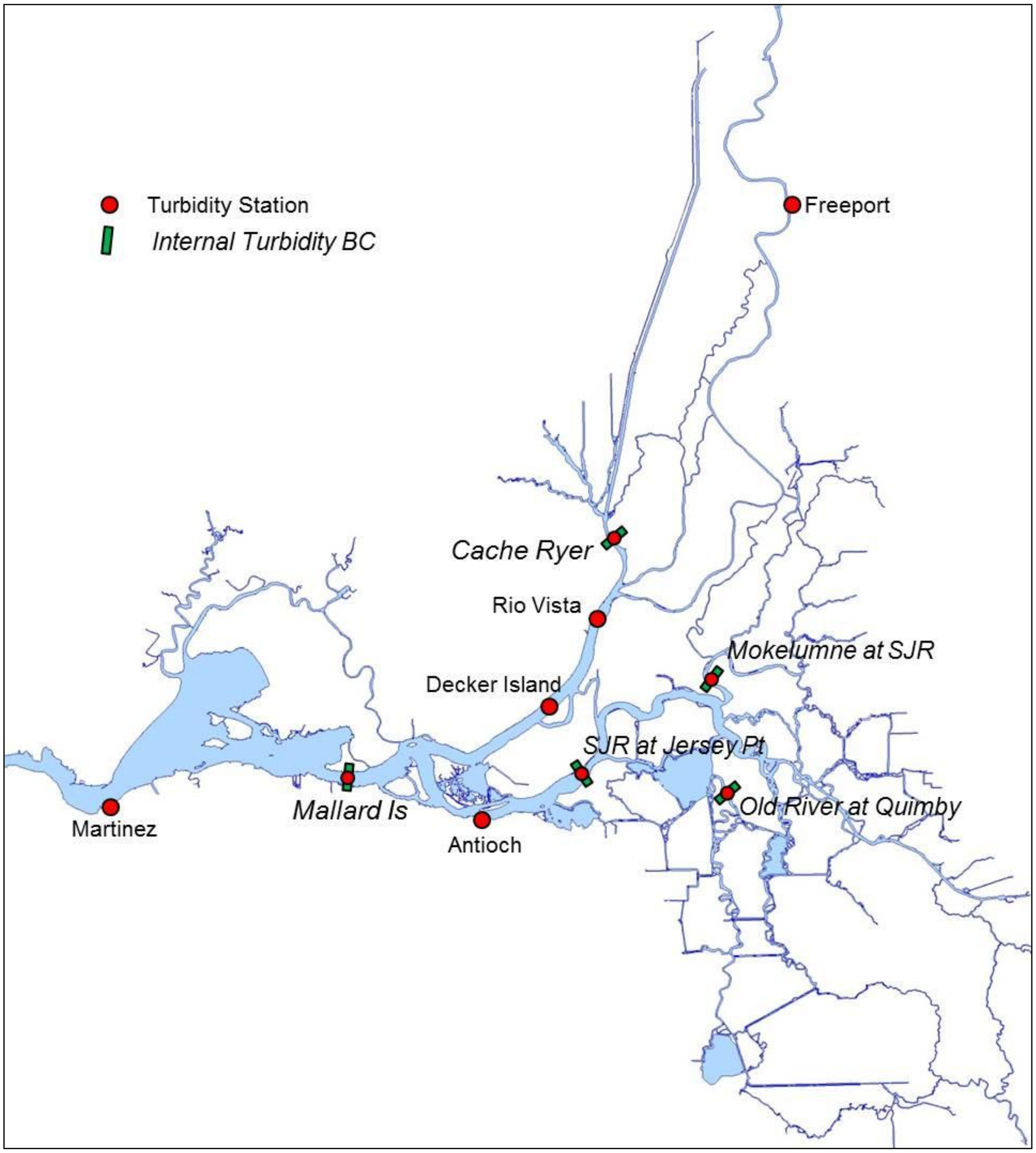

Figure 12-48 Locations of the internal turbidity boundary conditions used in the current turbidity forecast model run. Boundary conditions at the Mokelumne River at SJR, the SJR at Jersey Point, and Old River at Quimby Island were implemented in the January 19, 2012 forecast.

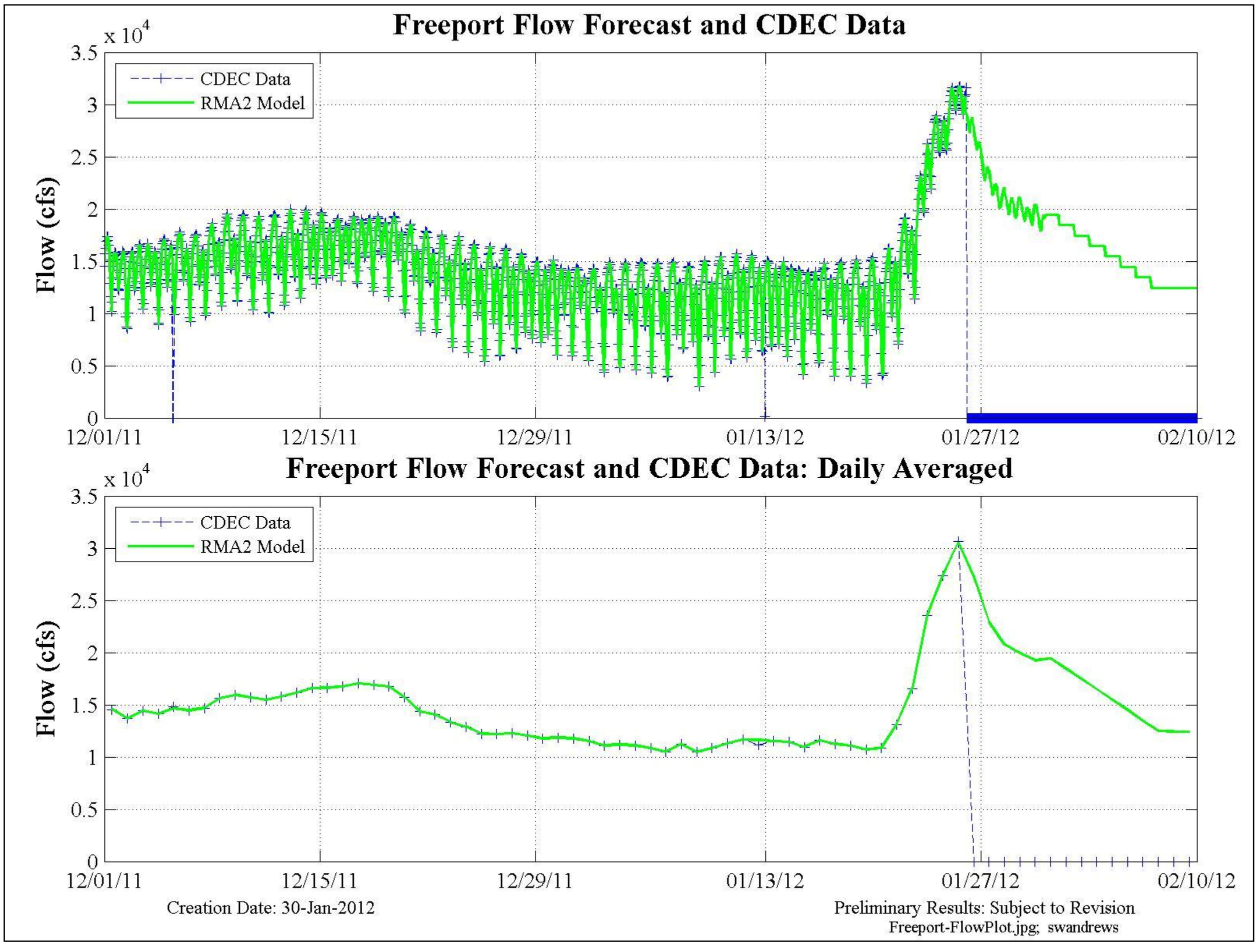

Figure 12-49 Freeport flow BC was compiled using CDEC data, CNRFC forecast, and then DWR DSM2 forecast. Note y-axis unit is cfs*10,000. Zero values indicate the end of data (blue).

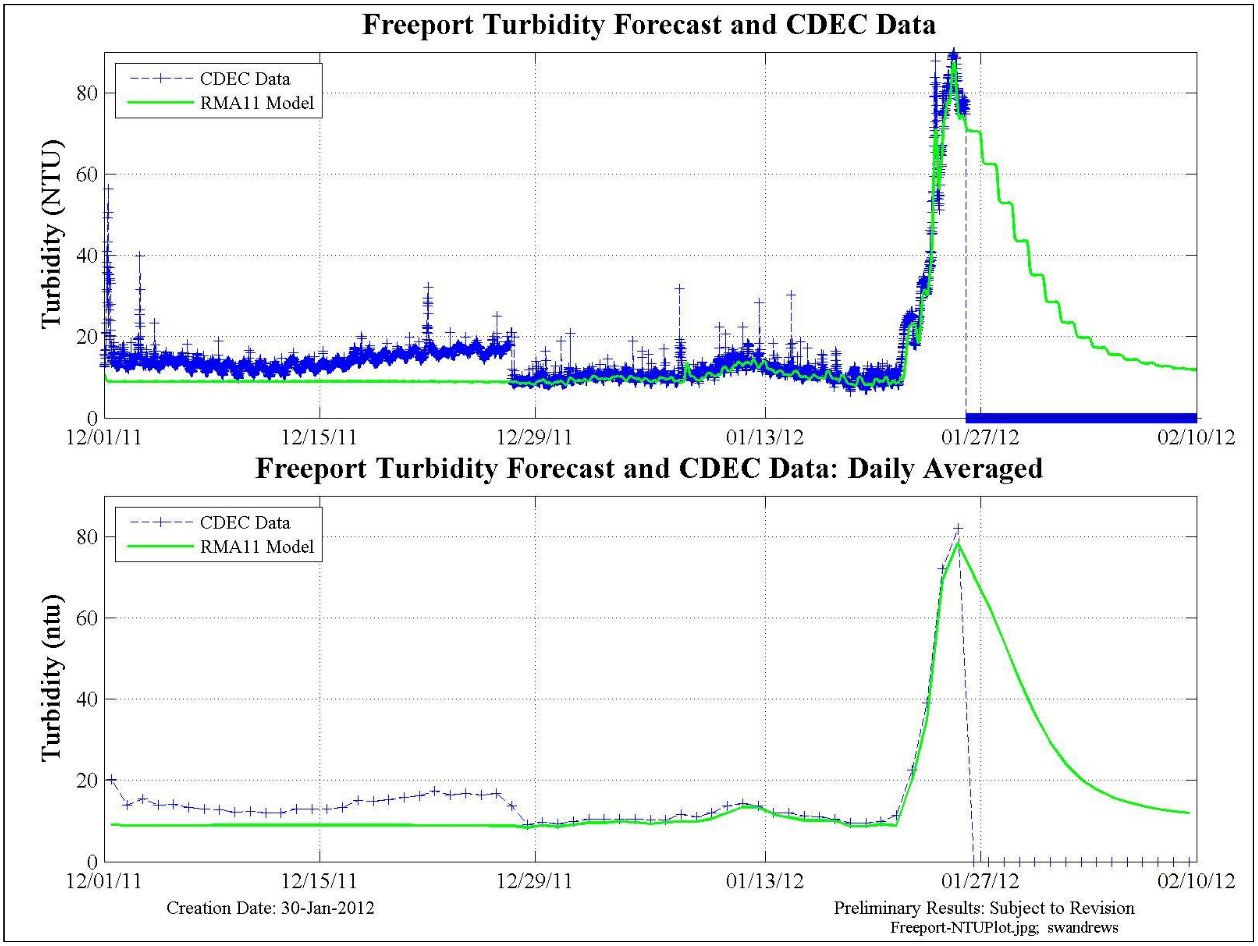

Figure 12-50 Freeport turbidity BC was compiled using CDEC data followed by the WARMF forecast. Zero values indicate the end of data (blue). Data prior to Dec. 27, 2011 was linearly interpolated after a comparison to the SRH CDEC station indicated unrealistically high recorded turbidities at the FPT station.

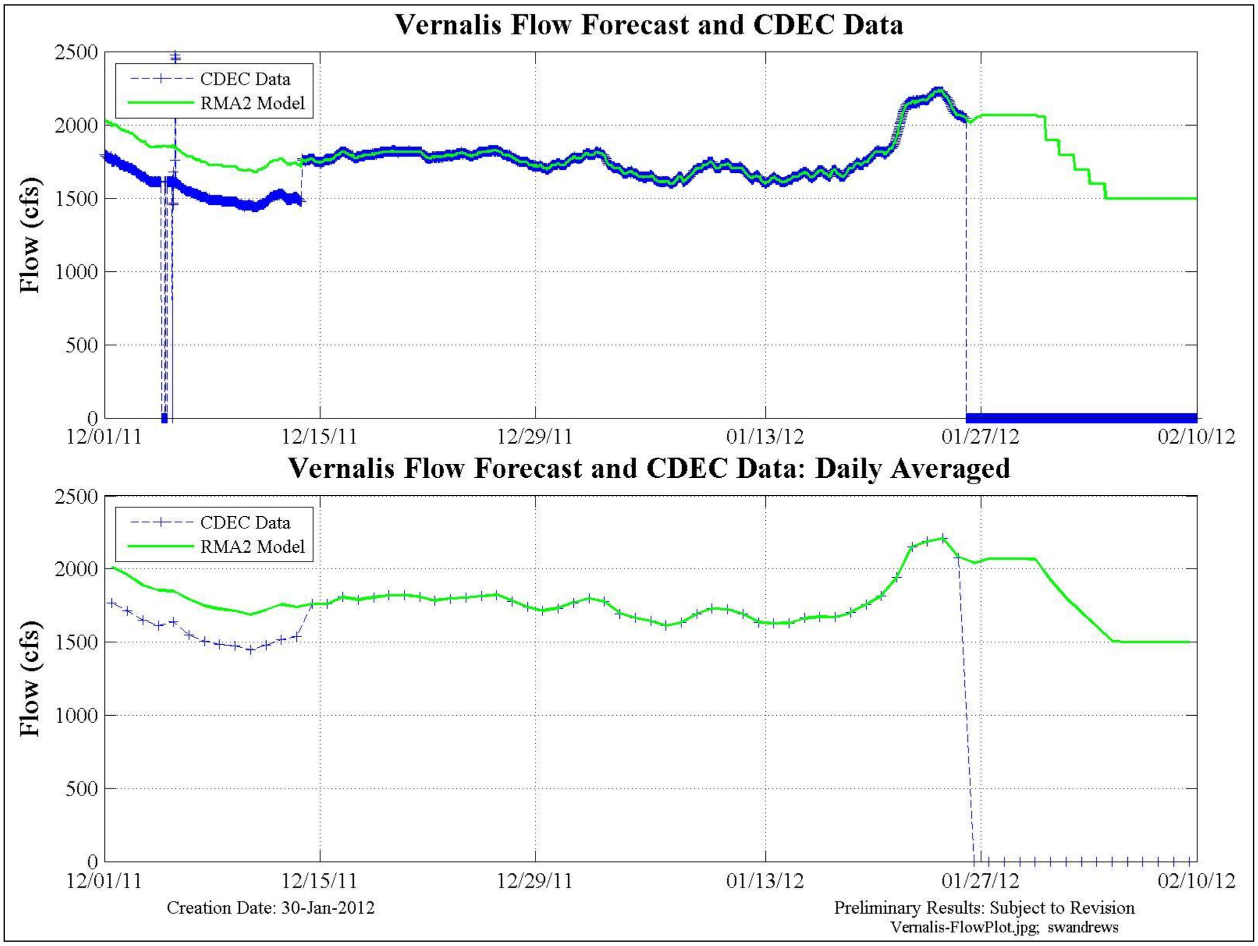

Figure 12-51 Vernalis flow BC was compiled using CDEC and USGS data and DWR DSM2 forecast flow. Zero values indicate the end of data (blue). The USGS rating for Vernalis changed Dec. 13, 2011 and is reflected in the RMA2 model flow. The flow was not shifted in the CDEC database prior to Dec. 13, 2011.

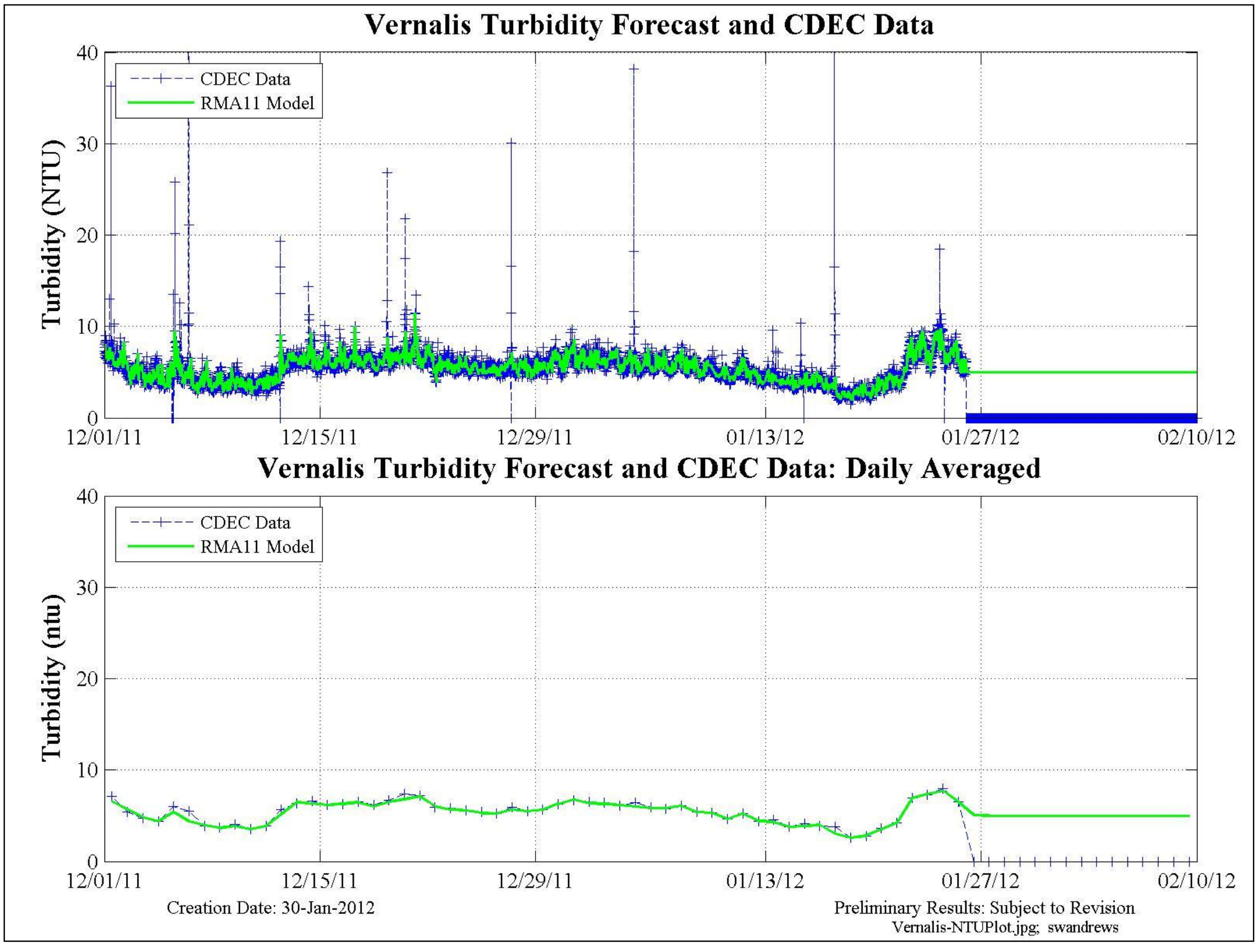

Figure 12-52 Vernalis turbidity BC was compiled using CDEC data, then extended as a constant. Zero values indicate the end of data (blue).

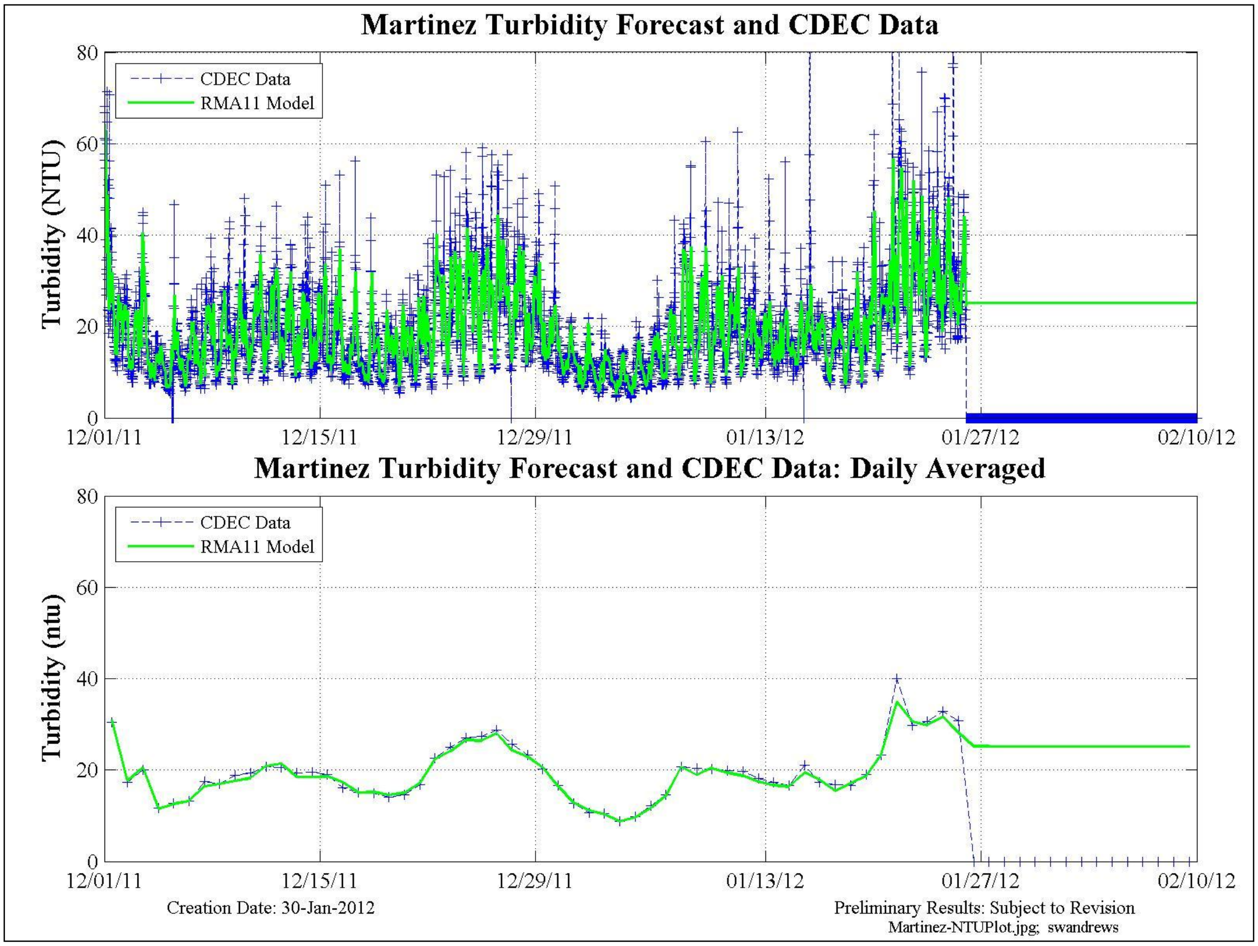

Figure 12-53 Martinez turbidity BC was compiled from CDEC data then extended linearly to a value of 25 NTU. Zero values indicate the end of data (blue).

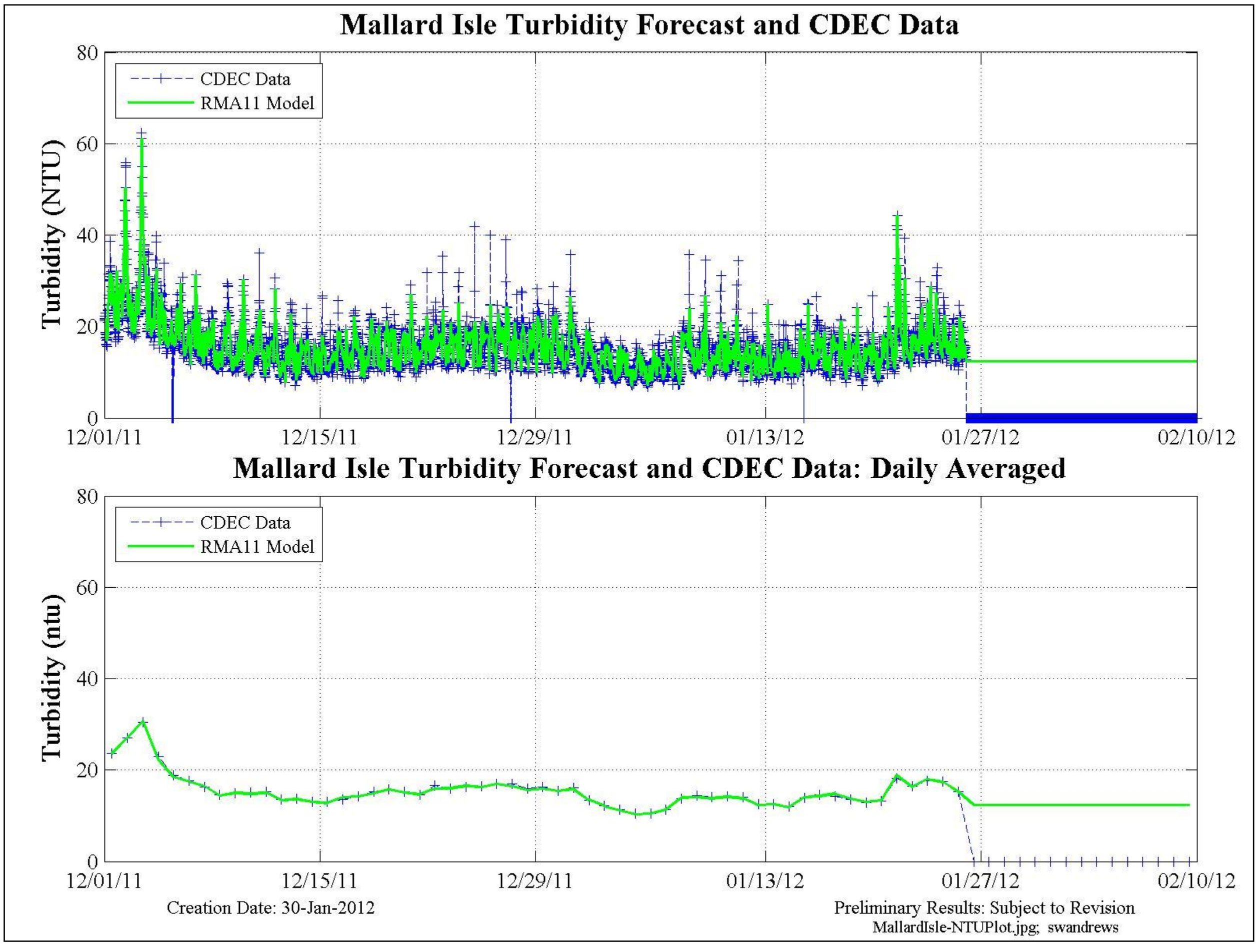

Figure 12-54 The Sacramento River at Mallard Island internal turbidity BC was compiled from CDEC data then extended linearly to a value of 12 NTU. Zero values indicate the end of data (blue).

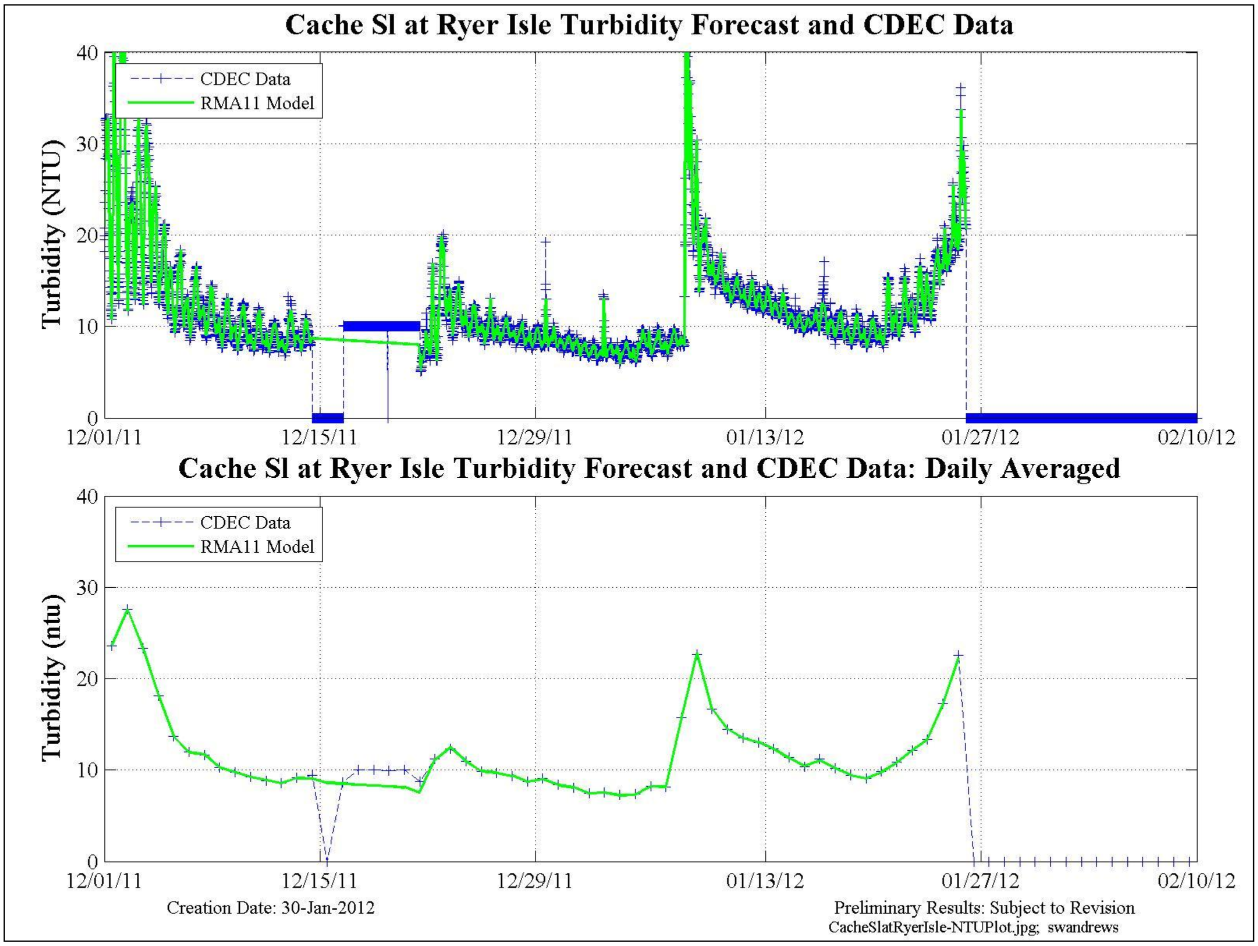

Figure 12-55 The Cache Slough at Ryer Island internal turbidity BC was compiled from CDEC data. The boundary condition was not applied beyond the end time of the observed data. Zero values indicate the end of data application period (blue).

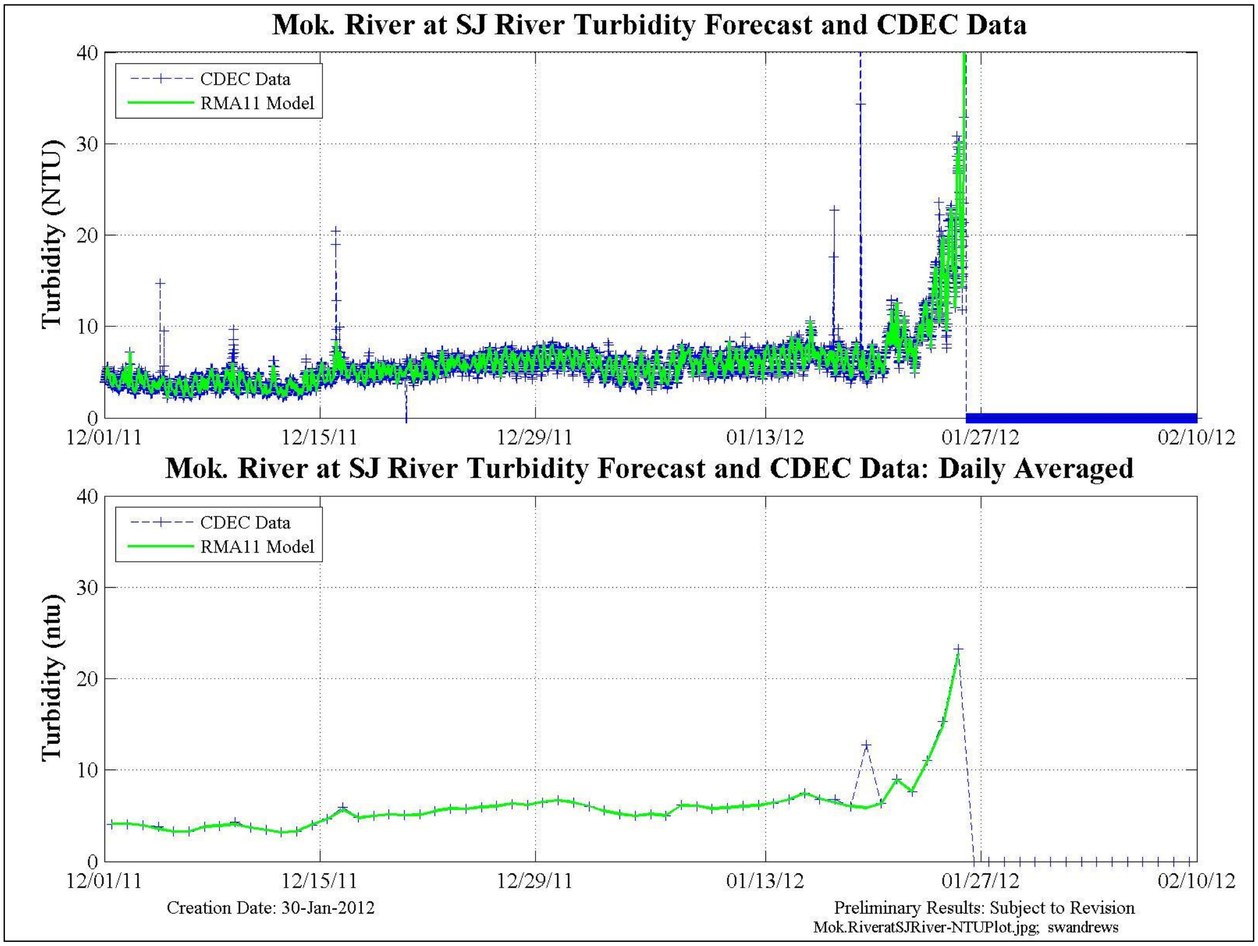

Figure 12-56 The Mokelumne River at the San Joaquin River confluence internal turbidity BC was compiled from CDEC data. The boundary condition was not applied beyond the end time of the observed data. Zero values indicate the end of data application period (blue).

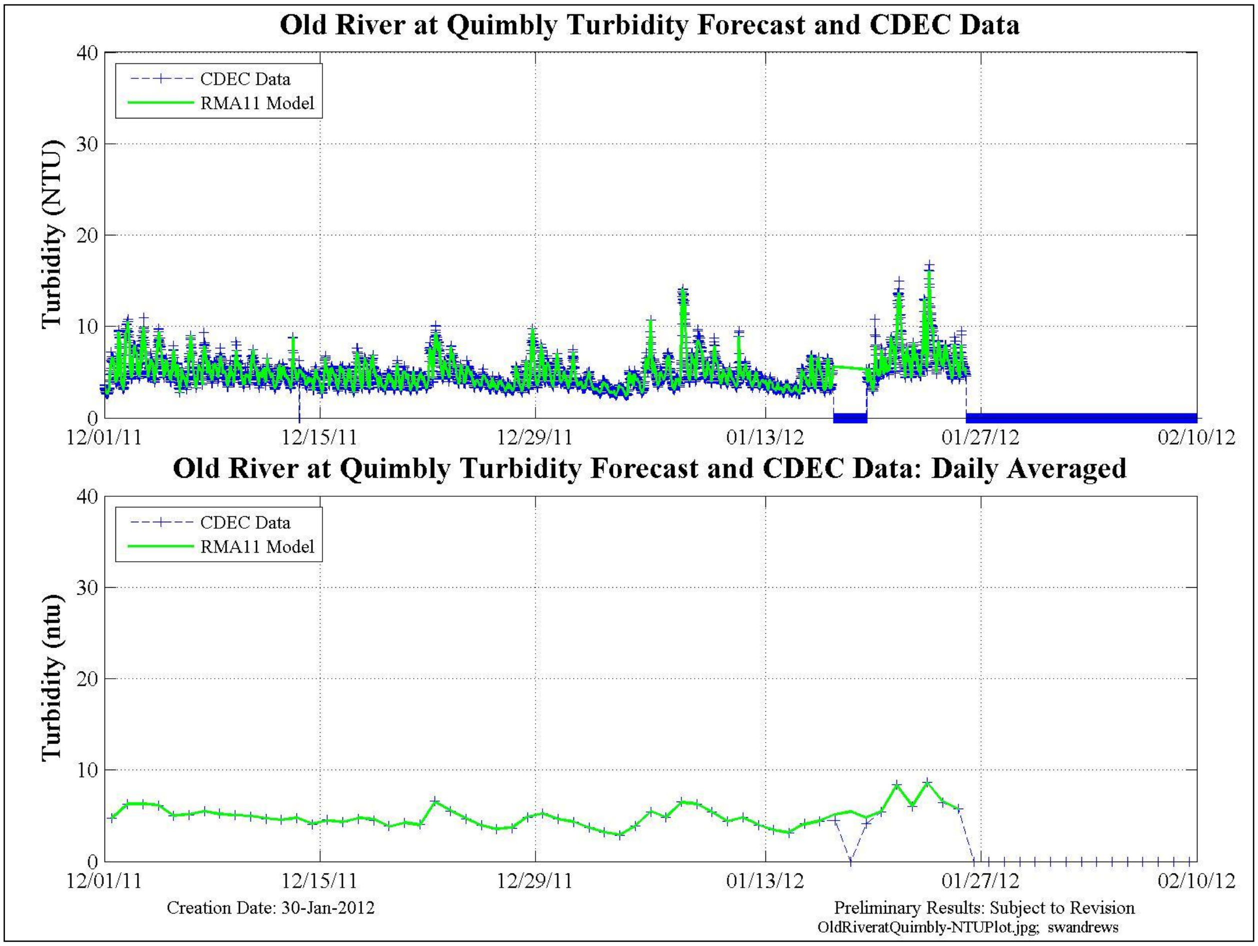

Figure 12-57 The Old River at Quimby Island internal turbidity BC was compiled from CDEC data. The boundary condition was not applied beyond the end time of the observed data. Zero values indicate the end of data application period (blue).

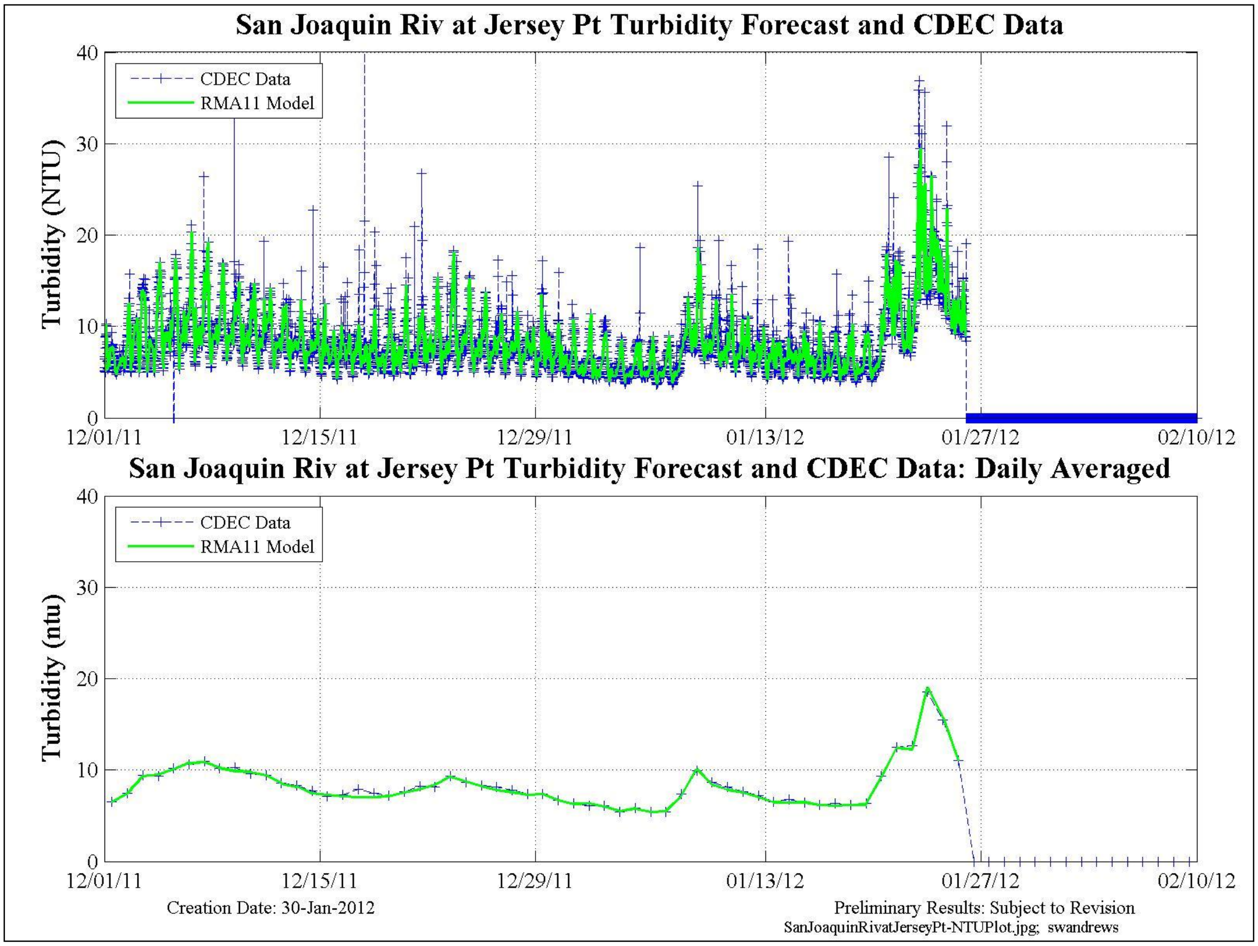

Figure 12-58 The San Joaquin River at Jersey Point internal turbidity BC was compiled from CDEC data. The boundary condition was not applied beyond the end time of the observed data. Zero values indicate the end of data application period (blue).

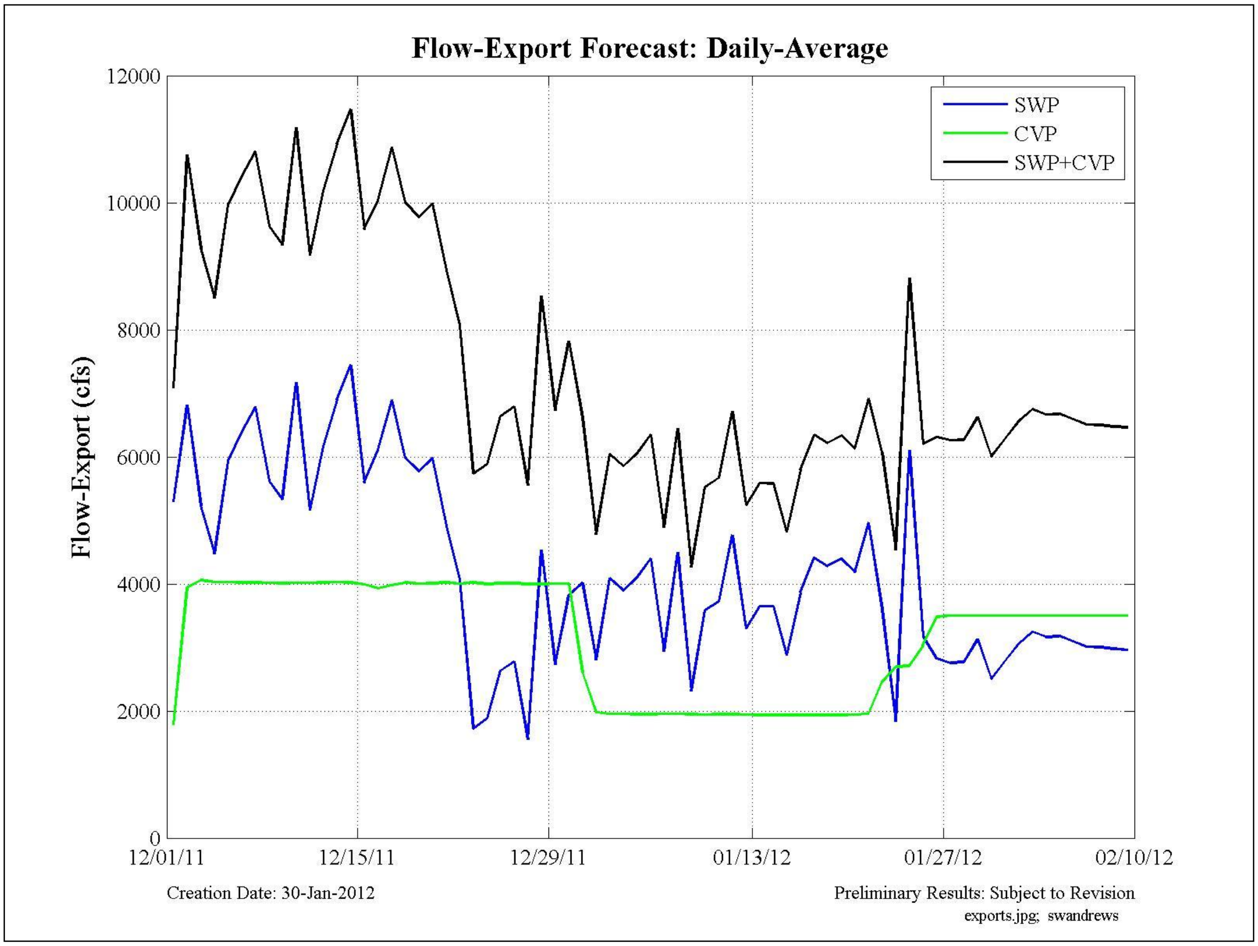

Figure 12-59 Historical and modeled daily-averaged exports at the SWP and CVP export locations, and the combined SWP+CVP exports.

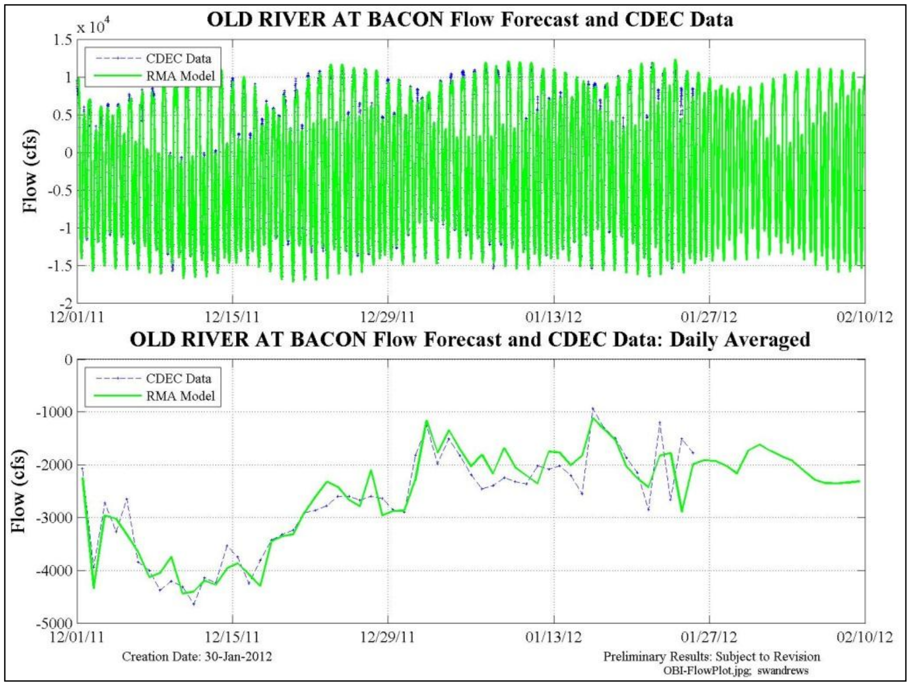

Figure 12-60 Model flow forecast output and raw CDEC data at Old River at Bacon (ROLD024) location. Both 15-min (upper) and daily averaged (lower) plots are shown.

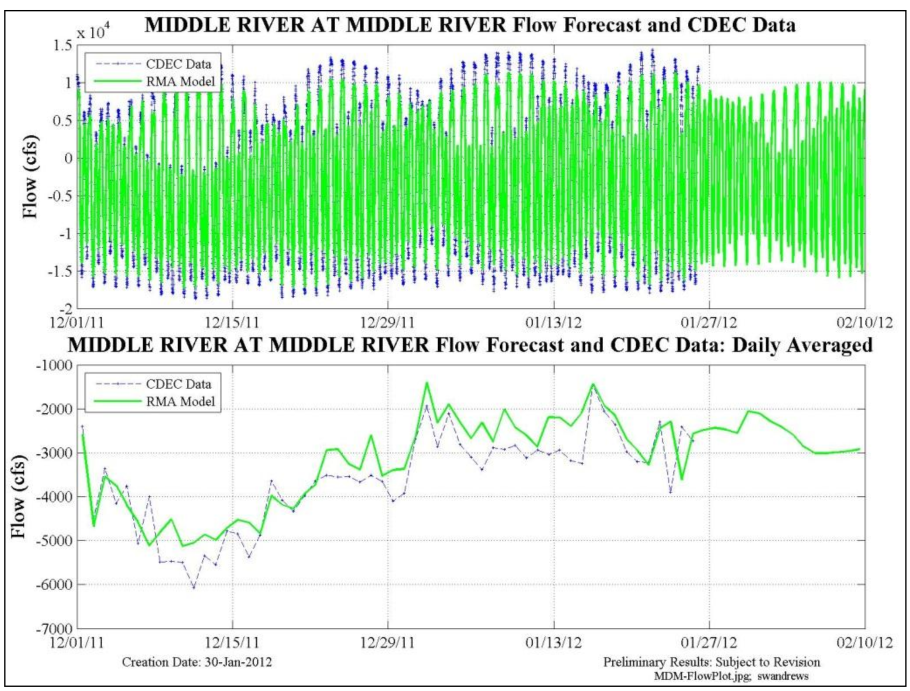

Figure 12-61 Model flow forecast output and raw CDEC data the Middle River-at-Middle (RMID015) location. Both 15-min (upper) and daily averaged (lower) plots are shown.

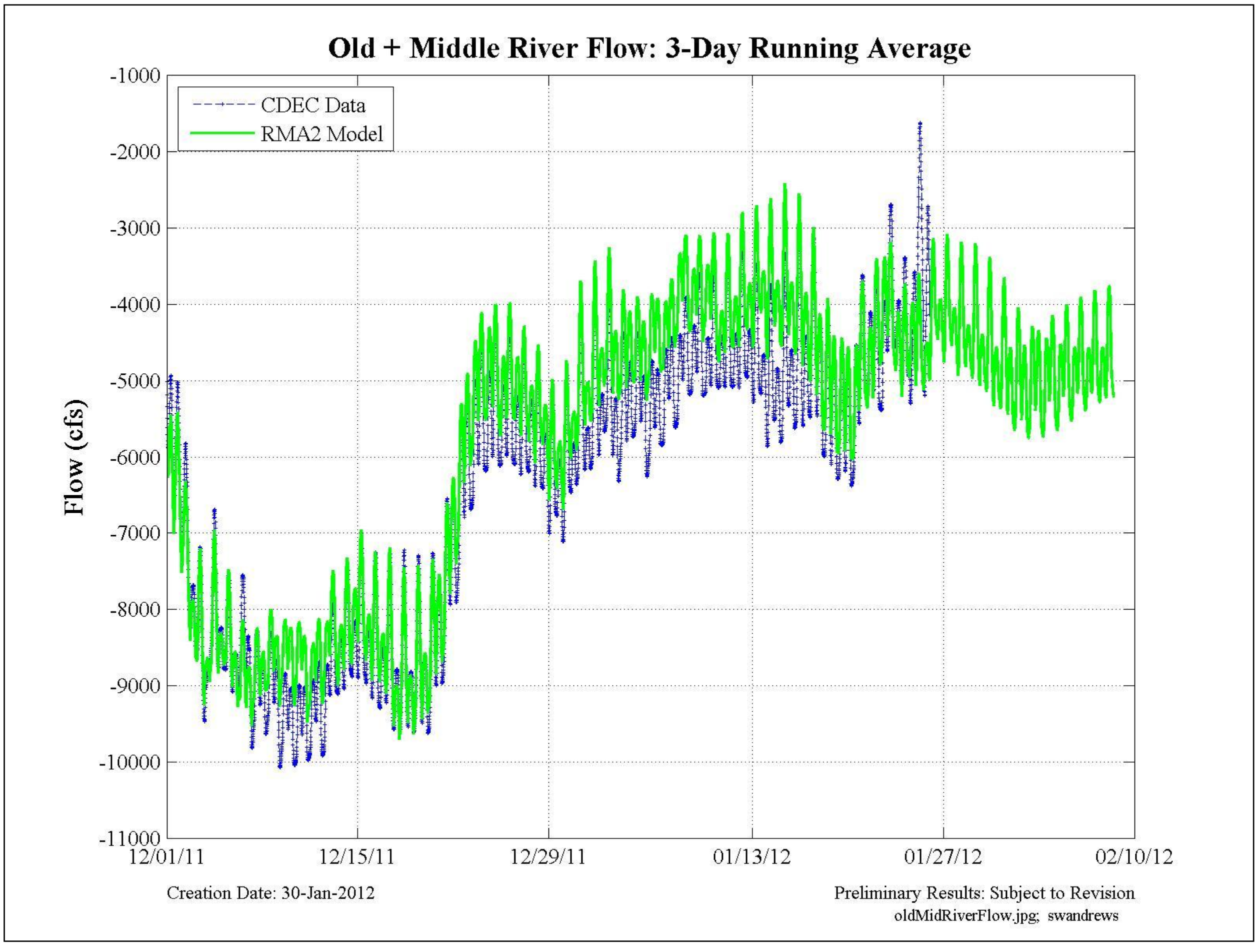

Figure 12-62 Model flow forecast output and raw CDEC data for the Old+Middle River flow criterion for three-day running-average flow.

Table 12-4 Boundary condition development for flow for this forecast period.

January 26, 2012	Historical DWR BC	Definition Historical Flow	Definition Forecast Flow	Comment
BC Location				
Yolo Bypass	Not used	Hourly CDEC LIS, cleaned+filled	Hourly CNRFC forecast (Yolo at Lisbon) for 5 days, constant 400cfs flow after	DWR flow prediction too low
Sacramento River at Freeport	Not used	Hourly CDEC FPT, cleaned+filled	Hourly CNRFC forecast (Sac R at I St.) for 5 days, Daily DSM2 RSAC155 results after, converted to hourly	
Mokelumne River	Daily DSM2 RMKL070, converted to hourly	Not used	Daily DSM2 RMKL070 results, converted to hourly	
Cosumnes River	Not used	Hourly CNRFC Cosumnes-McConnell, cleaned+filled	Hourly CNRFC forecast (Cosumnes R at McConnell) for 5 days, Daily DSM2 RCSM075 results after, converted to hourly	
Calaveras River	Not used	Hourly CDEC MRS, cleaned+filled	Daily DSM2 RCAL009 results, converted to hourly	Shifted CDEC data 28Nov-12Dec +37cfs to account for jump in data record
San Joaquin River at Vernalis	Not used	Hourly CDEC VNS, cleaned+filled	Hourly CNRFC forecast (SJ R at Vernalis) for 5 days, Daily DSM2 RSAN112 results after, converted to hourly	CDEC data shifted 240 cfs prior to Dec 13 to match USGS site data
Stage - Martinez	Not used	15min CDEC Martinez stage, cleaned+filled, and shifted -2.38 ft.	15min astronomically based DSM2 RSAC054	

Table 12-5 Boundary condition development for turbidity for this forecast period.

January 26, 2012	Definition Historical NTU	Definition Forecast NTU	Comment
BC Location			
Yolo Bypass	15min CDEC RYI, cleaned+filled, hourly averaged	linearly interpolated from last observed NTU to 10 NTU, then extended as constant	WARMF prediction too high
Cache Slough at Ryer internal BC	15min CDEC RYI, cleaned+filled, hourly averaged	not applied	
Sacramento River at Freeport	15min CDEC FPT, cleaned+filled, hourly averaged then shifted -15hrs to account for travel time from upstream boundary	WARMF	Constant value of 9.5NTU used between Dec. 1 and Dec. 27 because of FPT sensor problem
Mokelumne River	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	WARMF	
Cosumnes River	15min CDEC SMR, cleaned+filled, daily averaged then converted to hourly	WARMF	
Calaveras River	15min CDEC RRI, cleaned+filled, hourly averaged	extended as constant	
San Joaquin River at Vernalis	15min CDEC SJR, cleaned+filled, hourly averaged	extended as constant	
Mokelumne River at San Joaquin confluence internal BC	15min CDEC MOK, cleaned+filled, hourly averaged	not applied	
Old River at Quimbly Island internal BC	15min CDEC ORQ, cleaned+filled, hourly averaged	not applied	
San Joaquin at Jersey Pt internal BC	15min CDEC SJJ, cleaned+filled, hourly averaged	not applied	Not applied prior to Nov. 28 because of SJJ sensor problem
Sacramento River at Mallard Island internal BC	15min CDEC MAL, cleaned+filled, hourly averaged	extended as constant	
Martinez	15min CDEC MRZ, cleaned+filled, hourly averaged	extended as constant	

Table 12-6 Boundary condition development for EC for this forecast period.

January 26, 2012	Historical DWR BC	Definition Historical EC	Definition Forecast EC	Comment
BC Location				
Yolo Bypass	Not used	15min CDEC RYI, cleaned+filled, hourly averaged	extend as constant	
Sacramento River at Freeport	Not used	15min CDEC FPT, cleaned+filled, hourly averaged	WARMF	Shift back 10 hrs
Mokelumne River	Not used	15min CDEC SMR, cleaned+filled, filtered to remove tidal spikes in EC from the Sac River, daily averaged then converted to hourly	WARMF	Daily-avg to remove tidal variation, filter when when DCC open
Cosumnes River	Not used	15min CDEC SMR, cleaned+filled, filtered to remove tidal spikes in EC from the Sac River, daily averaged then converted to hourly	extend as constant	Daily-avg to remove tidal variation, filter when when DCC open
Calaveras River	Not used	15min CDEC RRI, cleaned+filled, hourly averaged	extend as constant	tidal variation not removed
San Joaquin River at Vernalis	Not used	15min CDEC SJR, cleaned+filled, hourly averaged	extend as constant	
Martinez	Not used	15min CDEC MRZ, cleaned+filled, hourly averaged	DWR forecast (quality.dss)	

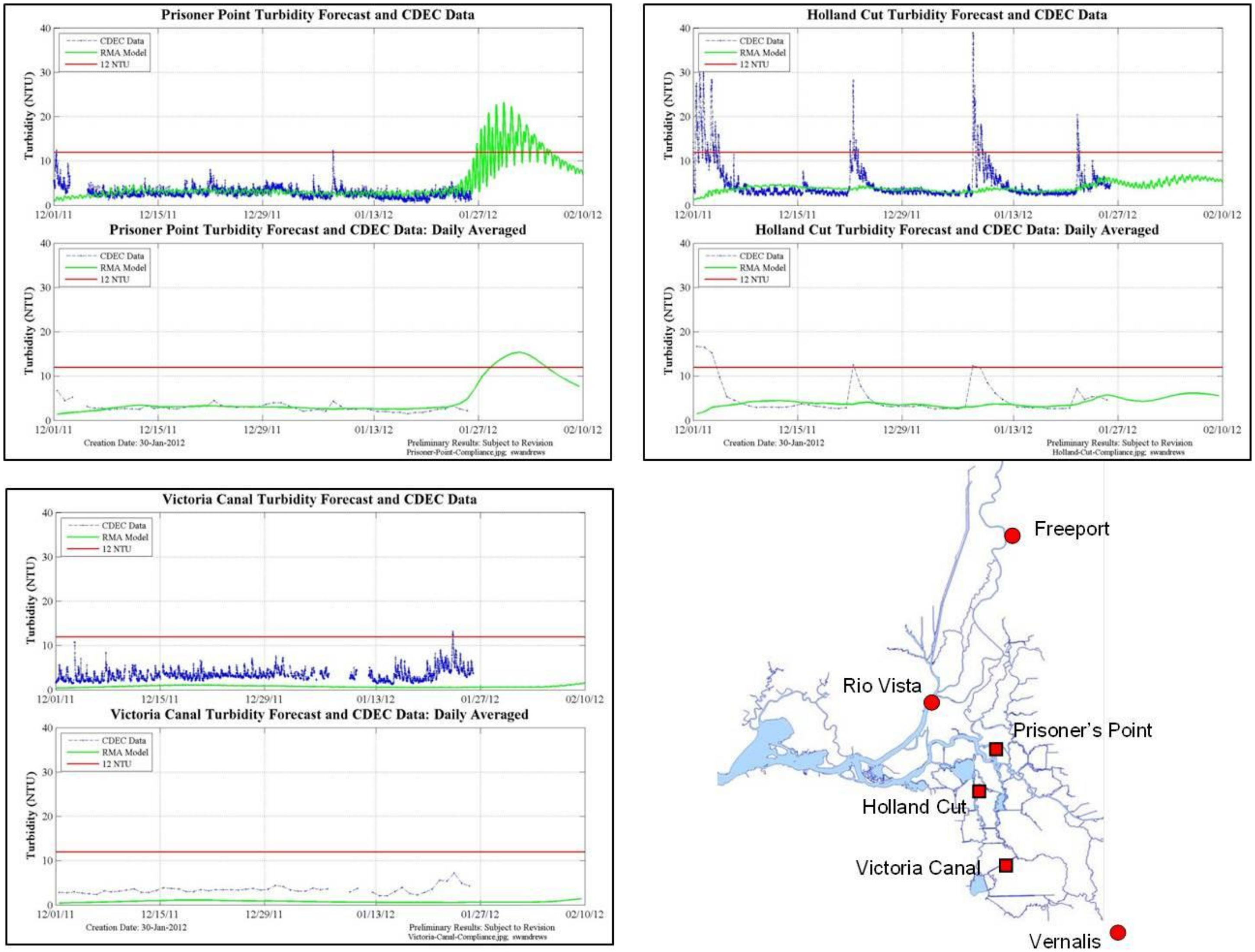

Figure 12-63 Modeled turbidity and data (cleaned and filled) at the three compliance locations. Both 15-min model output and data and daily averaged plots are shown. Red line illustrates the 12-NTU compliance value.

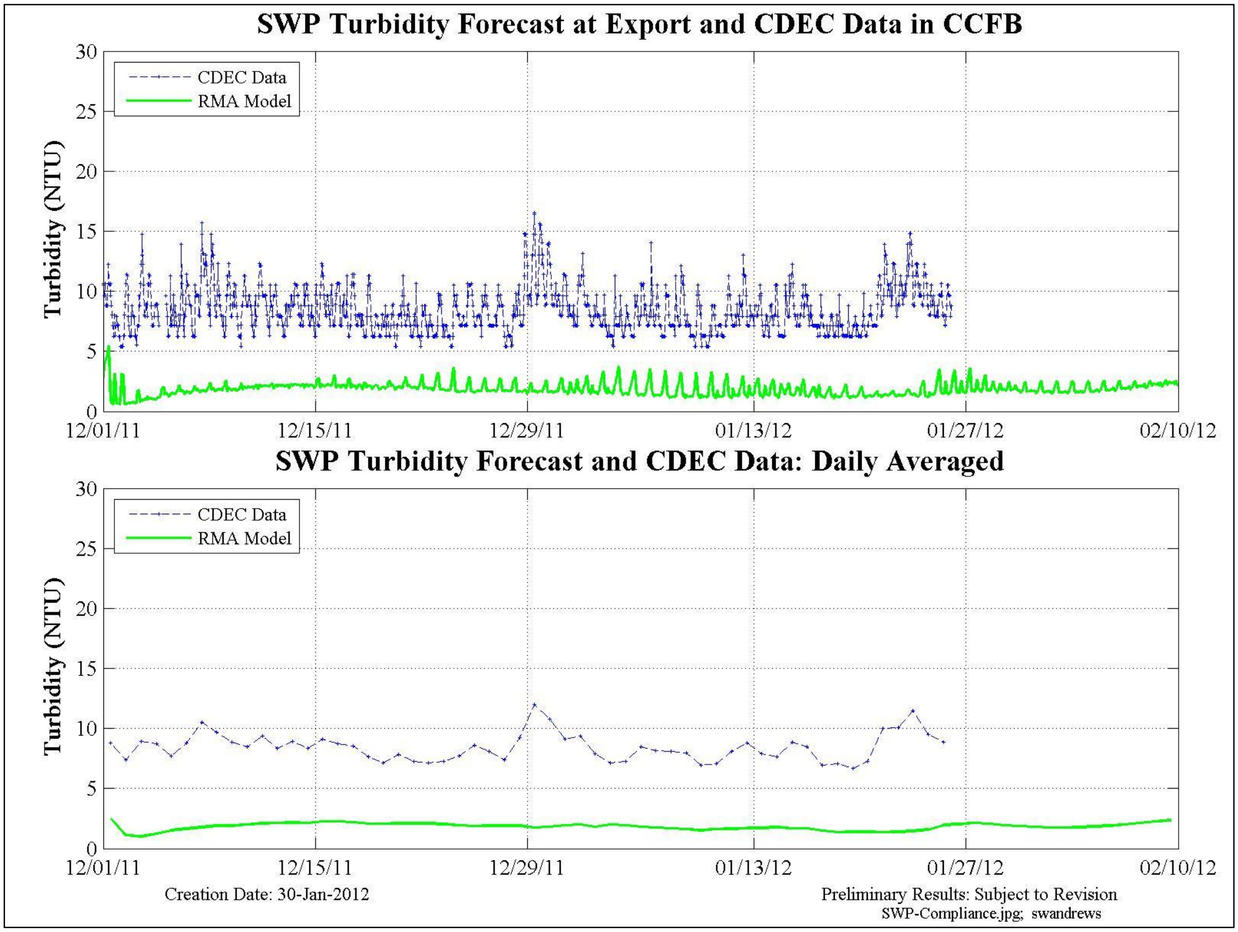

Figure 12-64 Plots compare model output at the SWP export location with data gathered inside Clifton Court Forebay. Both 15-min model output and daily averaged plots are shown.

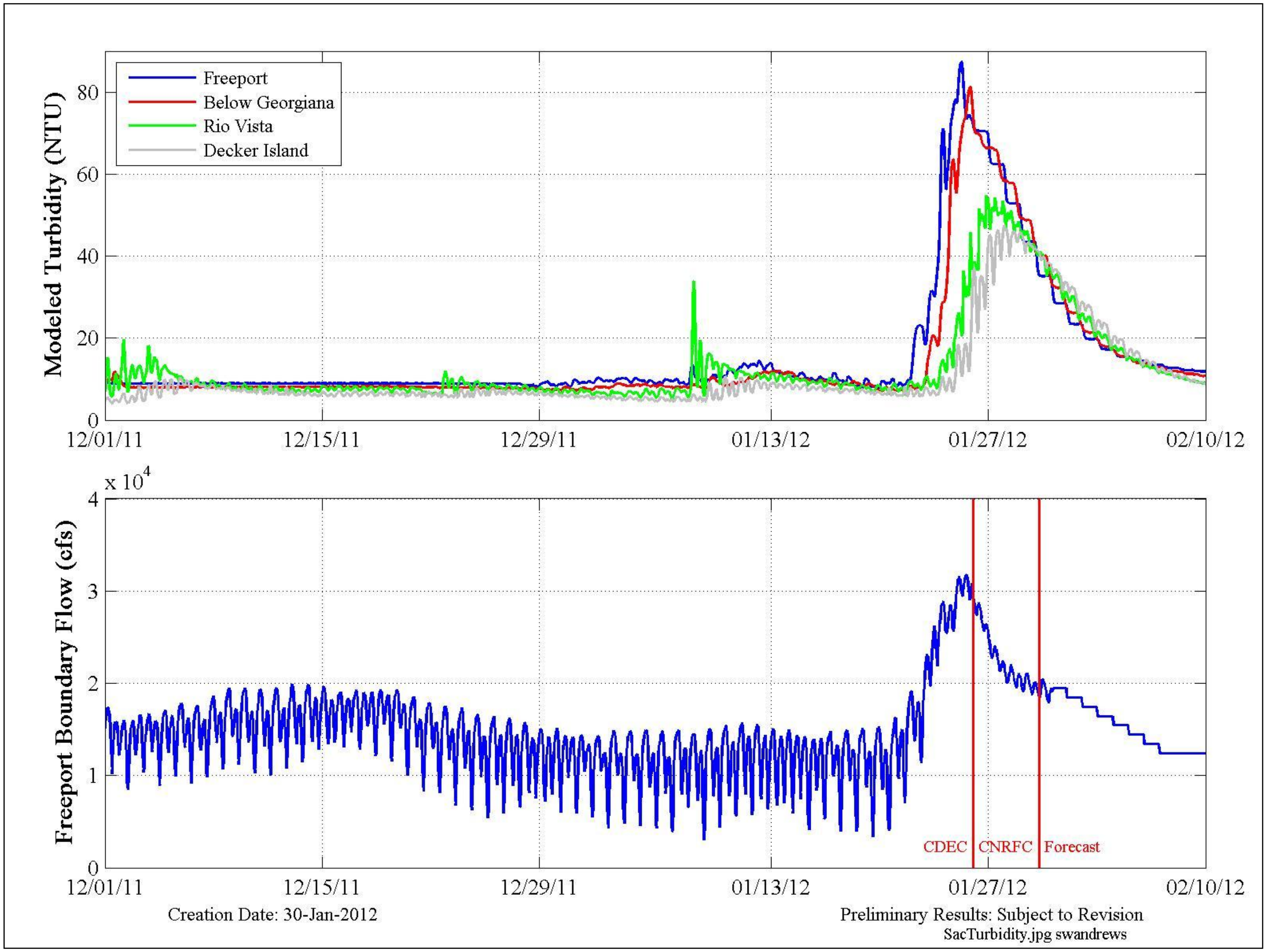

Figure 12-65 Freeport turbidity boundary condition progression down the Sacramento R. (upper plot) along with the flow boundary (lower plot) used during the historical and forecast periods. Forecast began on Jan. 26, 2012.

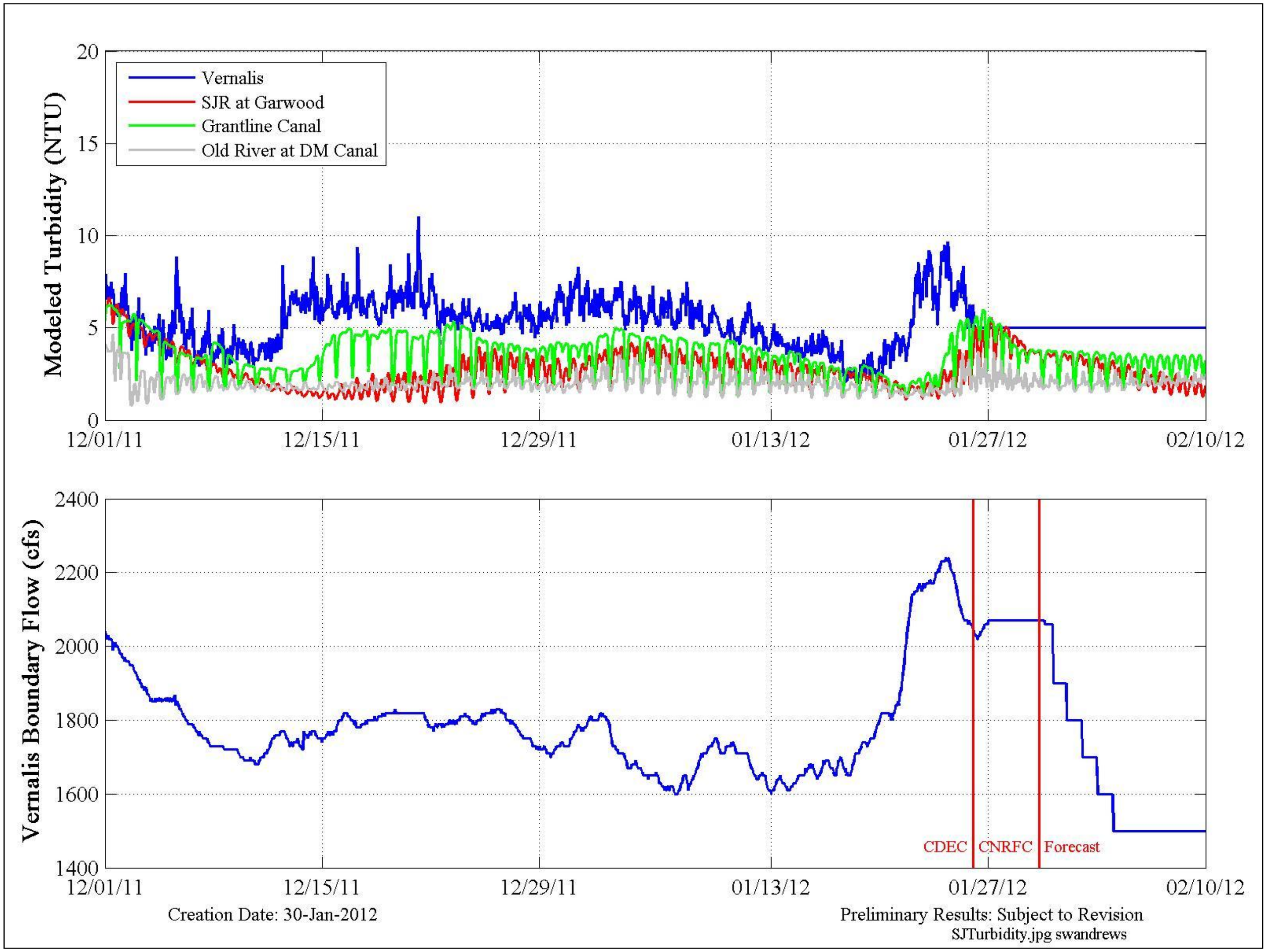

Figure 12-66 Progression of the turbidity boundary condition from Vernalis down the San Joaquin R. to Garwood, and down Old River. Vernalis flow forecast periods indicated by red lines (upper plot). Flow boundary conditions at Vernalis are shown in the lower plot.

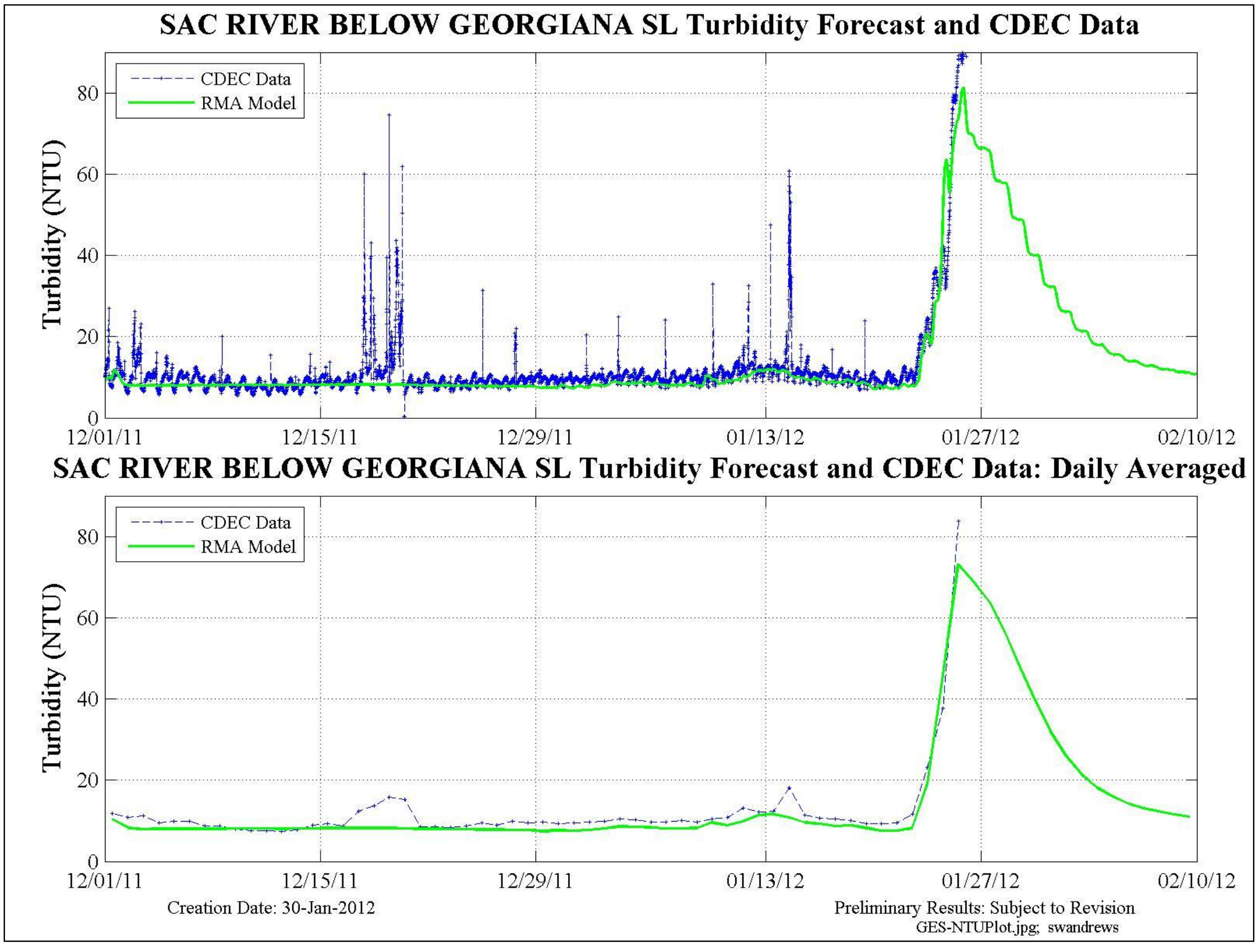

Figure 12-67 Model forecast and raw CDEC data at Sac. River Below Georgiana Sl. Both 15-min (upper) and daily averaged (lower) plots are shown.

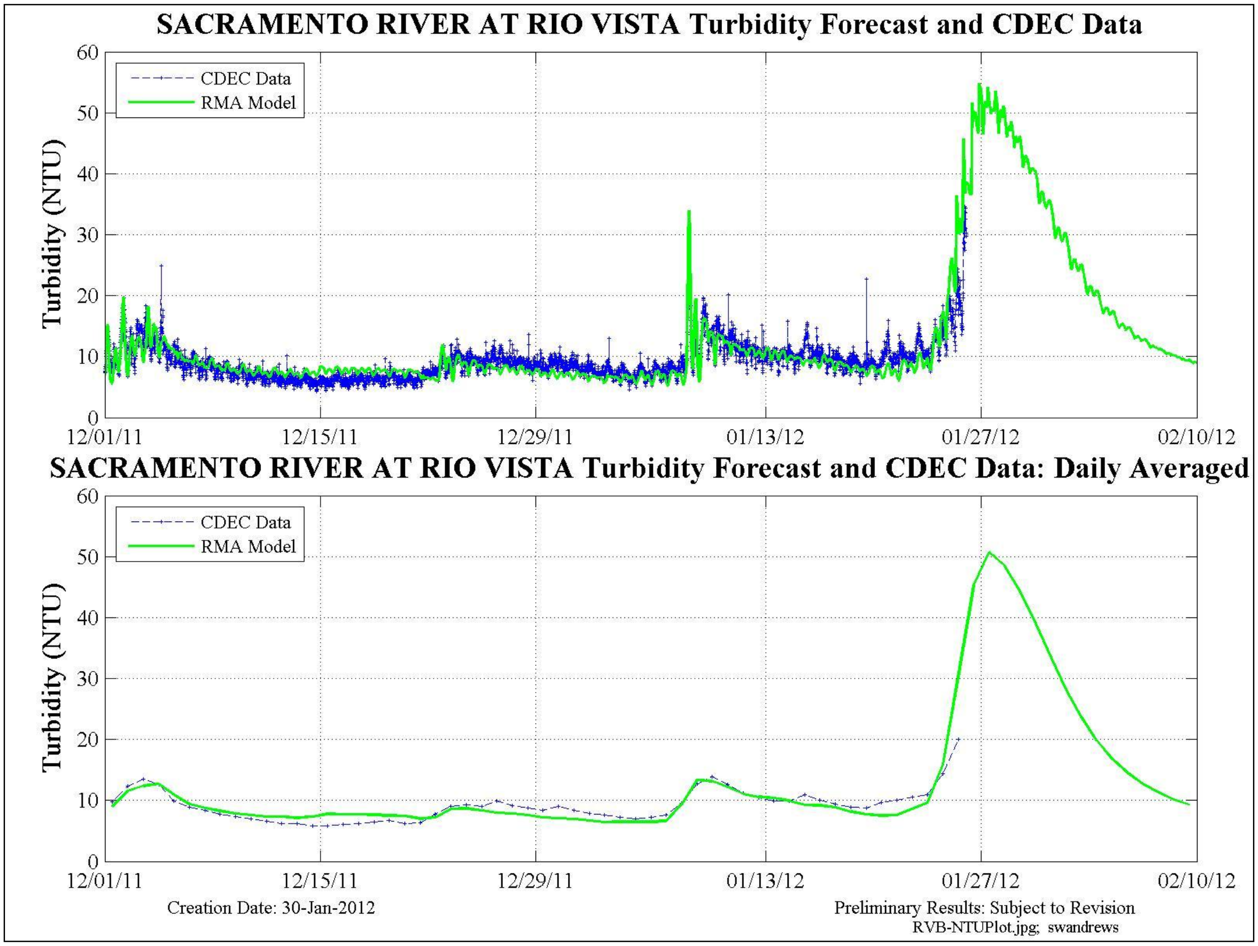

Figure 12-68 Model forecast and raw CDEC data at Rio Vista. Both 15-min (upper) and daily averaged (lower) plots are shown.

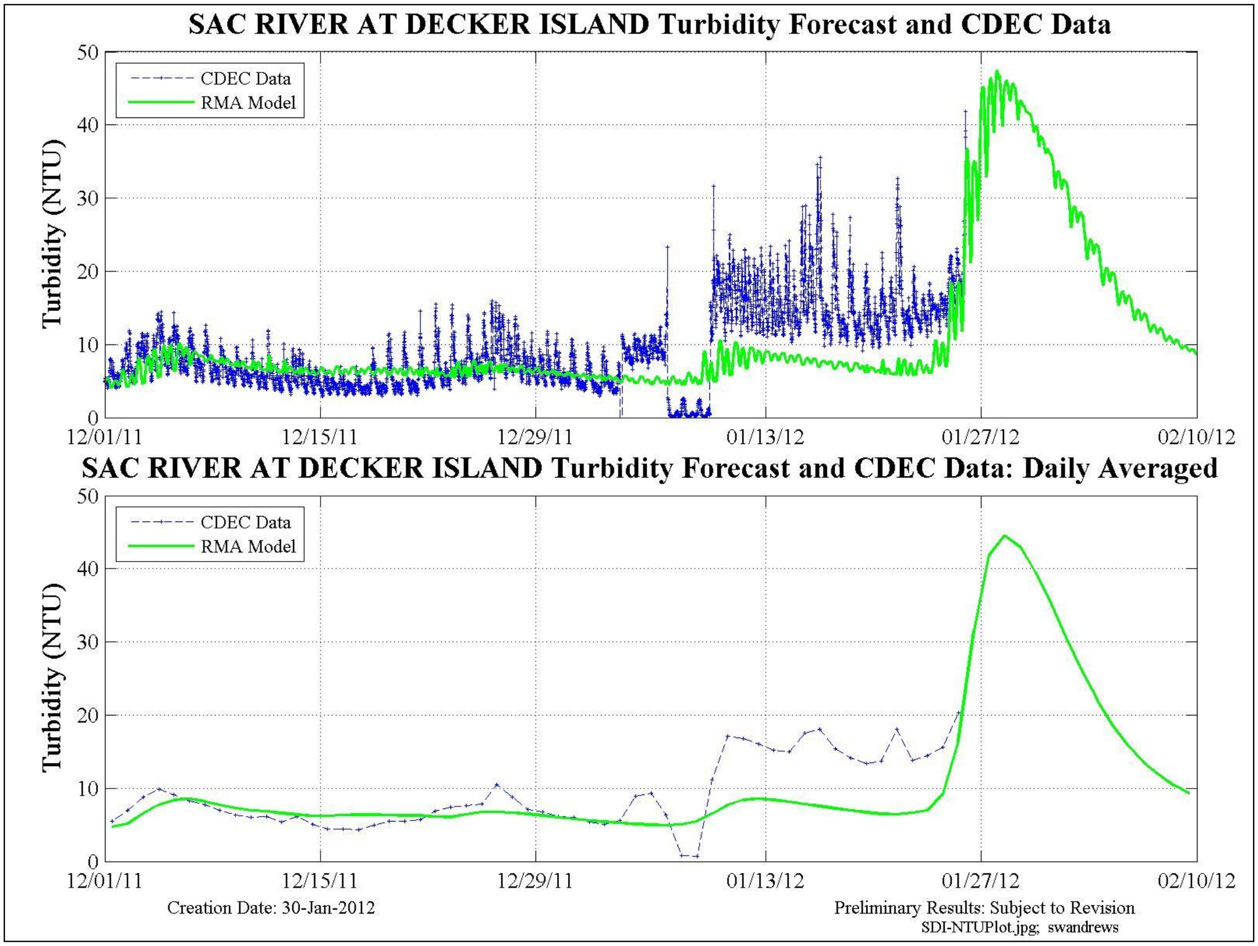

Figure 12-69 Model forecast and raw CDEC data at Decker Island. Both 15-min (upper) and daily averaged (lower) plots are shown.

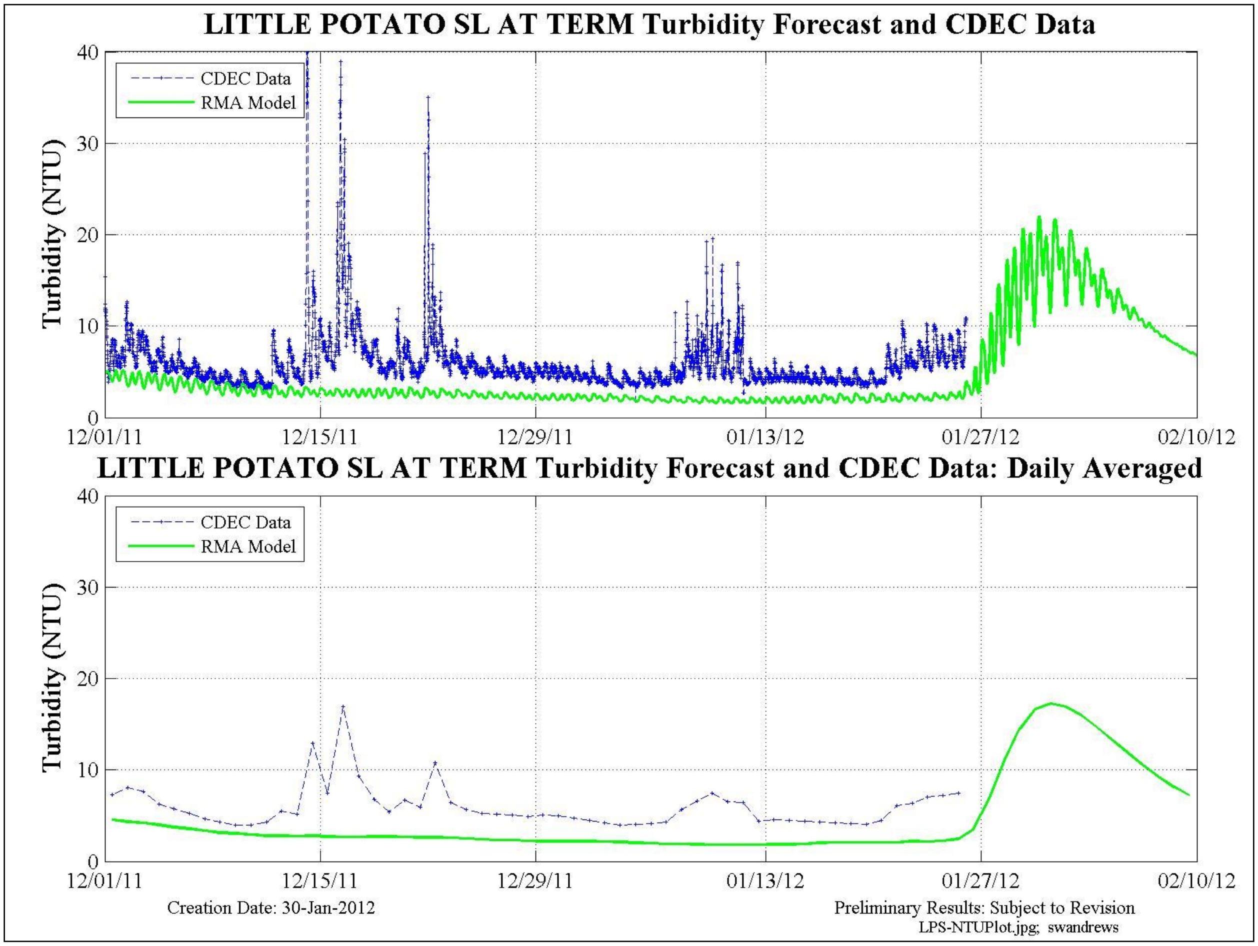

Figure 12-70 Model forecast and raw CDEC data at Little Potato Slough at Terminous. Both 15-min (upper) and daily averaged (lower) plots are shown.

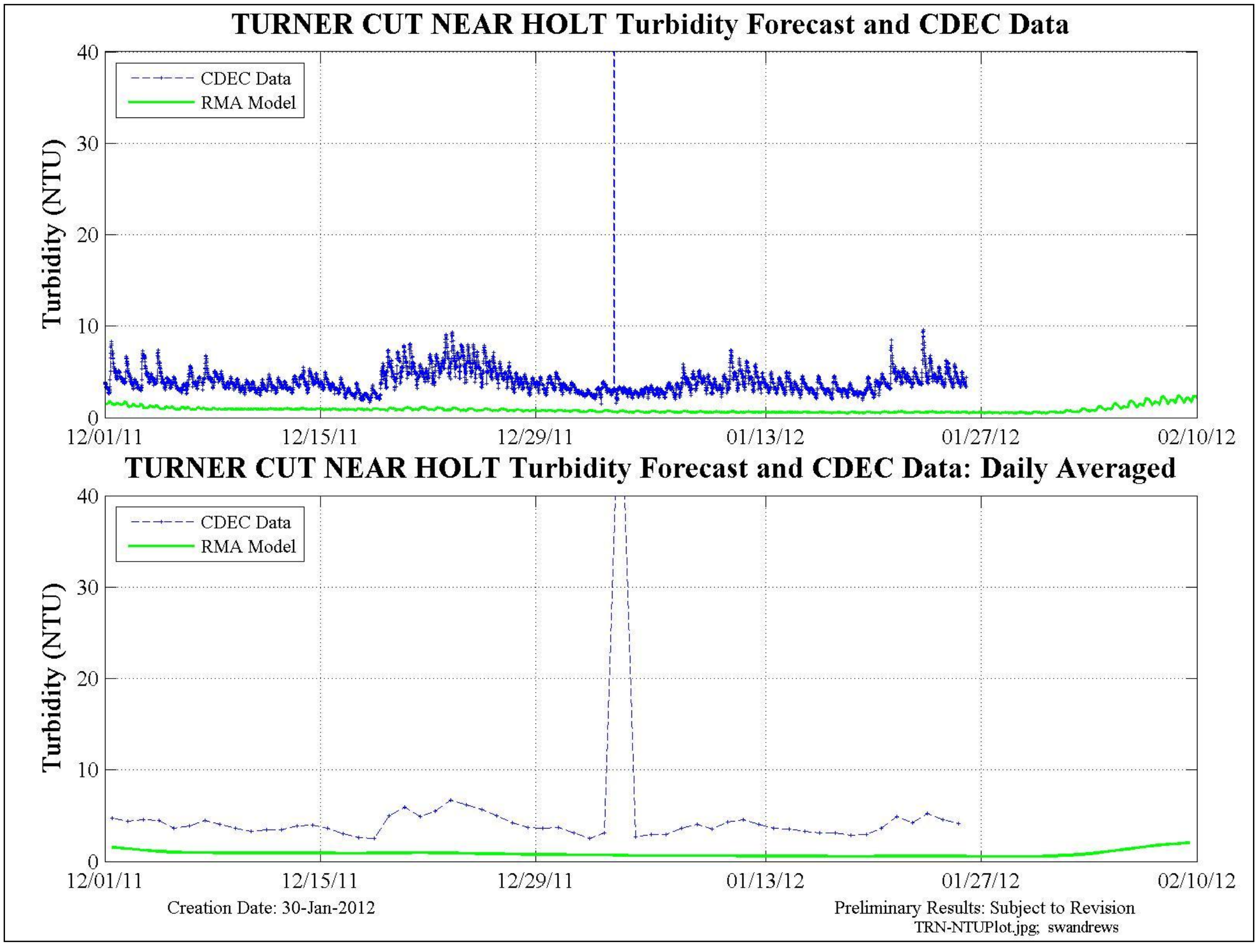

Figure 12-71 Model forecast and raw CDEC data at Turner Cut near Holt. Both 15-min (upper) and daily averaged (lower) plots are shown.

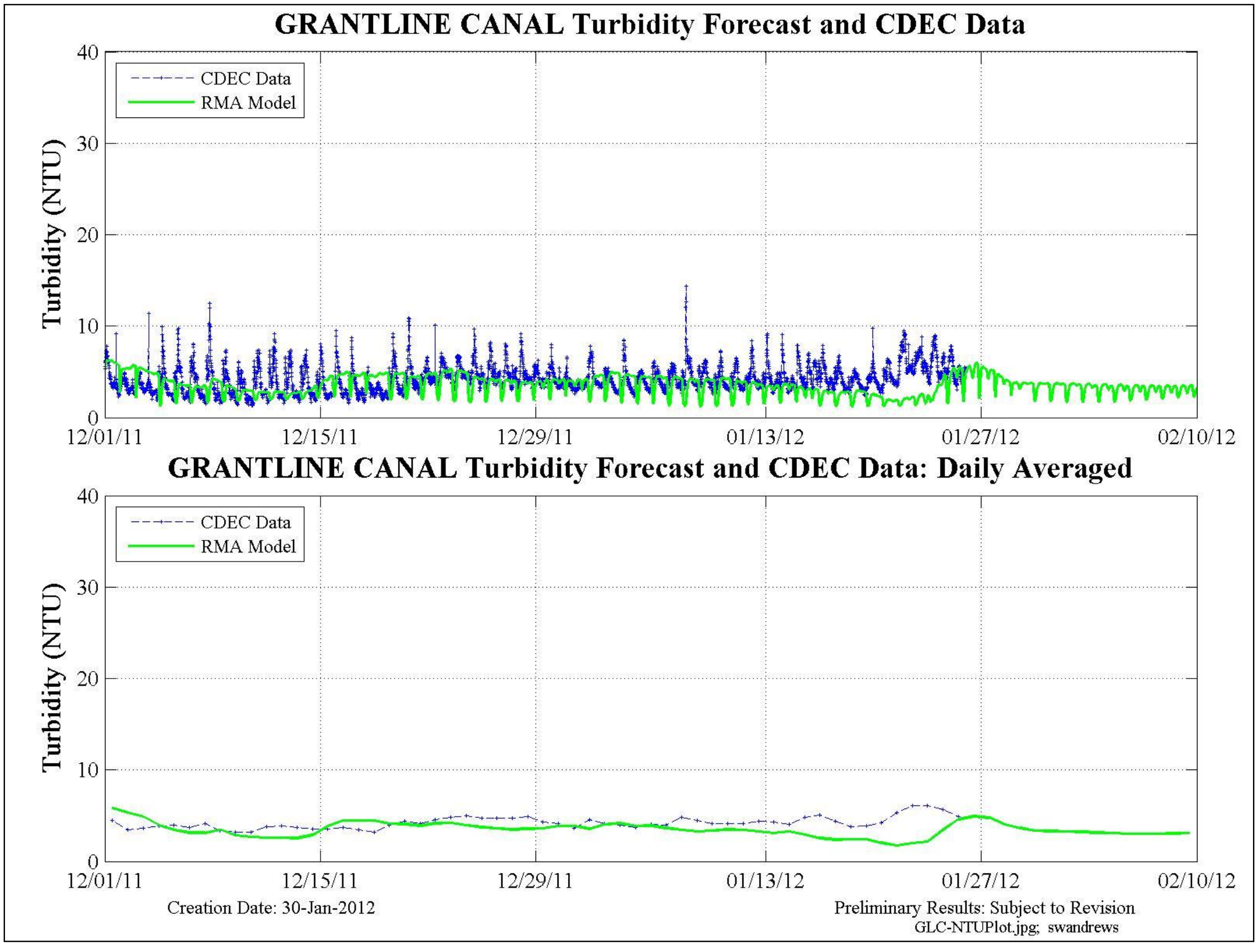

Figure 12-72 Model forecast and raw CDEC data at Grant Line. Both 15-min (upper) and daily averaged (lower) plots are shown.

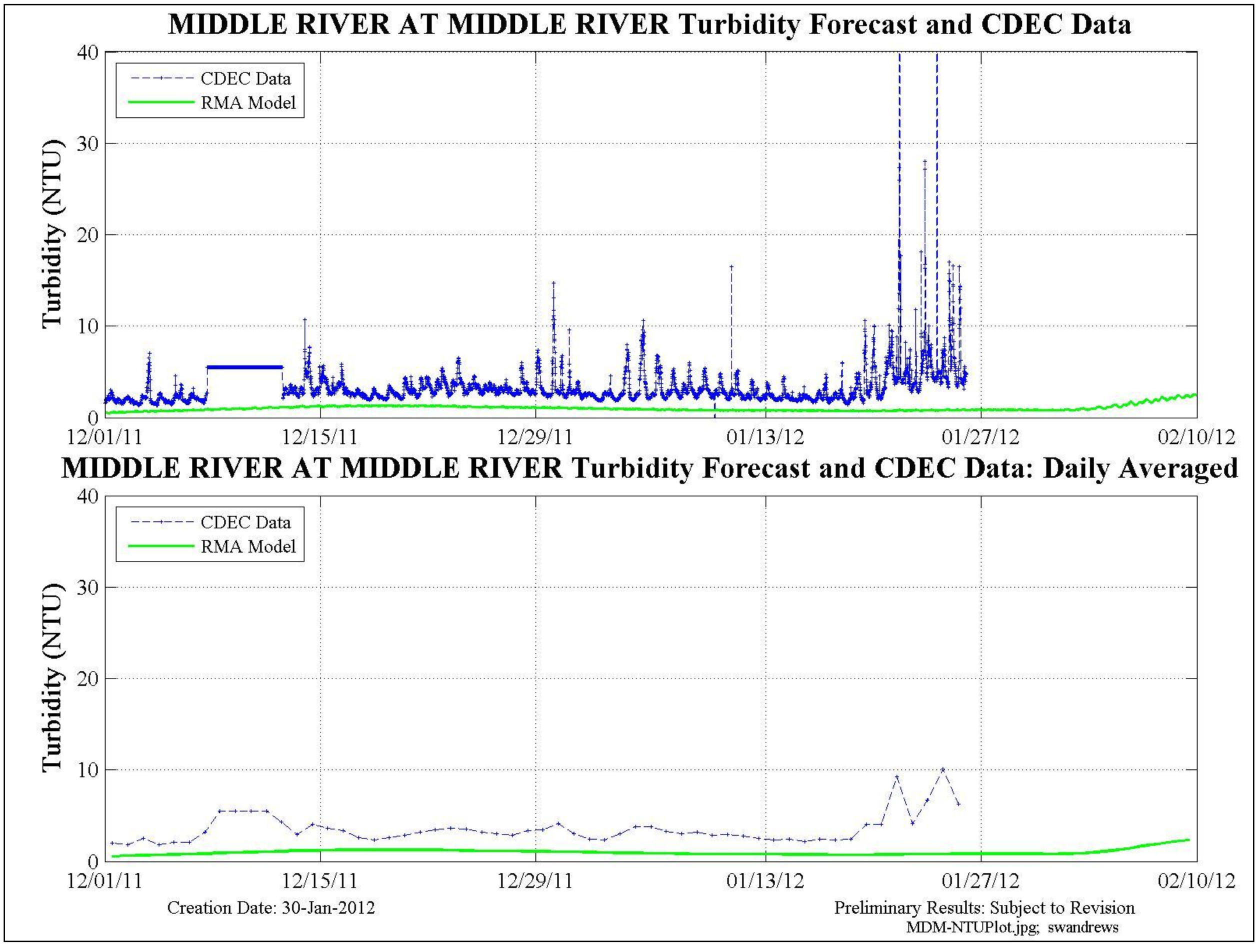

Figure 12-73 Model forecast and raw CDEC data at Middle R. at Middle R. Both 15-min (upper) and daily averaged (lower) plots are shown.

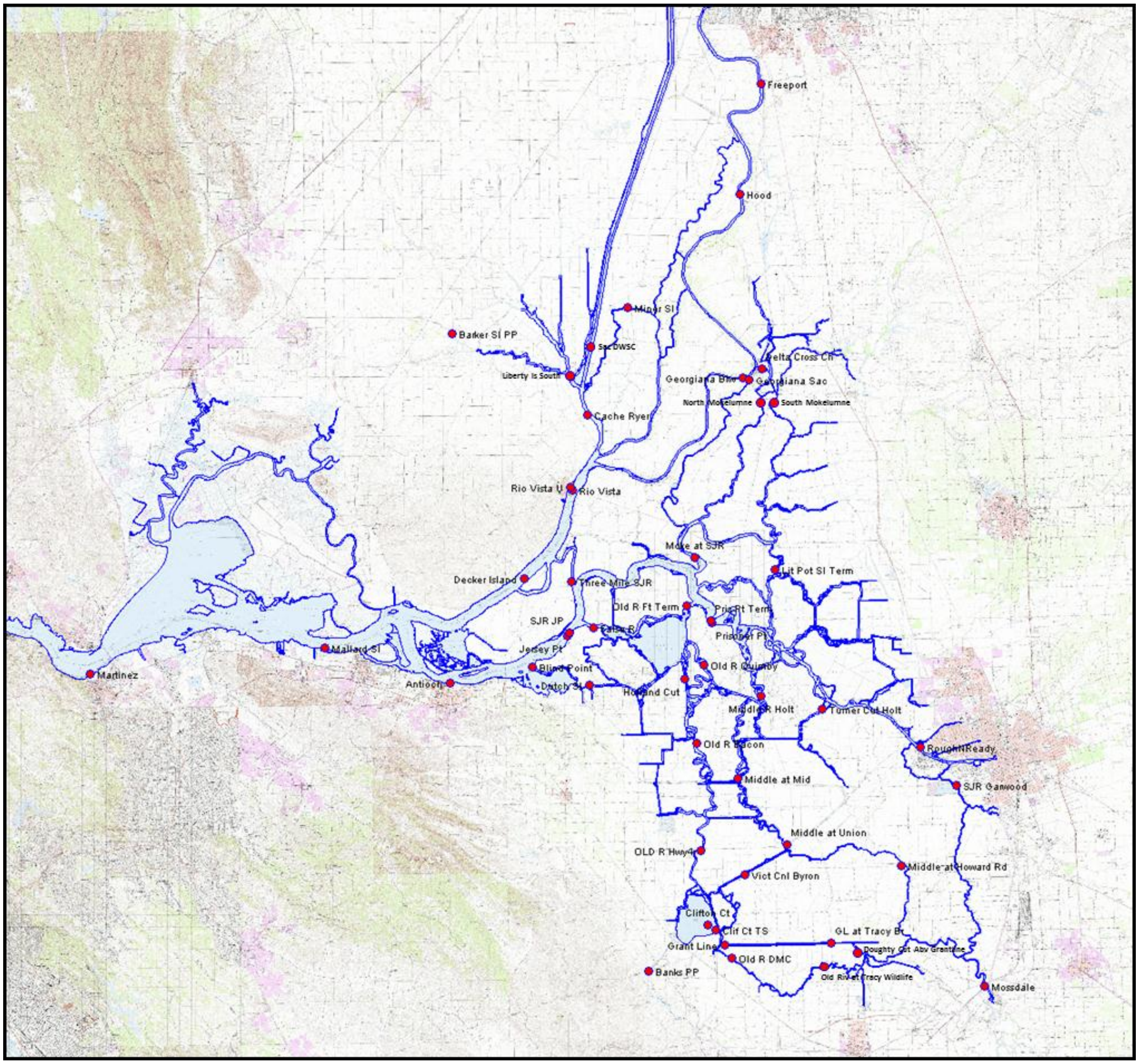

Figure 12-74 Figure illustrating model output and data collection locations.

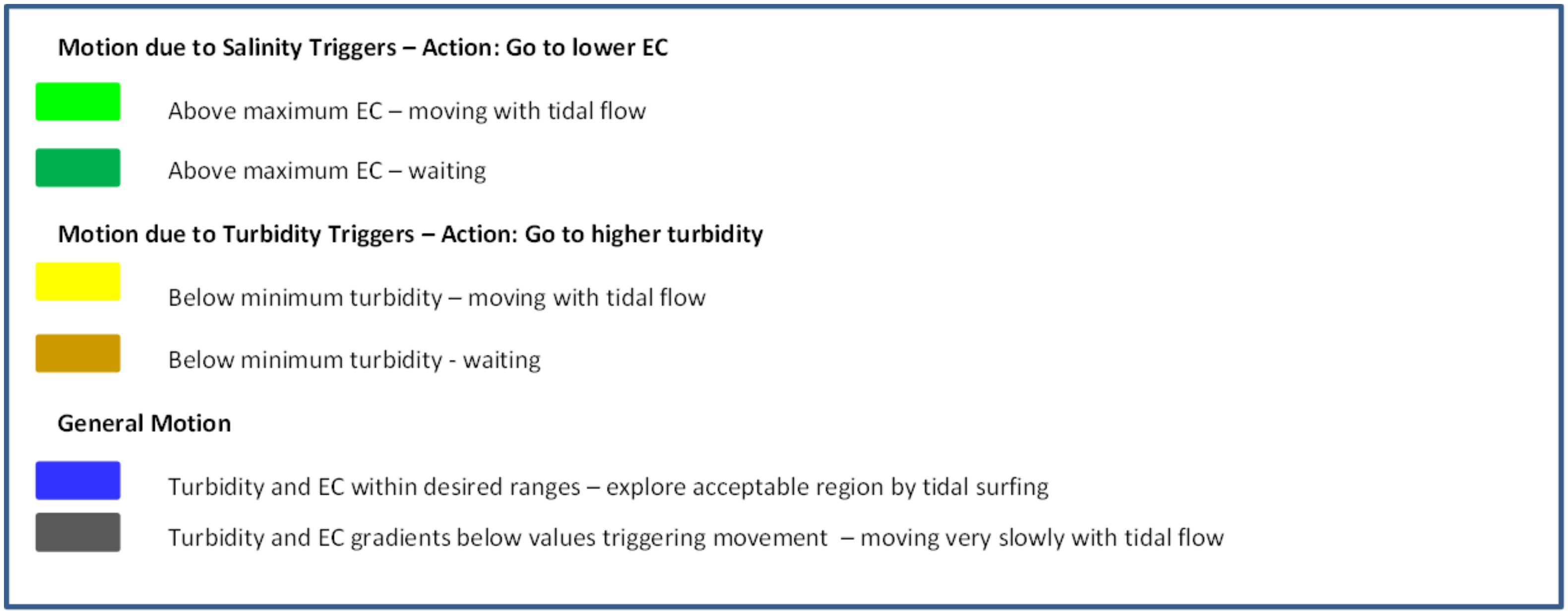

Figure 12-75 Particles in the Adult Delta Smelt particle tracking model are color-coded by the triggers influencing their behavior during the simulation. Use this figure to interpret the simplified color scale in the next three figures.

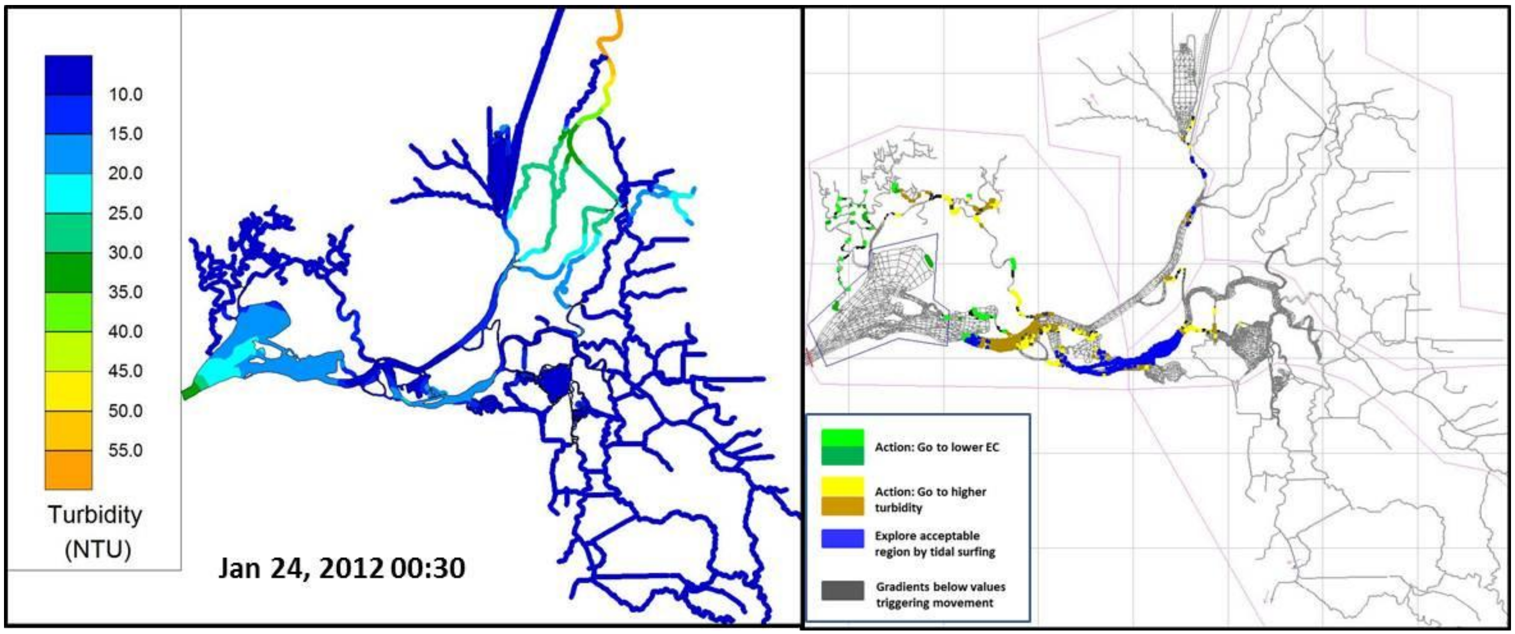

Figure 12-76 Turbidity contours and particle location in the RMA model grid on Jan. 24, 2012.

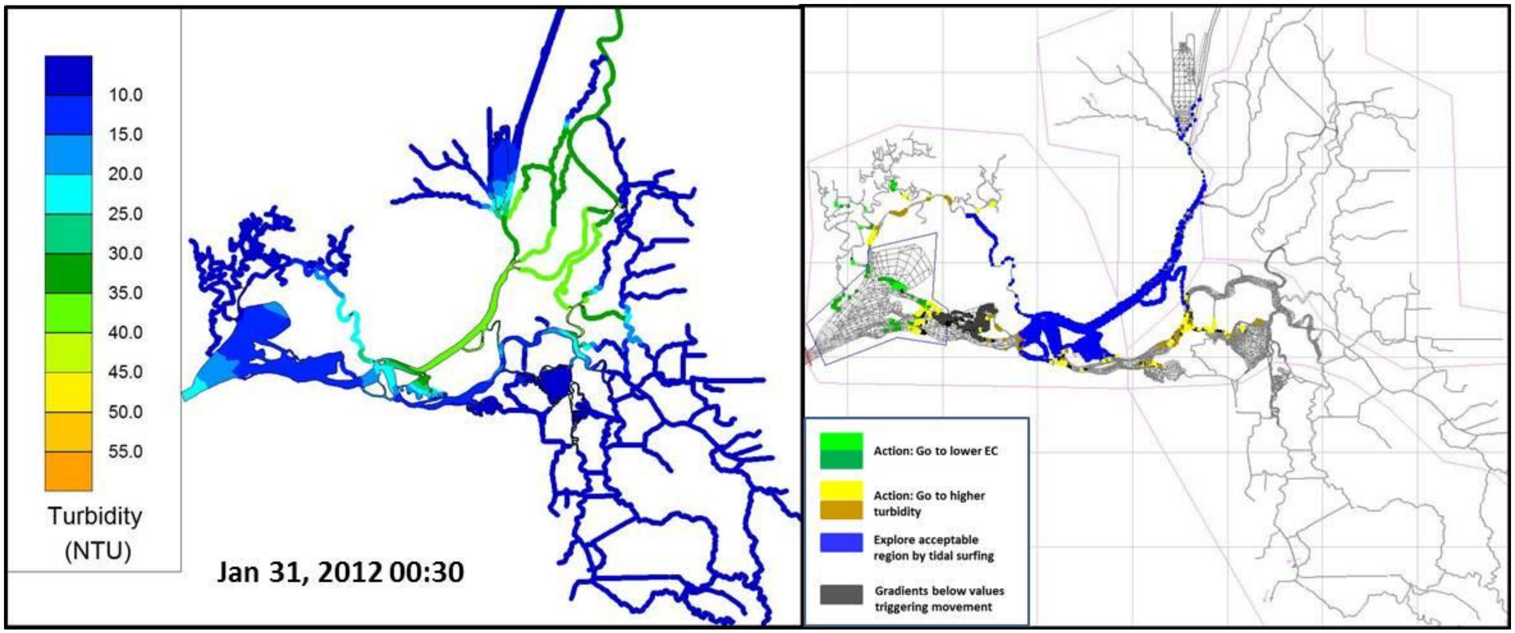

Figure 12-77 Turbidity contours and particle location in the RMA model grid on Jan. 31, 2012.

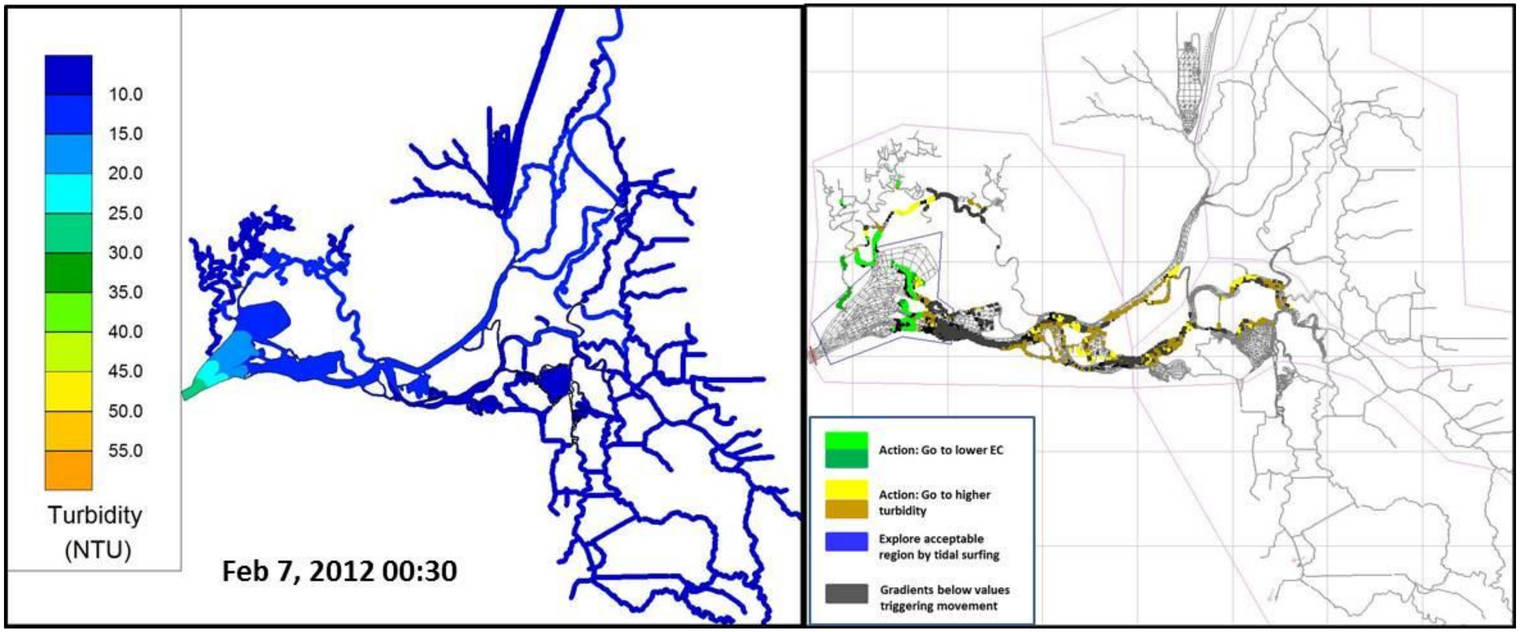

Figure 12-78 Turbidity contours and particle location in the RMA model grid on Feb. 7, 2012.

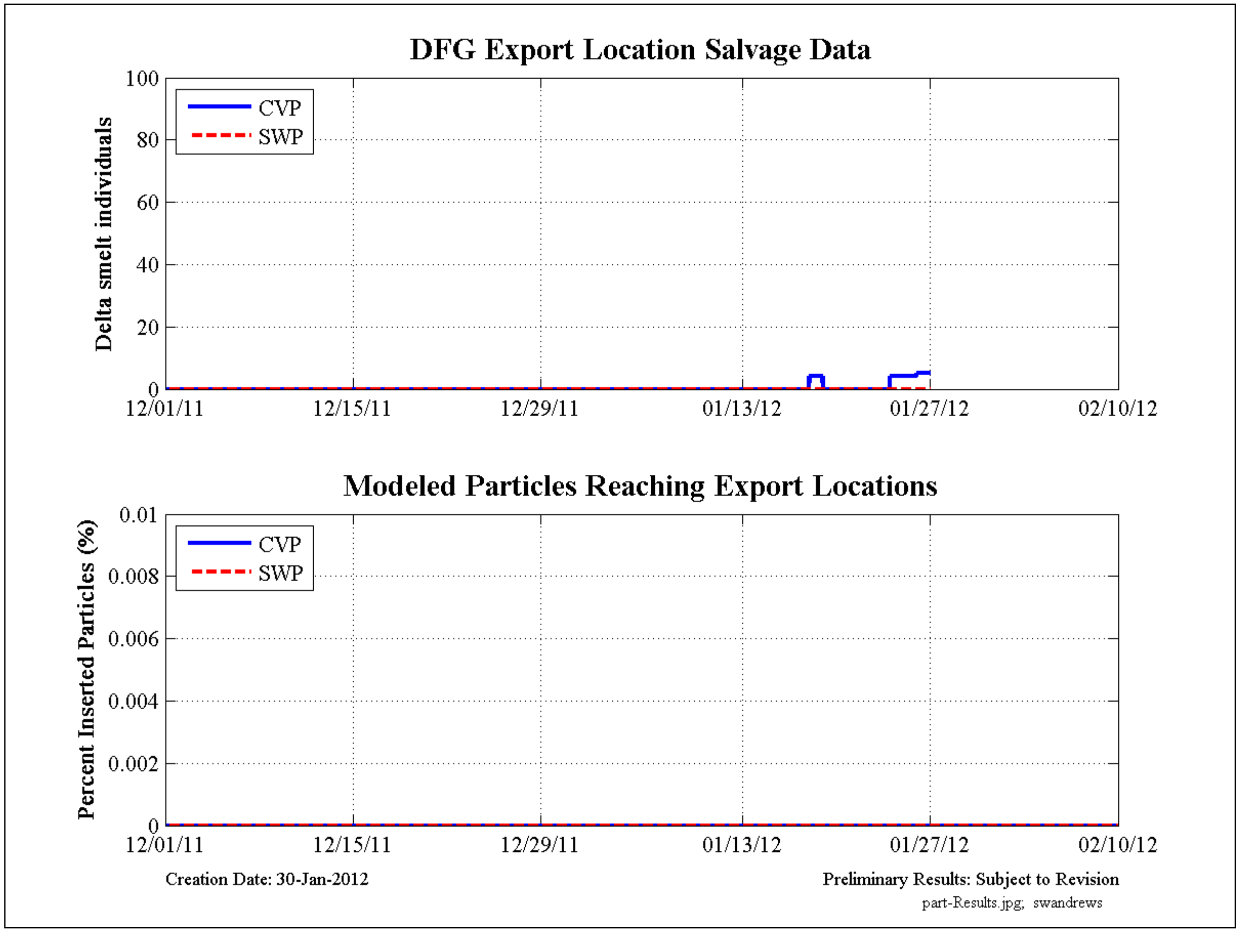

Figure 12-79 Comparison of DFG export location delta smelt salvage data (top) and RMA adult delta smelt particle tracking behavioral model results (bottom).

13 Delta Smelt Monitoring Areas Appendix

13.1 Background

For weekly forecast write-ups starting in January 2012, coarser regions were used to display the particle tracking results than were used in previous forecasts. Figure 13-1shows the original 26 smelt tracking regions, used prior to January 2012 and in forecasting for previous water years. The five new regions are shown in Figure 13-2.

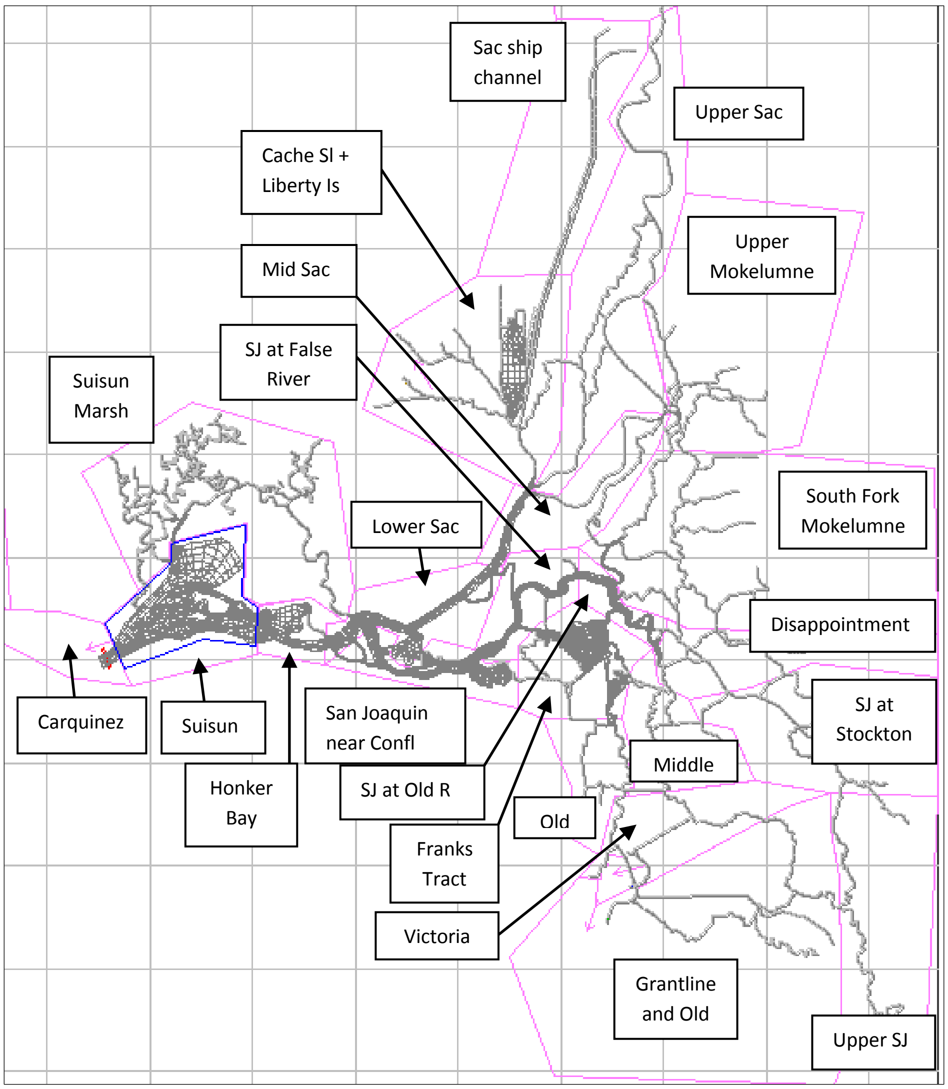

Figure 13-1Previous (fine scale) smelt regions.

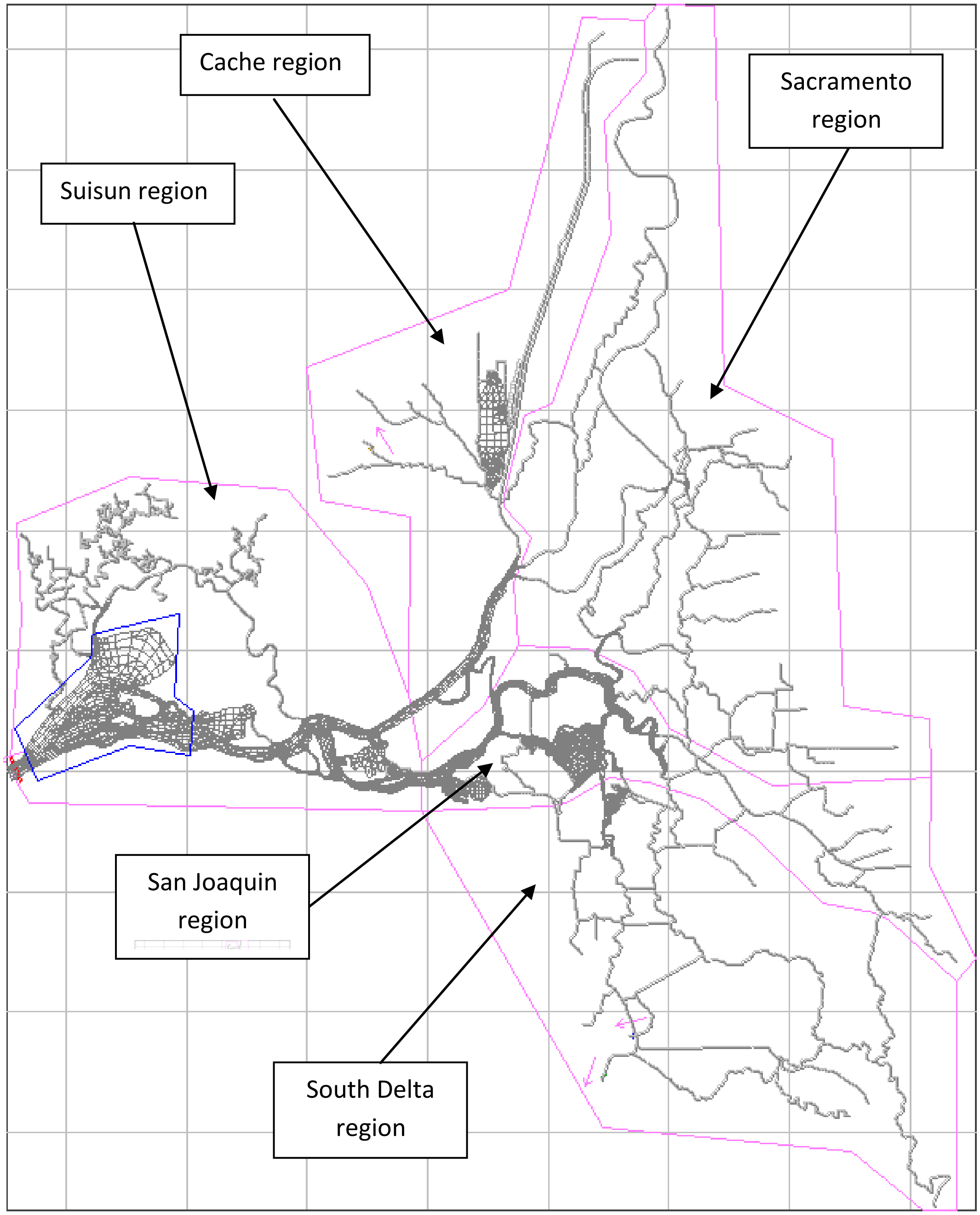

Figure 13-2 New (coarse scale) smelt regions

The coarser polygons were used in order to provide a broader classification of smelt distribution throughout the Delta and reduce public misinterpretation of the capabilities of the smelt model (i.e., the model's ability to accurately simulate smelt distributions at the scale of the polygons shown in Figure 13-2). The five new regions were created to differentiate between areas of non-concern (Suisun, Cache, Sacramento), a "watch" area (San Joaquin), and an "action" area (South Delta).

13.2 Modeling comparison study

A WY2011 hindcast particle tracking run was performed using both the new and the old regions, in order to compare results for accuracy and validate the new regions. Although the new particle region boundaries did not correspond directly to old region boundaries, a rough comparison between the two model runs can be made using the region correspondences shown in Table 13-1.

Table 13-1 Old and new particle tracking region rough correspondence

New Particle Region	Old Particle Regions
Suisun	Suisun, Suisun Marsh, Honker Bay
Cache	Cache Sl + Liberty Is, Mid Sac, Lower Sac, Sac Ship Channel
Sacramento	Upper Sac, Upper Mokelumne, South Fork Mokelumne
San Joaquin	Disappointment, Franks Tract, SJ near Confl, SJ at False Riv, SJ at Stockton, SJ at Old R
South Delta	Old River, Middle River, Grantline and Old, Upper SJ, Victoria

The initial Suisun bay particle drop location (outlined in blue in Figure 13-1) was kept the same. Figure 13-3 through Figure 13-7 show time series of the particles contained in each region. Note the different y-axis scales for each figure. Temporal trends between the two region groupings are similar, with absolute differences resulting from the differing region boundaries.

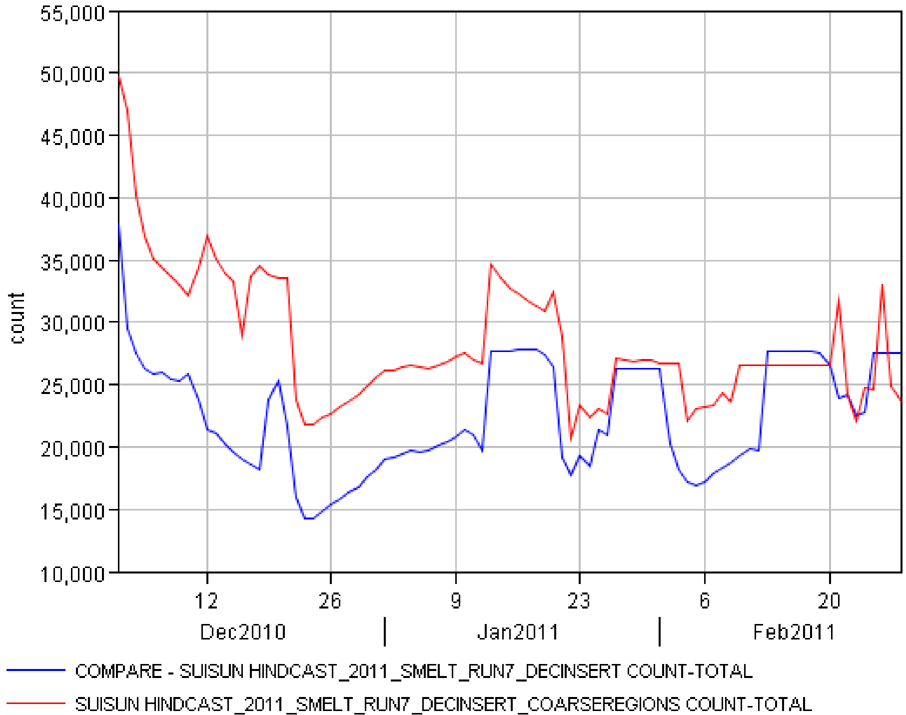

Figure 13-3 Time series of total particle counts in Suisun region (red line) and sum of roughly corresponding old regions, as indicated in Table 1 (blue line).

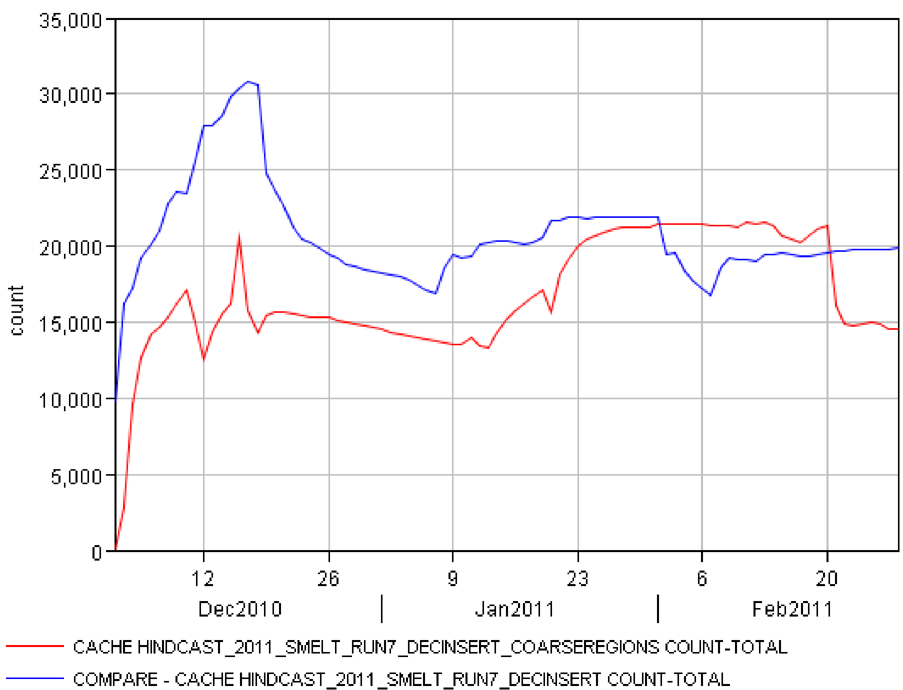

Figure 13-4 Time series of total particle counts in Cache region (red line) and sum of roughly corresponding old regions, as indicated in Table 1 (blue line).

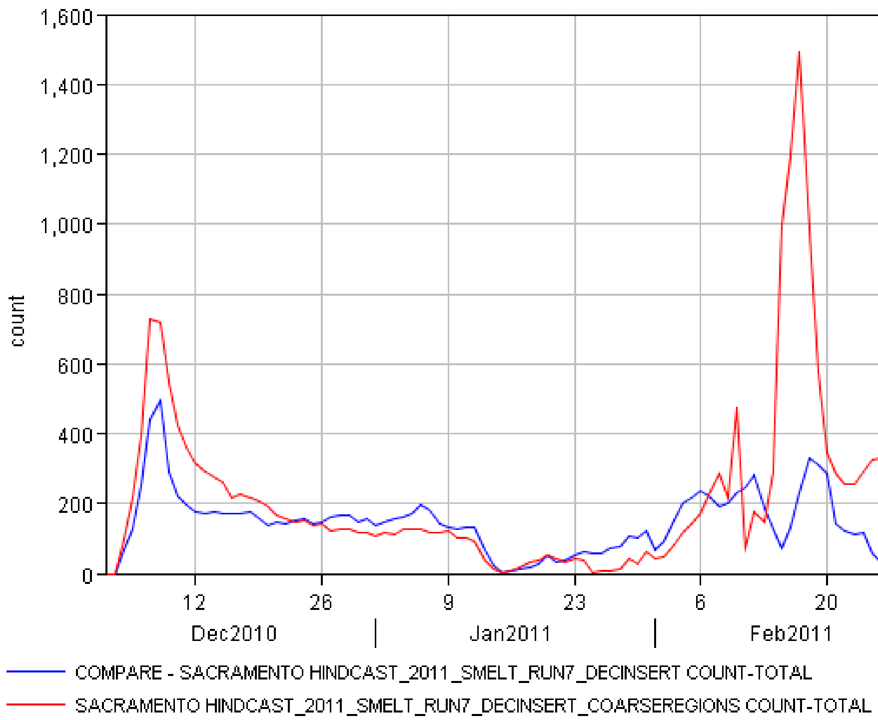

Figure 13-5 Time series of total particle counts in Sacramento region (red line) and sum of roughly corresponding old regions, as indicated in Table 1 (blue line).

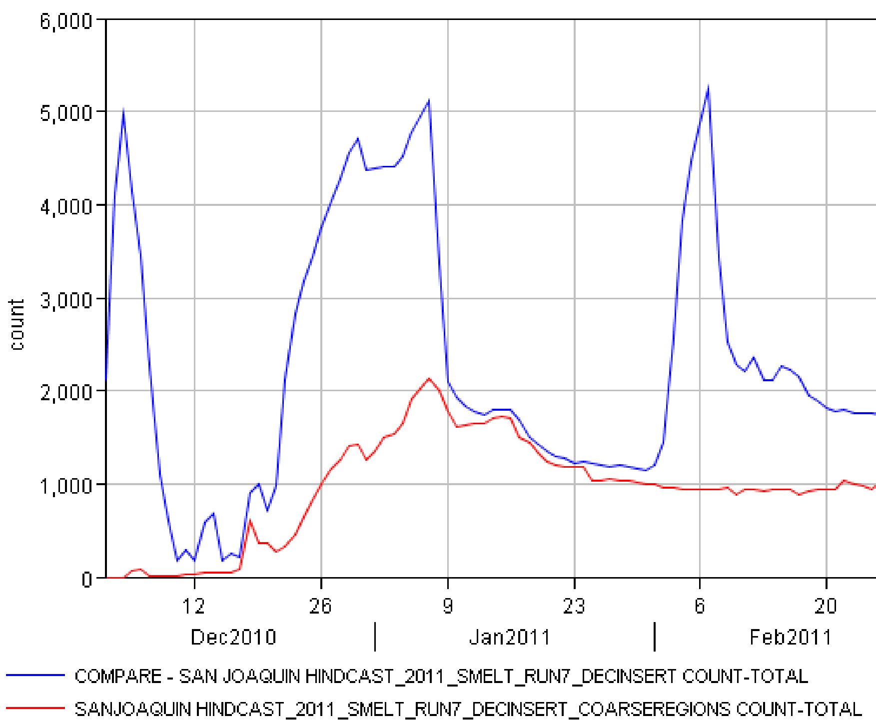

Figure 13-6 Time series of total particle counts in San Joaquin region (red line) and sum of roughly corresponding old regions, as indicated in Table 1 (blue line).

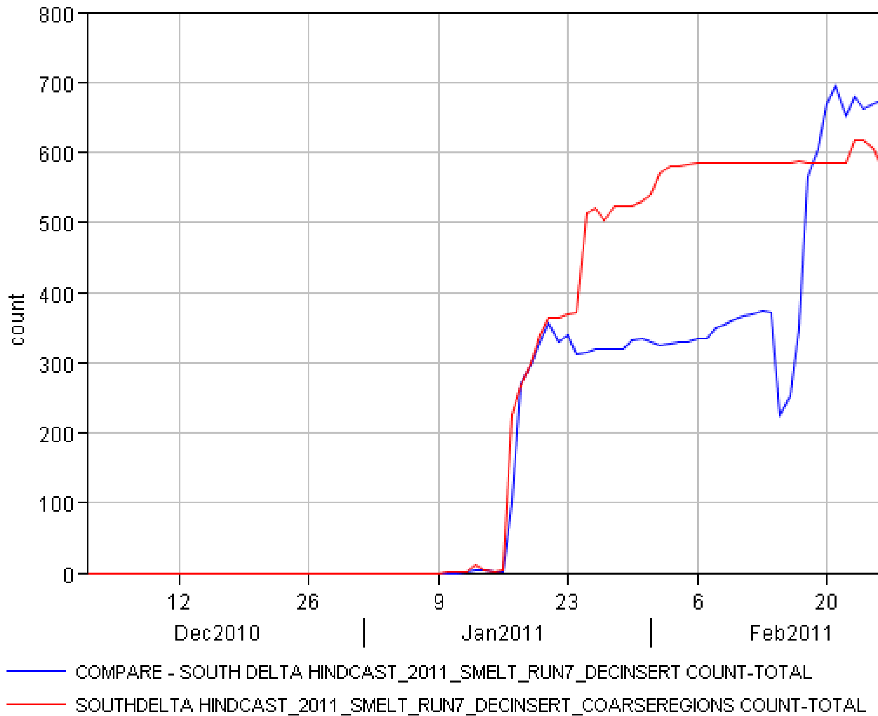

Figure 13-7 Time series of total particle counts in South Delta region (red line) and sum of roughly corresponding old regions, as indicated in Table 1 (blue line).

14 Appendix: Bay-Delta Live RMA Model Disclaimer document

Web-based Visualization of RMA Turbidity and Adult Delta Smelt Modeling Forecasts, Water Year 2012

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Project Summary

The visualizations, images, data files, and documentation shown under this project represent the fourth year of efforts by MWD and Resource Management Associates (RMA) to forecast flows, salinity, turbidity, and adult delta smelt movement within the Sacramento-San Joaquin Delta. Near-term climate predictions are used to inform watershed runoff models that provide boundary conditions to RMA's in-Delta flow and water quality models. These are used to drive an adult delta smelt (*Hypomesus transpacificus*) behavioral model, predicting movement and population distribution two weeks into the future. Metropolitan Water District of Southern California has funded this project in an effort to aid conservation efforts for the endangered smelt as well as reduce smelt mortality at water export locations in the southern Delta. New forecast reports, turbidity visualizations, and smelt distribution maps will be posted on a weekly basis during the wet season (December through March), unless climatic and hydrologic forecasts indicate little future variation in conditions.

Modeling Methodology

The two-dimensional hydrodynamic flow model, RMA2, is used to predict in-Delta flows on a high resolution (≈39,000 nodes) 1D-2D grid. The model includes 3-4 weeks of model spin-up using historical flow data collected at the major river inflow boundaries (Sacramento River at Freeport, San Joaquin River at Vernalis, the Calaveras, Cosumnes, and Mokelumne Rivers, and the Cache Slough/Yolo Bypass region) and recorded exports for the State Water Project, Central Valley Project, and Contra Costa Water District. Forecast flows and exports, along with future Delta Island Consumptive Use and gate operations, are provided by the California Department of Water Resources (DWR) DSM2 model (baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm) and are modified as necessary based on the professional judgment of RMA (see weekly documentation reports, Table 1). The resulting in-Delta flows are used to drive water quality simulations of salinity and turbidity over the same forecast period. Water quality boundary conditions are taken from observed measurements, collected by local agencies and posted on the California Data Exchange Center website (cdec.water.ca.gov), for the historical spin-up period. Forecasted boundary conditions are developed using one or more of the following methods: assigned as constant values based on the prior two week period (typically for low-flow or steady flow conditions), predicted based on a rating methodology developed by RMA (see WY2011 final project report), or predicted using the USEPA WARMF model (www.epa.gov/athens/wwqtsc/html/warmf.html) as calibrated to the Sacramento-San Joaquin watershed by Systec Water Resources, Inc. (for higher flow conditions). Modifications to water quality boundary conditions are done on a weekly basis, based on professional judgment and depending on the quality of the observed and predicted data, and are documented in the weekly forecast report (see Tables 2 and 3). Turbidity is modeled using a simple time-dependent exponential decay equation. The two-dimensional distribution of decay coefficients was based on calibration over the 2011 water year and is shown in Figure 1.

Modeled in-Delta salinity, turbidity, and flows are used to drive a particle tracking model with a behavioral component designed to simulate adult delta smelt movement. Fifty-thousand particles are randomly distributed in the Suisun Bay region on November 1, 2011. Particle movement through the end of the forecast period is tracked and proceeds based on the following decision tree:

- If the local salinity experienced by a particle is greater than the maximum prescribed salinity limit
    - Surf (travel with the tide) toward areas of lower salinity
- Else, if local turbidity is below a prescribed minimum limit
    - If the local turbidity gradient is greater than the minimum detectable gradient
        - Surf toward higher turbidity
    - Else
        - Hide (remain in a stationary position until conditions change)
- Else, if local salinity is less than the minimum tolerable limit
    - Surf toward higher salinity
- Else (both local turbidity and salinity are within appropriate limits)
    - Randomly move to explore desirable habitat

Prescribed values of 16 NTU (minimum turbidity), 0.0001 NTU/m (minimum turbidity gradient), 0 ppt (minimum salinity), and 1.5 ppt (maximum salinity) are used for all forecasts.

The full documents detailing the model calibration and performance for water year 2011 are posted in the Related Files section of this Bay-Delta Live project directory.

Web-based Visualization Methodology

Results from the RMA water quality models are output at 15 minute intervals for approximately 60 locations spaced throughout the Delta. These time series data are used to drive the RMA turbidity visualization shown on the Bay-Delta Live website. A new visualization is posted each week, showing one week of historical model results followed by two weeks of forecasted turbidities. The polygons used in the visualizations are colored based on their spatial proximity and hydrologic connectivity to the model output locations, and the output turbidity values at those sites.

To visualize forecasted delta smelt distributions, the Delta is divided into 5 broad regions (see Figure 2). Daily averaged particle populations in each region, given as a percentage of the total number of input particles, are displayed on a map for each forecast. Distribution data are given for three times: the start of the forecast period, one week into the forecast, and two weeks into the forecast. The coarse spatial and temporal resolution of the particle tracking model results are intended to give a broad overview of the in-Delta conditions and were chosen based on the magnitude of uncertainties associated with the smelt behavioral model.

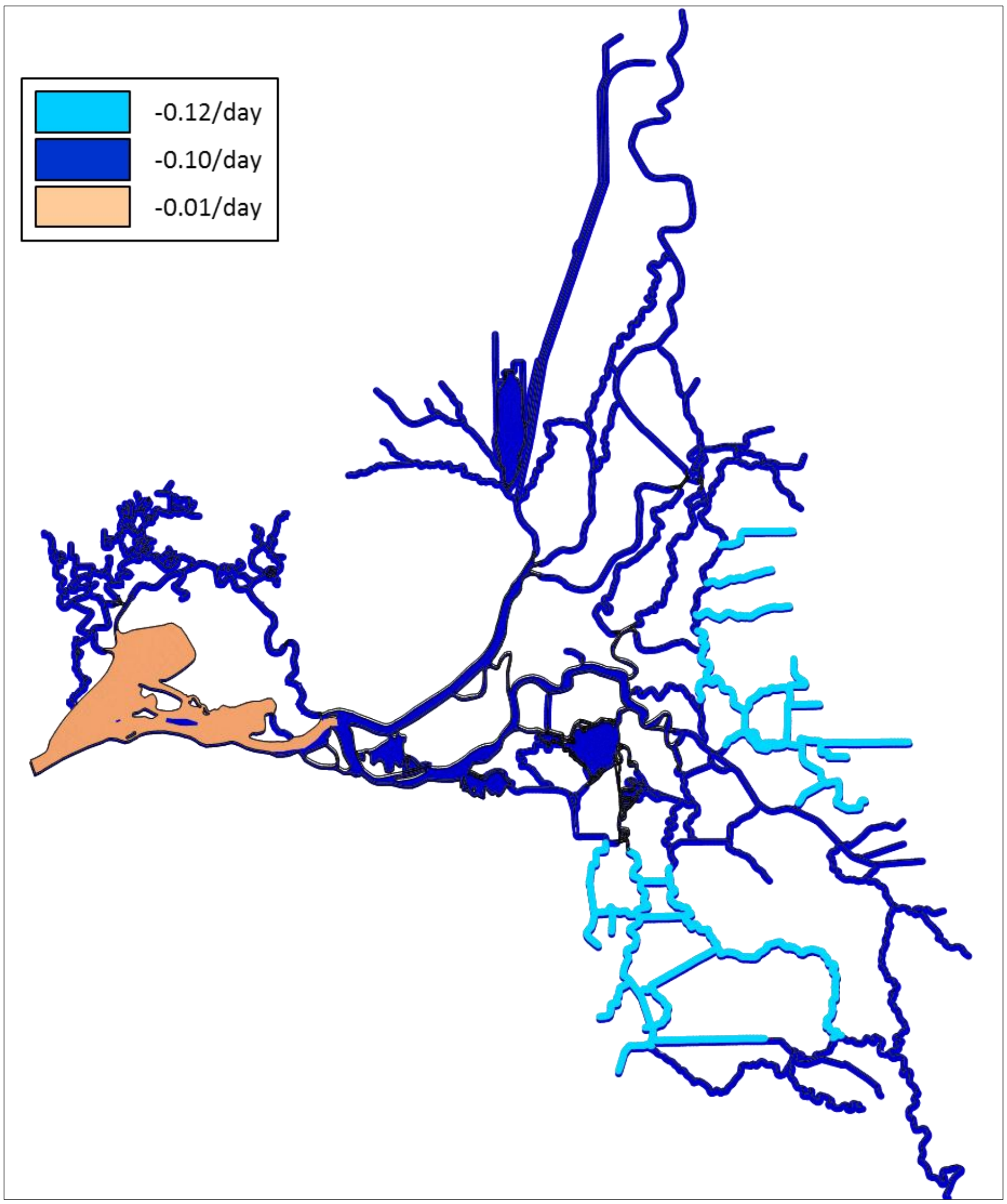

Figure 14-1 RMA turbidity model decay coefficients and regions.

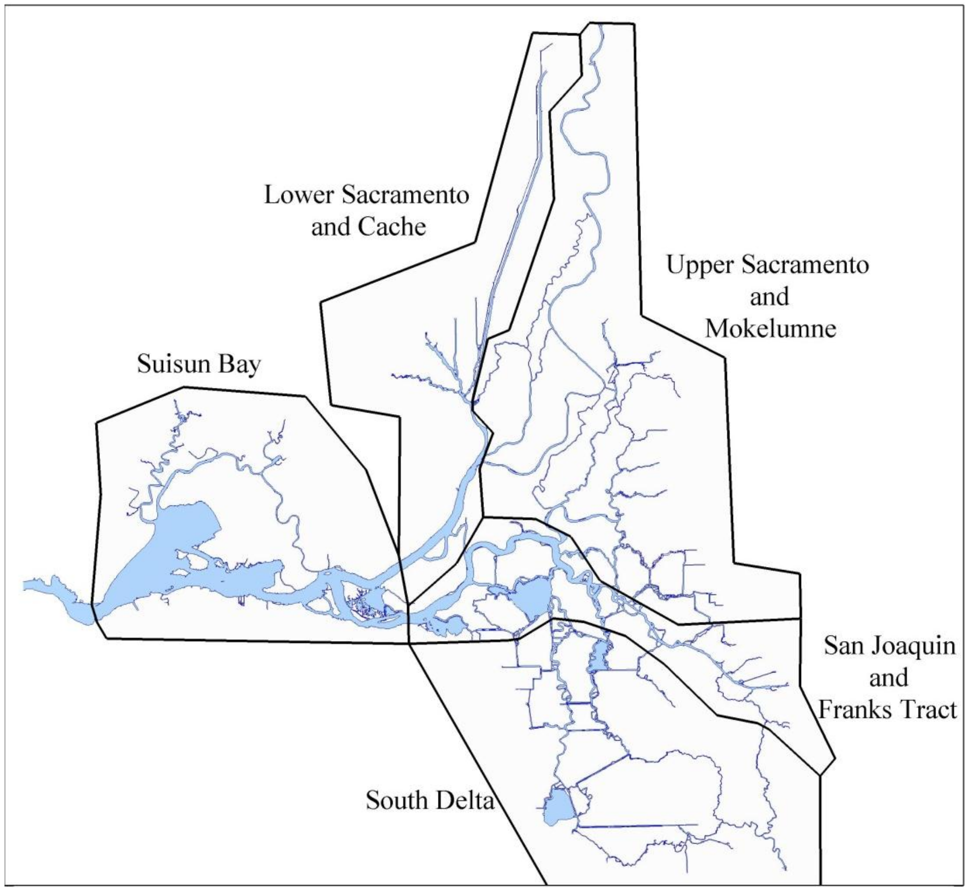

Figure 14-2 RMA delta smelt behavioral model regions.

Additional Technical Notes, Comments, and Assumptions

- The two-dimensional distributions of mixing coefficients, turbulent diffusion energy losses, and bathymetry data used in the RMA models have been accumulated over many years of applying, calibrating, and validating the models to the Bay-Delta system.
- Turbidity model decay coefficients were calibrated to be most accurate during periods of high flow, when turbidity pulses from inflowing rivers are hypothesized to attract delta smelt into the Delta interior to spawn.
- Since turbidity is not being predicted by a full suspended sediment model, turbidity sources due to wind wave induced resuspension during the forecast period (internal Delta loading) may not be accurately predicted. This has the largest consequences for model accuracy in regions adjacent to large areas of shallow open water areas, such as Suisun Bay, Liberty Island, and Franks Tract.
- Boundary condition data exert a large influence over modeled in-Delta flows and turbidity. As a result, model results are only as accurate as the boundary conditions used to generate them. The accuracy of forecast flows and water quality is usually high for the near term (≈5 days), but declines thereafter. Since it takes approximately five days of travel time for water from the model boundaries to reach the central Delta, we can expect decreased accuracy in our model results after approximately 10 simulation days.

- Adult delta smelt are hypothesized to move in response to local flow and water quality conditions according to the rules listed above. This is a very simplified paradigm for fish behavior and includes no dependence on benthic habitat structure, foraging or schooling instinct, or predator avoidance. As a consequence of the low and sporadic smelt distribution data within recent years (when accurate turbidity boundary condition data were available) the smelt model has not undergone a detailed calibration at Delta locations other than at the southern export locations.
- Each particle tracked in the adult delta smelt model has a deterministic component of motion (e.g., smelt movement along with the local tidal flow) and a stochastic component, designed to simulating the random, dispersive aspects of fish movement. The number of virtual particles used in the smelt behavior simulation (50,000) was chosen large enough so that random aspects of fish movement could be captured and statistically significant conclusions could be drawn from the results. We emphasize here that the initial particle population does not represent any estimate of the adult delta smelt population in Suisun Bay and that there is not a one-to-one correspondence between simulated particles and individual adult delta smelt.
- The RMA models predict flow and turbidity at approximately 39,000 nodes, generating large volumes of data. In order to create an efficient web-based visualization, simplified model output and interpolation is necessary. Figure 3 shows an example of turbidity data visualized with contouring based on values at the full set of nodes in the RMA model. Figure 4 shows the web-based visualization from Bay-Delta Live corresponding to the same time period. Note that while the overall agreement in turbidity distribution is excellent, some polygon interpolation may not reflect RMA model results due to a lack of nearby output locations (e.g., at Sherman Island or Taylor Slough) or due to data extrapolation (e.g., Cache Slough). The complex 2D mixing processes that occur near Threemile Slough and the Mokelumne-San Joaquin confluence are also not included in the simplified visualization. Finally, areas such as the Montezuma Slough region and some east side sloughs are included in the RMA model, but are not shown in the Bay-Delta Live visualization. For a full description of the RMA model grid, please see the Related Files section of this project directory.

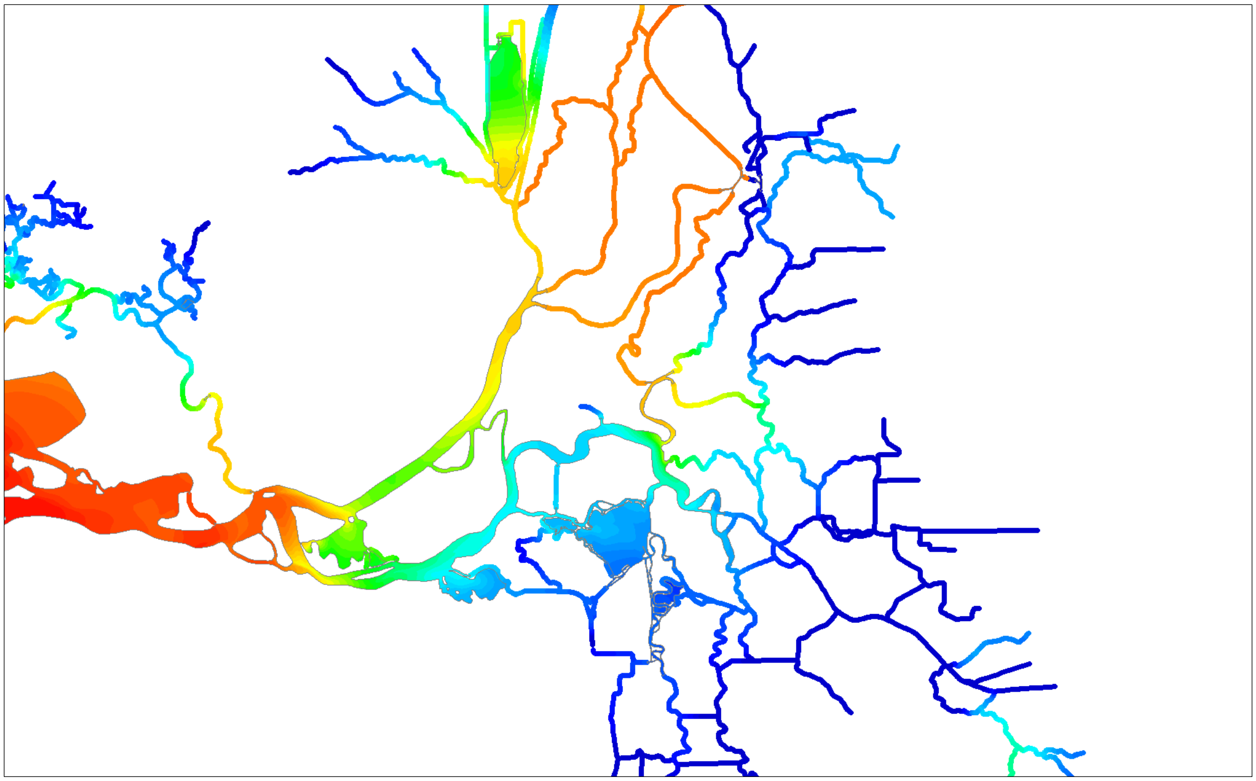

Figure 14-3 RMA turbidity model results visualization for Dec 25, 2011 12:00 based on interpolation using 39,000 nodes.

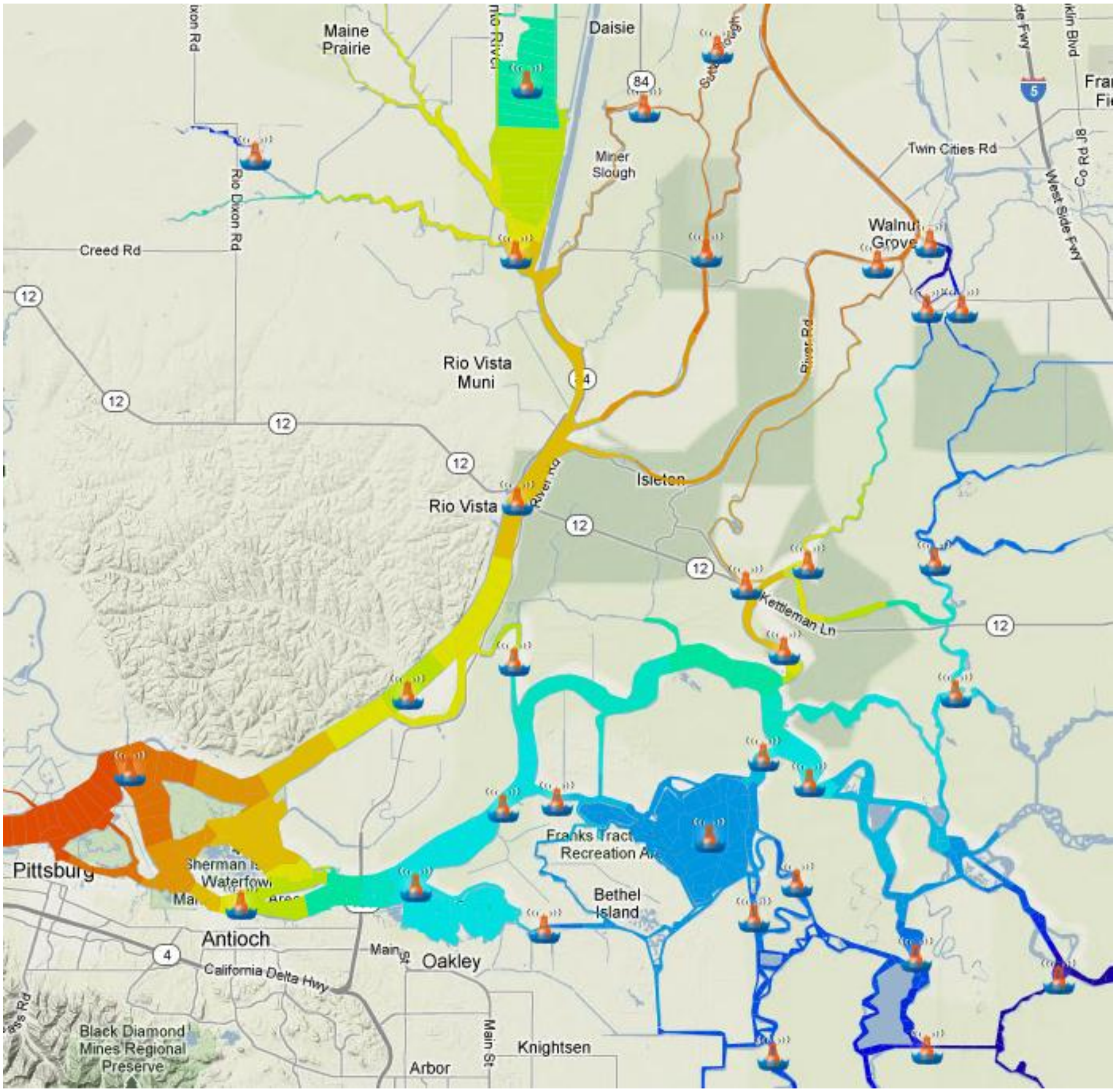

Figure 14-4 Bay-Delta Live web-based visualization of RMA turbidity model results. Approximately 2,000 polygon are colored based on interpolation between values given at approximately 60 model output locations. Data is for Dec 25, 2011 12:00 as in Figure 5. Buoy icons show the locations of RMA model output.