Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

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Chapter 9: DSM2 Simulation of Historical Delta Conditions over the 1975 – 1990 Period

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9 DSM2 Simulation of Historical Delta Conditions over the 1975 – 1990 Period

9.1 Introduction

The Delta Simulation Model II (DSM2) is a one-dimensional mathematical model for simulating Sacramento-San Joaquin Delta hydrodynamics, water quality, and particle tracking though the modules HYDRO, QUAL, and PTM respectively. DSM2 was first calibrated and validated in 1997. In 1999 the Environmental Services Office (ESO) modified the representation of Delta bathymetry that DSM2 uses. The Interagency Ecological Program's (IEP) DSM2 Project Work Team (PWT) adopted this new representation for DSM2 in its recalibration and validation of the model in 2000 (Nader-Tehrani and Shrestha, 2000). This effort used four periods to calibrate HYDRO (May 1988, April 1997, April 1998, and September-October 1998) and one three-year period to calibrate QUAL (October 1991 – September 1994). HYDRO and QUAL were then both validated by simulating historical hydrodynamics and electrical conductivity from 1990 through 1999. This calibration and validation process resulted in an overall good fit with the field data for stage, flow, and water quality (Nader-Tehrani, 2001). Recently, the historical simulation by DSM2 has been extended to include the 1975 -1990 period. This chapter discusses some of the key issues in this work and summarizes model results.

9.2 Input Data

A simulation of historical Delta conditions by DSM2-HYDRO and QUAL requires recorded or estimated key historical Delta inflows and exports, the stage at Martinez, Delta islands consumptive use (DICU), and operational information of gates and barriers in the Delta. Required input data were retrieved from the Interagency Ecological Program (IEP). The IEP data vault has limited information on the operation of gates and barriers prior to 1986. For operational information before 1986, two DWR publications were consulted:

- DWR Bulletin 132 (1976 to 1982), The California State Water Project, Appendix E, Water Operations in the Sacramento-San Joaquin Delta.

- DWR Bulletin 69 (1975 to 1985), California High Water.

As part of trial measures to improve water quality in the south Delta and west Delta during the drought of 1976 and 1977, several temporary-barriers were installed and later removed. Using the information from these DWR publications, gates input files for DSM2 were updated for the period before 1986.

9.3 Discussion

DSM2-HYDRO simulated flow and stage in Delta channels and then DSM2-QUAL simulated electrical conductivity (EC). Discussions on the comparisons of DSM2 simulation results to the recorded historical data will be presented in three parts: stage simulation, flow simulation, and EC simulation. The locations in the Delta where measured and simulated results are discussed in this report are shown in Figure 9.1.

9.3.1 Stage Simulation

Most of the available measured stage began to be collected in late 1985. Stage data which covers the entire 1975 – 1990 simulation period is available at only a few locations in the Delta.

For the simulation period of 1975 – 1990, California experienced all five types of water-years: Wet, Above Normal, Below Normal, Dry, and Critical. At times during this period, extreme high and low stages were monitored in the Delta. DSM2 simulated stages generally matched the observed field data well, including during times of extreme stages. As examples, for the San Joaquin River at Brandt Bridge, Figure 9.2 compares simulated and observed stages during the flood of February 1986 and Figure 9.3 compares observed and simulated stages for the low stages of June 1988.

At a few sites the stage data recordings before October 1, 1987 were not referenced to mean sea level. On October 1, 1987 the reference datum for stage data recordings was shifted to 0.0 NGVD (National Geodetic Vertical Datum) mean sea level (IEP, 2006). DSM2 simulated stages, which are entirely referenced to mean sea level, were compared to the recorded stages at these sites and substantial discrepancies were exposed. To demonstrate this phenomenon, Figures 9.4 and 9.5 show recorded and simulated stages for RSAC123 (Sacramento River at Georgiana Slough) and RMKL005 (Mokelumne River N. Fork at Georgiana Slough). As shown in these figures, the recorded stages before the reference-datum change of October 1, 1987 widely deviated from the simulated stages, but after this date the recorded and simulated data agreed well.

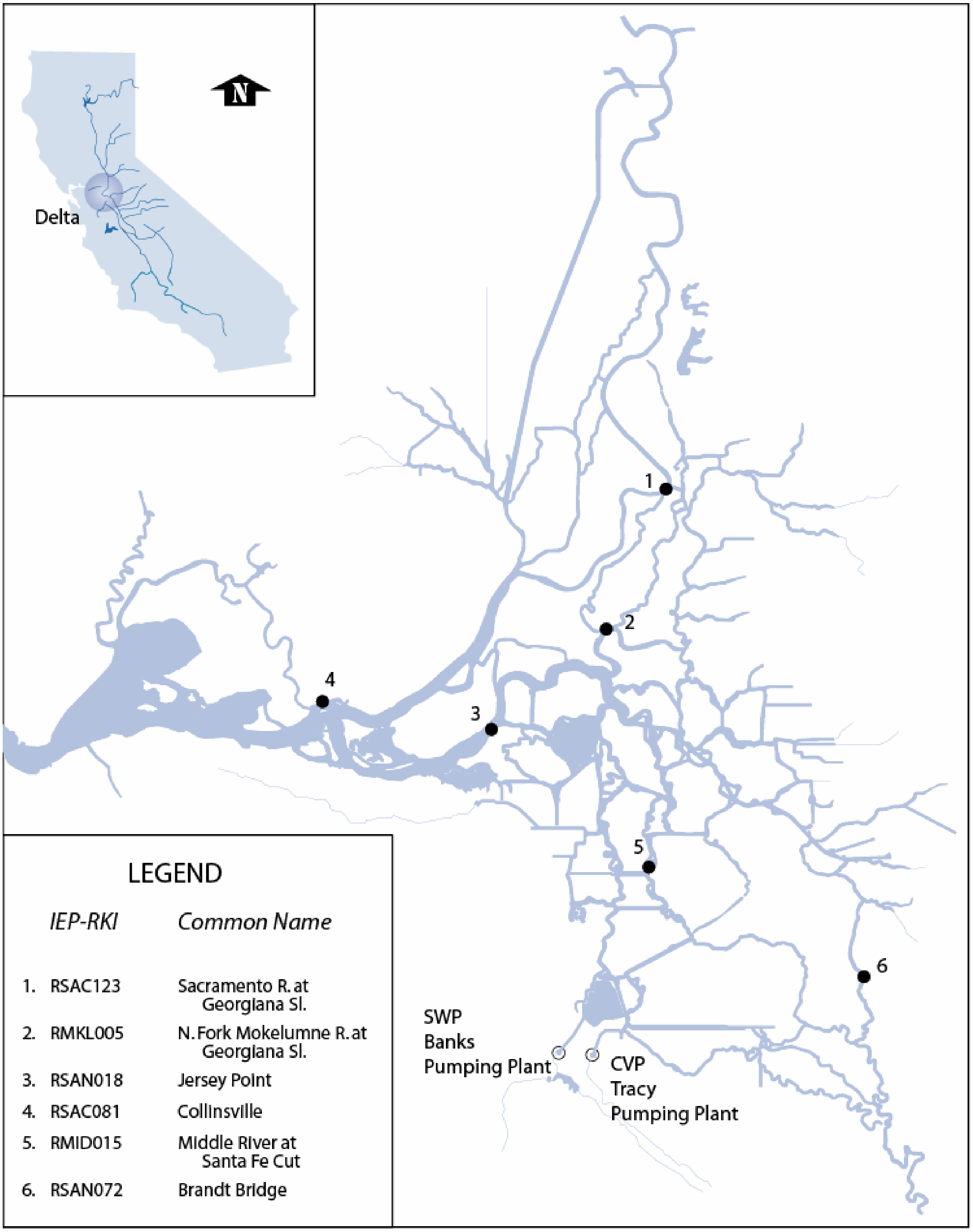

Figure 9.1: Locations that the DSM2 simulation results are compared to observed data.

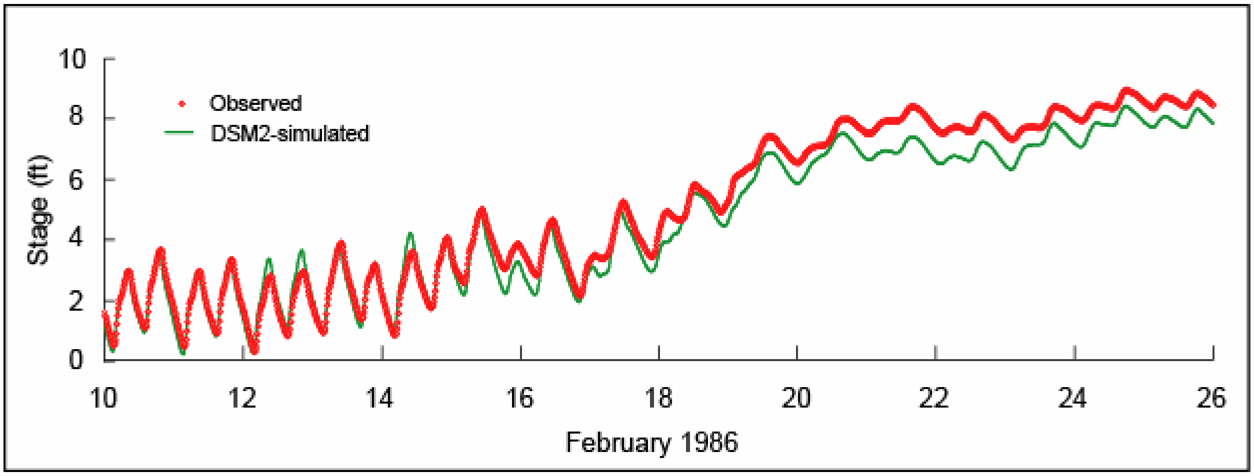

Figure 9.2: Observed and DSM2-simulated 15-minute stage at RSAN072 (San Joaquin River at Brandt Bridge) during the February 1986 flood.

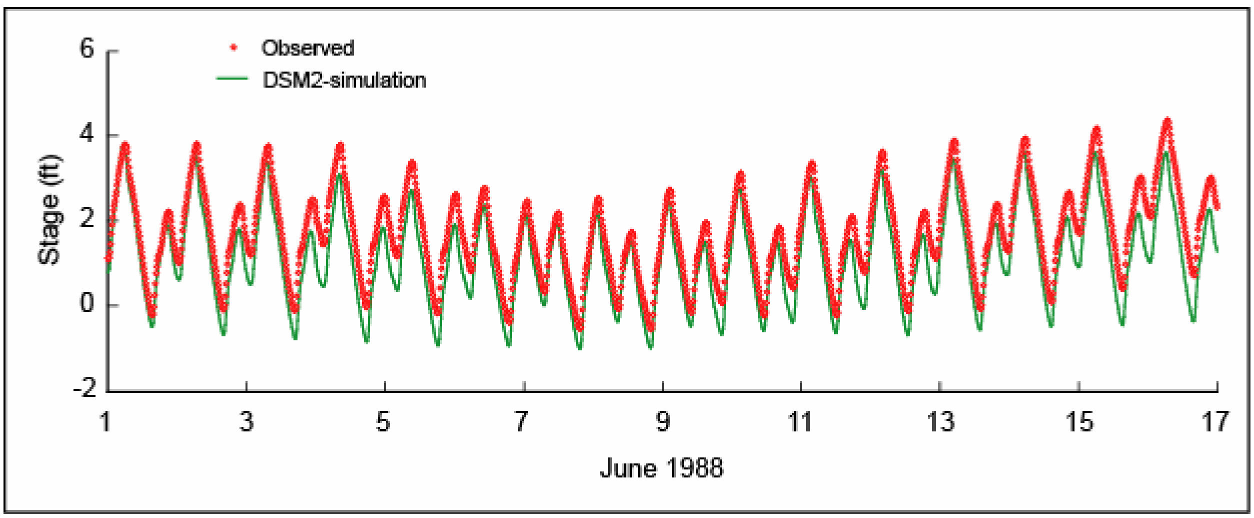

Figure 9.3: Observed and DSM2-simulated 15-minute stage at RSAN072 (San Joaquin River at Brandt Bridge) during the summer of 1988.

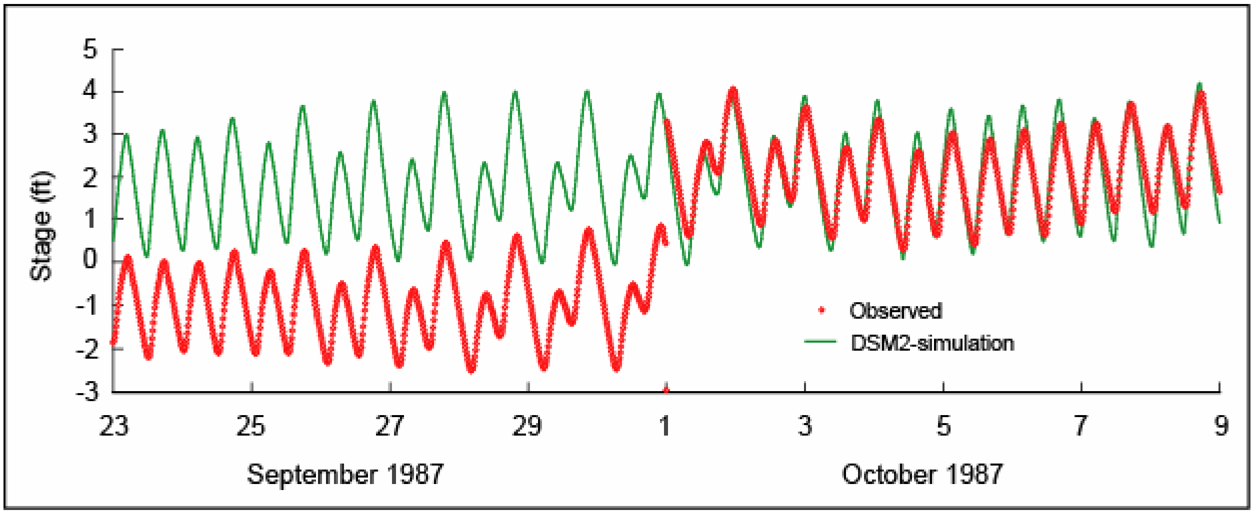

Figure 9.4: Observed and DSM2-simulaed 15-minute stage at RSAC123 (Sacramento River at Georgiana Slough) before and after the stage reference-datum for was changed on October 1, 1987.

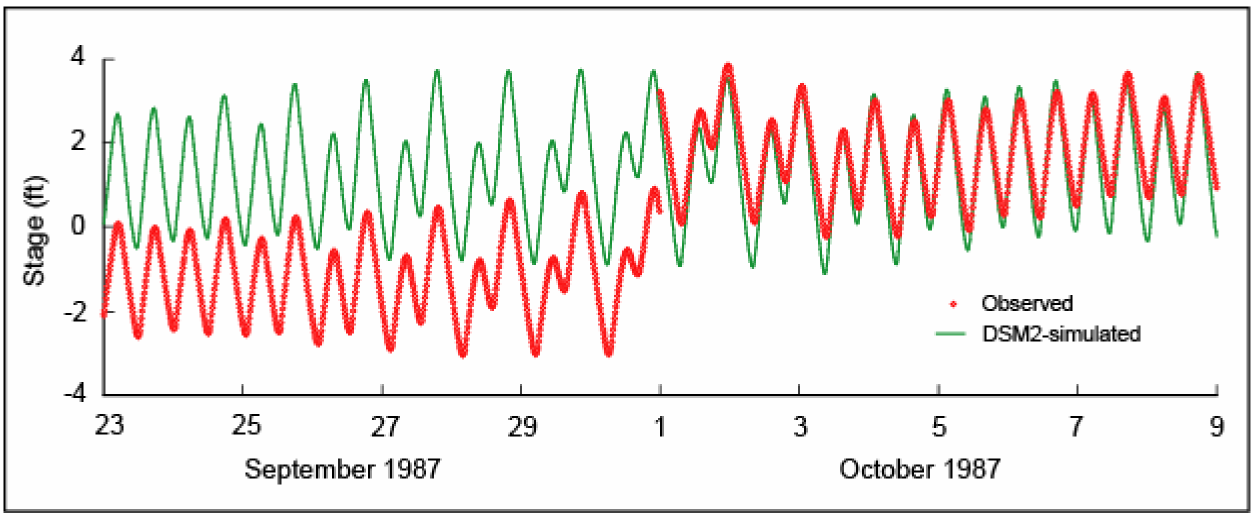

Figure 9.5: Obseved and DSM2-simulated 15-minute stage at RMKL005 (North Fork of the Mokelumne River at Georgiana Slough) before and after the stage reference-datum was changed on October 1, 1987.

9.3.2 Flow Simulation

Prior to 1990 there were very few sites in the Delta where flow data were recorded. Only two IEP sites have a sizeable amount of recorded 15-minute flow data prior to1990 available to verify the DSM2 simulated results. These two sites are RMID015 (Middle River at South East of Bacon Island) and ROLD024 (Old River at Bacon Island). At these sites, 15-minute flow data started to be recorded in January 1987. SWP and CVP pumping stations draw water primarily from Middle River and Old River. RMID015 and ROLD024 are located upstream of the pumping stations (Figure 9.1) so that the effects of pumping on flow are at times distinctly noticed at these sites.

A comparison plot of typical 15-minute flow data between DSM2 simulations and monitored field data is shown in Figure 9.6. In this figure, negative values signify water moving upstream. Tidally-varying DSM2-simulated flows closely match observed flows including flow reversals and tidal fluctuations.

To assess the general pattern of net flows at RMID015, daily-averaged DSM2-simulated flows are compared with averaged observed flows in Figure 9.7. Negative values indicate net flow in the upstream direction. The higher negative values reflect larger export rates and lower San Joaquin River inflows, and higher positive values reflect higher San Joaquin River inflows and lower export rates. During low San Joaquin River inflows, the net flows at RMID015 tend to be upstream towards the SWP and CVP pumps, indicating the movement of water originating from Sacramento River and eastside streams towards the pumping stations. During high San Joaquin River inflows, the net flows at RMID015 towards the pumps are significantly reduced indicating that a larger part of the export water is coming from the San Joaquin River.

9.3.3 EC Simulation

Beginning in 1964, daily-averaged electrical conductivity (EC) data were recorded at a number of sites throughout the Delta. An analysis of DSM2's EC simulation was performed at 17 sites in the Delta where adequate EC data were available. DSM2's EC-simulation results agreed well with the monitored field data at most of the sites. Yearly peak EC values in the Delta generally occurred during the fall or early winter periods. For the majority of comparisons, DSM2 captured the peak values fairly well; however, as a general trend, DSM2 tended to overestimate EC in most summers of dry periods. In fact, at times DSM2 predicted higher EC during the summer than in the fall when observed EC values were higher. Figures 9.8 and 9.9 compare measured EC to DSM2-simulated EC at RSAC081 (Sacramento River at Collinsville) and RSAN018 (San Joaquin River at Jersey Point), respectively.

Large discrepancies between observed EC and DSM2-simulated EC during the summers of dry periods were studied in detail. During the preprocessing of input data for DSM2 simulations, the Delta Islands Consumptive Use (DICU) model was used to estimate the irrigation and agricultural drainage flows throughout the Delta. The principal cause of the EC discrepancies between observed and simulated EC during critical and dry summers was hypothesized to be the inaccuracy in the DICU model's estimates of consumptive use. According to the DSM2 input, Delta outflow was lower in the summers of 1976, 1981, 1985, 1987, 1988, and 1989 than in the subsequent fall periods and DSM2 responded as expected by simulating relatively high salinity intrusion during those summers. However, field data showed no evidence of extreme salinity intrusion during those same summer periods. Assuming EC measurements are accurate, one can conclude that, for the summer periods mentioned above, net Delta outflow must have been higher than that reflected in DSM2 input. This would be consistent with the hypothesis that DICU values might cause the discrepancies between observed and simulated EC.

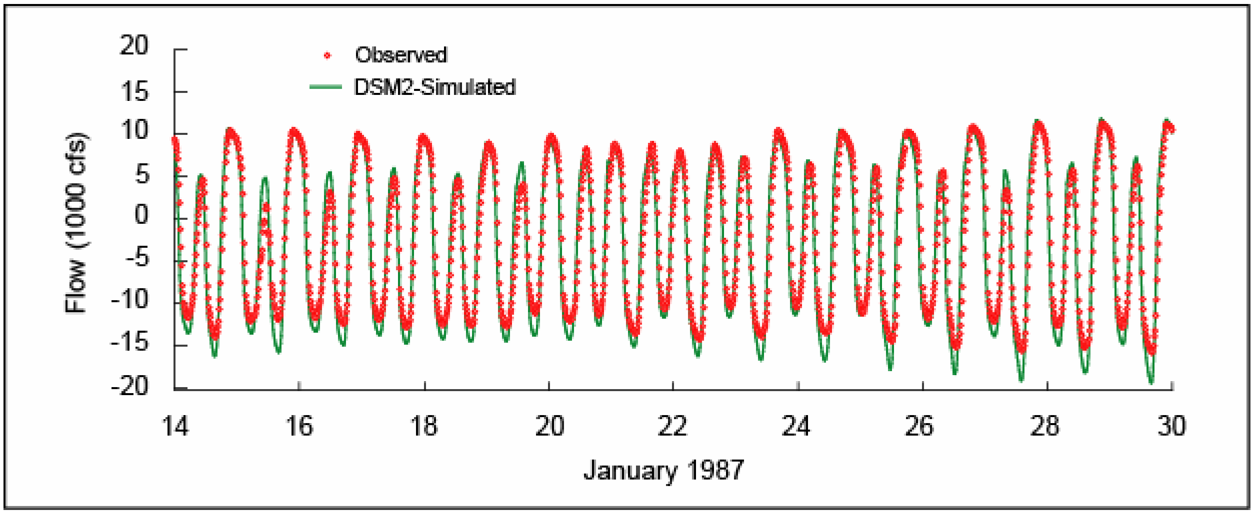

Figure 9.6: 15-minute observed flows and DSM2-Simulated flows at RMID015.

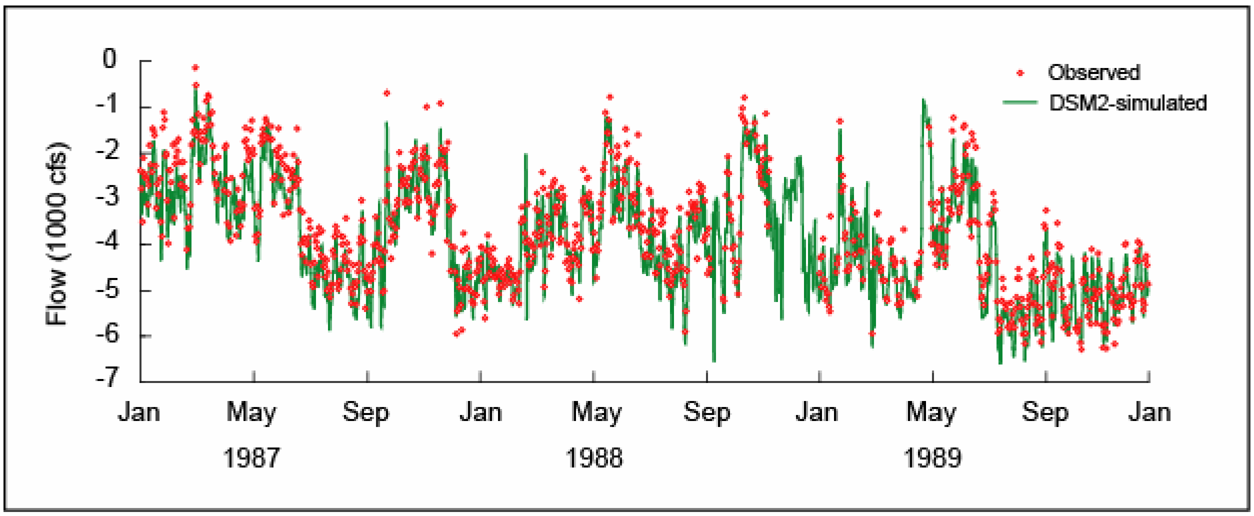

Figure 9.7: Daily-averaged observed flows and DSM2-simulated flows at RMID015.

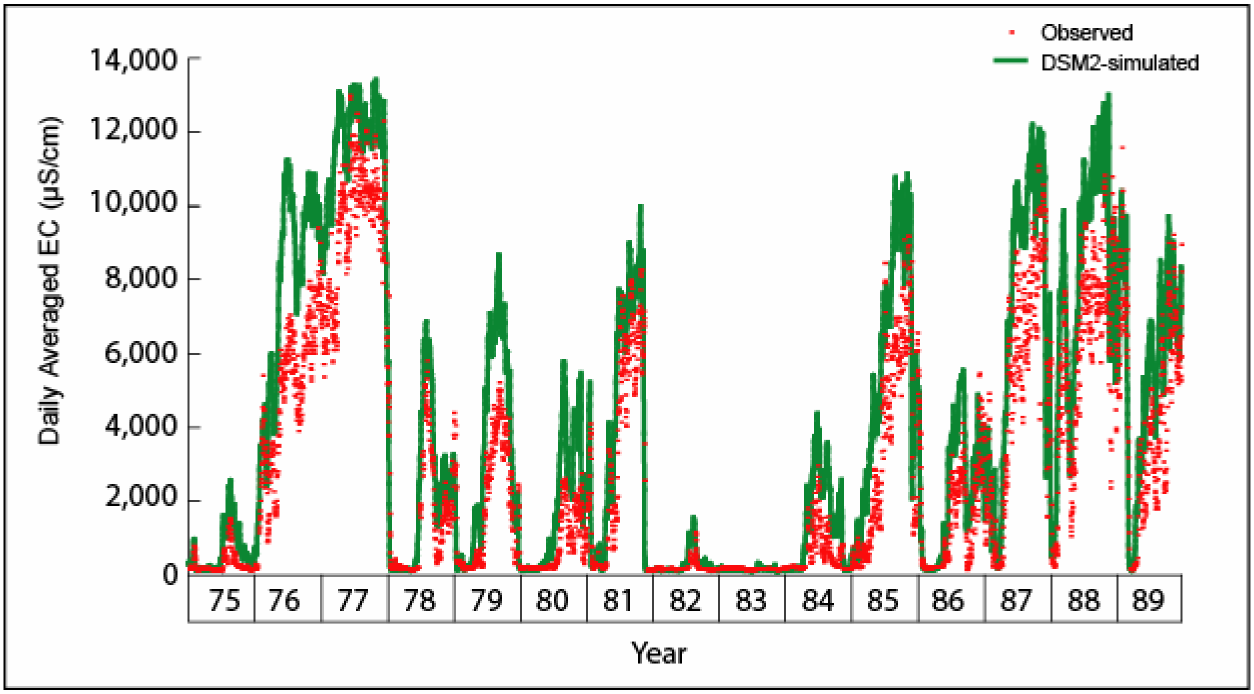

Figure 9.8: Daily-averaged observed flows and DSM2-simulated EC at RSAC081 (Sacramento River at Collinsville), 1975 to 1989.

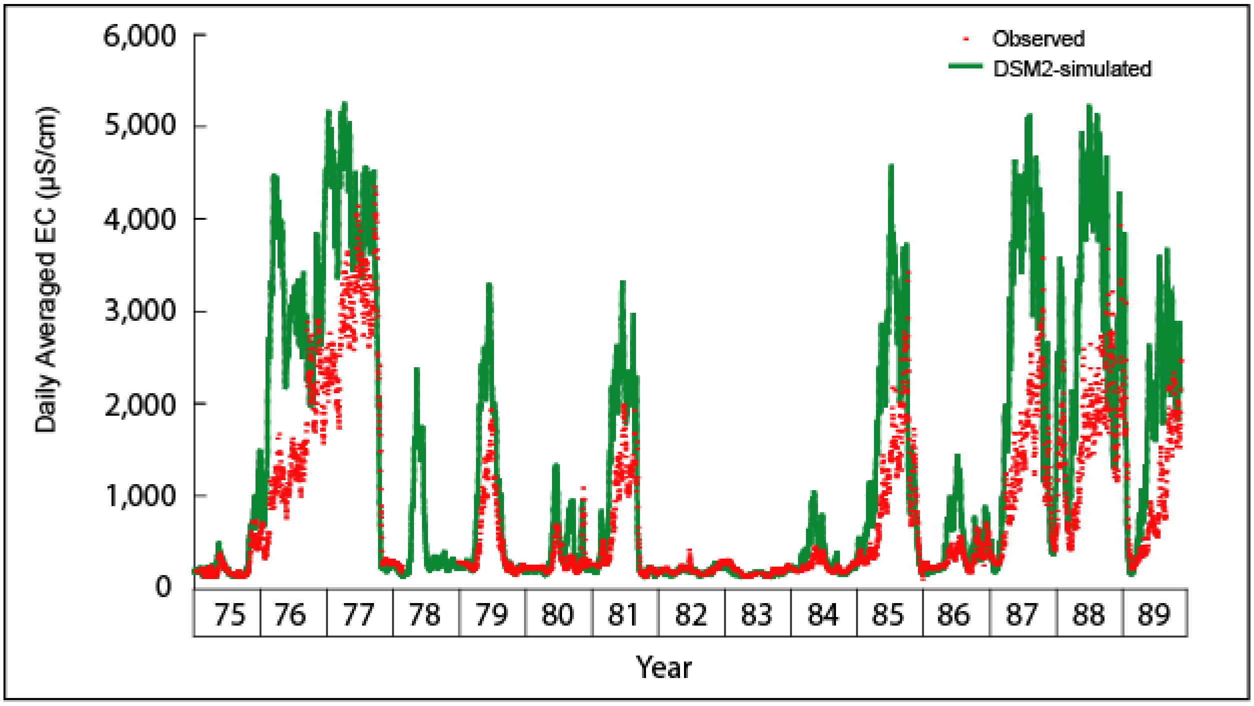

Figure 9.9: Daily-averaged observed flows and DSM2-Simulated EC at RSAN018 (San Joaquin River at Jersey Point) 1975 to 1989.

9.4 Impacts of DICU Estimates on DSM2-simulated EC

To investigate the hypothesis that DICU estimates may be the cause of error in DSM2-simulated EC, additional DSM2-HYDRO and QUAL simulations were conducted in which all DICU inputs, including the agricultural diversions, agricultural drainage returns, and seepage, were removed. Three-way comparisons were made between the output from the two DSM2 runs and the field data.

The results at RSAC 081 (Sacramento River at Collinsville) and RSAN018 (San Joaquin River at Jersey Point) are shown in Figures 9.10, 9.11, 9.12, and 9.13. The two DSM2 runs are referred to as Run A (with DICU input) and Run B (excluding DICU input). Any difference between the two DSM2 runs can be directly attributed to the effect of the DICU input. The following observations apply to locations affected by sea water intrusion.

The difference in EC between Run A and Run B is larger during summer months when the magnitude of the net Delta consumptive use is higher. At times, especially during the summers of dry periods, the difference in EC between the two model runs is very wide, suggesting that the EC results can be very sensitive to changes in DICU values. This illustrates the importance of having accurate estimates for the net Delta consumptive use.

In contrast, the model output for Run B matched the field data better during most dry summer periods. This is especially true for years 1976, 1979, 1980, 1984, 1985, 1987, and 1988. This may indicate that DICU significantly overestimates the Delta consumptive use, at least during the summer of dry periods when the net Delta outflow is particularly low. DICU is a water demand model and assumes that in lieu of rain, irrigation water is available in plentiful supply from adjacent channels.

An exception to the observation noted above is for 1977. For most locations, the simulated EC from Run A is closer to the field data than that from Run B. This is due to 1977 being a critically dry year that was preceded by another critical dry year. The salt intrusion in 1977, contrary to what typically happens for yearly dry periods, never subsided in the winter time because Delta inflows continued to be low throughout the winter. The field data suggests that the majority of the high salt intrusion occurred during the fall and winter seasons of dry periods, times when the net Delta consumptive use is usually low. As a result, the difference in EC between the two DSM2 model runs is much narrower in the fall and winter, suggesting that any error in net Delta consumptive use estimates in the fall and winter does not have a significant impact on the model output. DSM2 simulated EC for both DSM2 runs matches the field data fairly closely during these periods, raising the confidence for DSM2's ability to simulate salt intrusion.

Judging from these observations, the most likely reason for the differences between the observed EC data and DSM2-simulated EC in Run A is the inaccuracy of the DICU estimates during the summers of dry periods. DSM2 successfully recreates the high salinity intrusion that typically occurs during the fall and spring, times of low net Delta consumptive use.

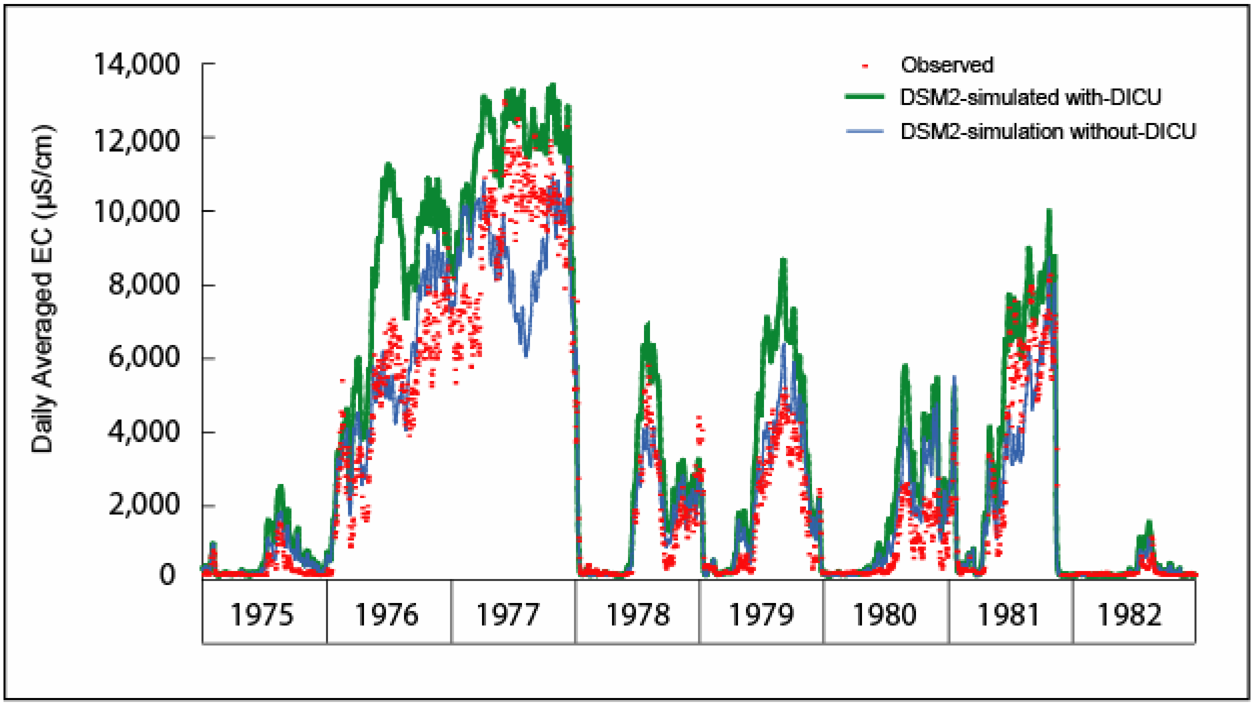

Figure 9.10: Daily-averaged observed and DSM2-simulated EC at RSAC081 (Sacramento River at Collinsville), 1975 to 1982.

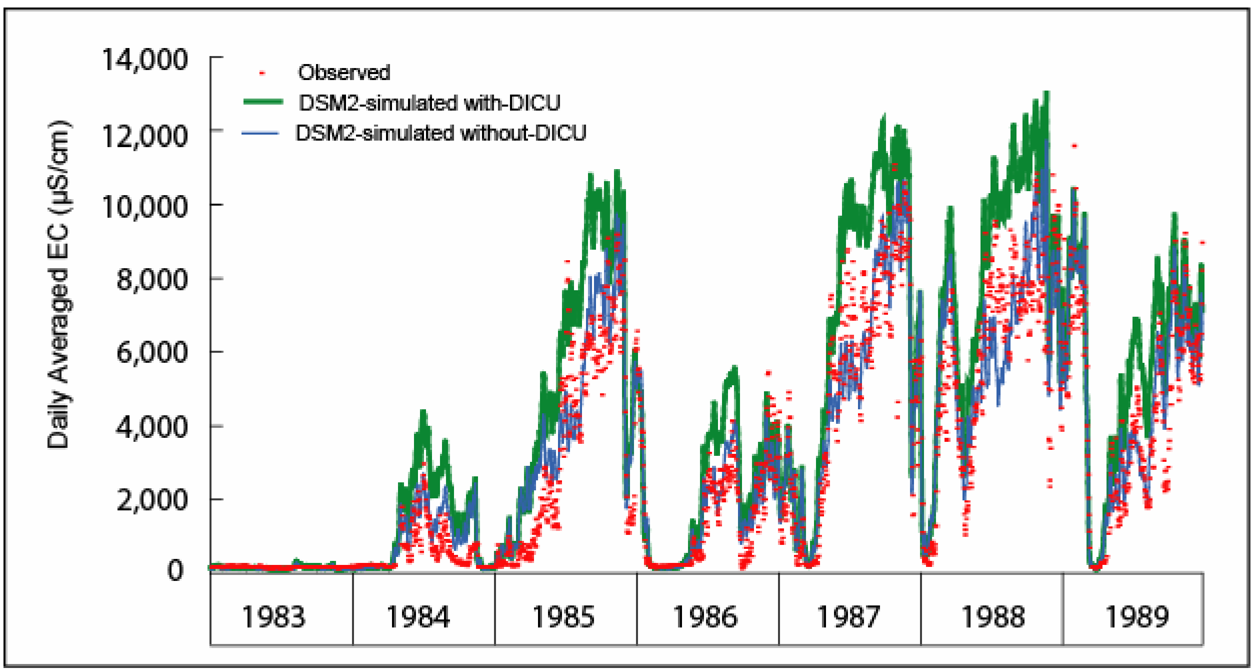

Figure 9.11: Daily-averaged observed and DSM2-simulated EC at RSAC081 (Sacramento River at Collinsville), 1983 to 1989.

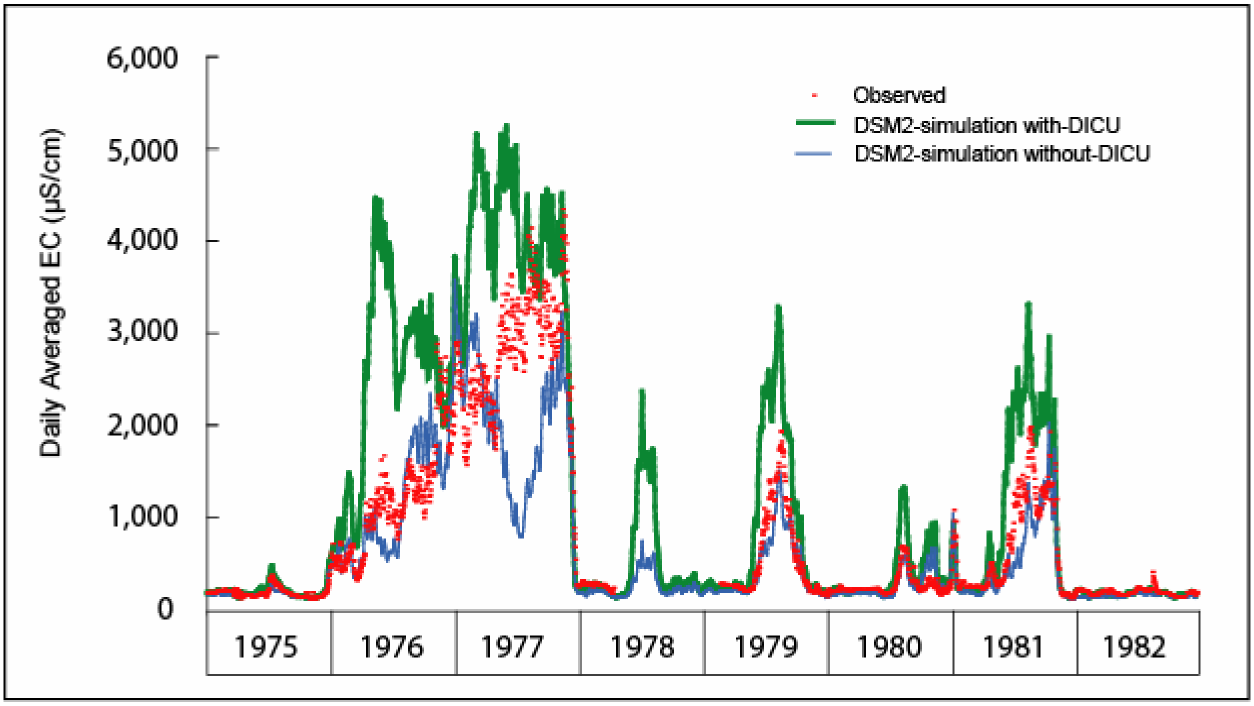

Figure 9.12: Daily-averaged observed EC and DSM2-simulated EC at RSAN018 (San Joaquin River at Jersey Point), 1975 to 1982.

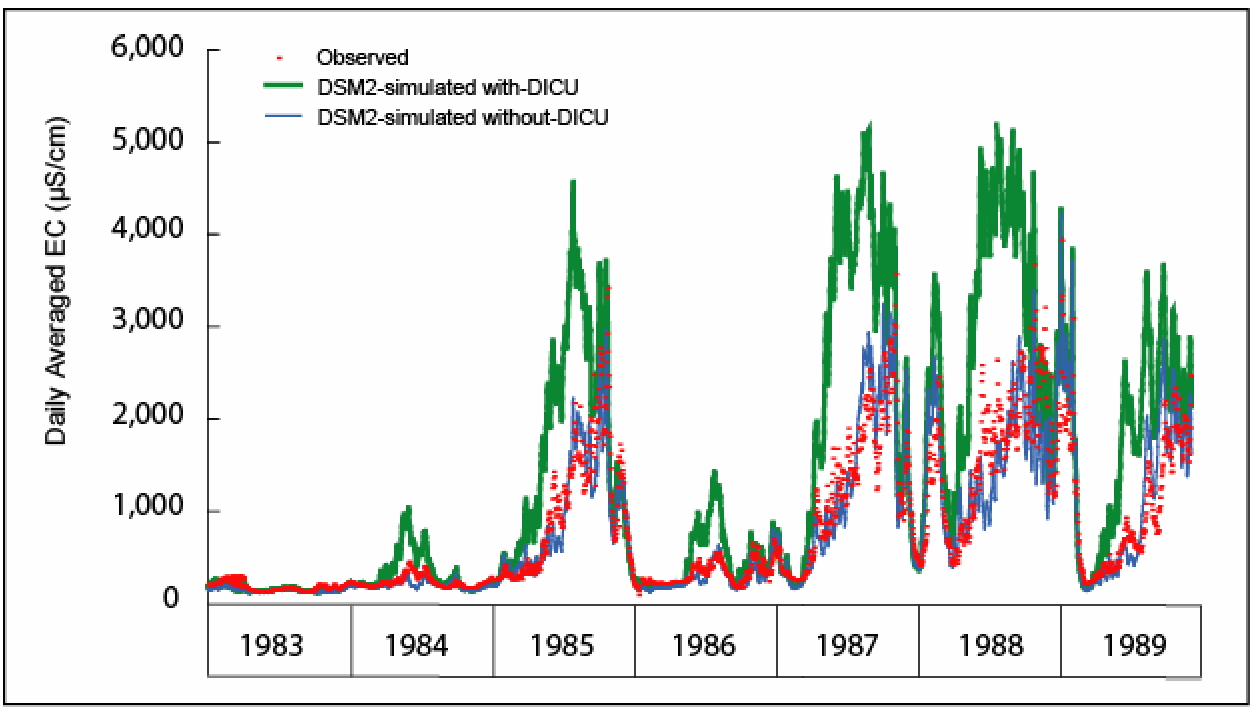

Figure 9.13: Daily-averaged observed EC and DSM2-simulated EC at RSAN018 (San Joaquin River at Jersey Point), 1983 to 1989.

9.5 Summary and Conclusions

DSM2-simulated stage and flow match well with the field data that is available for the historical 1975-1990 period. For the water-years of wet, above-normal, and below-normal, simulated EC generally agrees with the monitored EC data. DSM2 captures peak EC values that typically occur during fall or early winter months; however, DSM2 tends to overestimate EC during the summer of dry periods. Evidence indicates the reason for this overestimation of EC is that the DICU model may be overestimating the net Delta consumptive use at these times.

9.6 Recommendations

Inaccuracies in DICU estimated consumptive use may occasionally significantly impact simulated EC. At times, these inaccuracies may be the primary source of the discrepancies between simulated and field-measured EC. Modifying the existing DICU model or using an alternative DICU model may be essential for DSM2 to better match field measured EC during the summers of the critical and dry water-years, especially at the sites located in the vicinity of the confluence of the Sacramento and San Joaquin rivers. This may be challenging since no direct measurements of net Delta consumptive use is available. Indirect calculation of net Delta consumptive use by utilizing a flow balance approach on certain isolated regions might be considered. Another approach may be to develop Artificial Neural Networks that are trained to estimate net Delta outflow (NDO) based on measured EC values at Martinez and nearby areas. Once estimates for the NDO are available, the values for net Delta consumptive use could be calculated.

9.7 References

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