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

34th Annual Progress Report
June 2013

Chapter 3
DSM2 Version 8.1 Calibration with NAVD88 Datum

Authors: Lianwu Liu and Prabhjot Sandhu,
Delta Modeling Section,
Bay-Delta Office,
California Department of Water Resources


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3.1 Introduction

A new calibration has been performed for Version 8.1 of DSM2, which incorporates the latest improvements to the DSM2 code. The main differences in DSM2 version 8.1 include: DSM2-Qual model formulation change to improve model convergence (presented at CWEMF 2011 conference and discussed in (Liu & Ateljevich, Improvements to DSM2-Qual: Part 1, 2011)); modifications to the DSM2-Hydro program source code that improve channel geometry calculation (presented at CWEMF 2012 conference and documented in (Liu & Ateljevich, Improved Geometry Interpolation in DSM2-Hydro, 2012)); datum conversion to NAVD88; and Martinez EC boundary correction. Since these changes affect results both in DSM2 Hydro and Qual, a new calibration is needed. This calibration is done by adjusting Manning's coefficient values in Hydro and dispersion coefficients in Qual. Further improvements involving other changes, e.g. new bathymetry and grid change, may come in future releases.

3.2 Hydrodynamics Calibration

This calibration is based on the 2009 BDCP Calibration grid (CH2M Hill, October 2009), and converted to NAVD88. CDEC has been reporting stage data in NAVD88 since 2006. Before then, although stage stations were reported using a common datum (NGVD 1929), in fact individual stage stations had different, unknown local datums. Minor changes were made to some channels and cross sections, e.g., channels 141 and 144 were corrected. Those cross sections having a negative conveyance gradient (dConveyance) were modified. Some corrections were made to Martinez stage and Clifton Court Gate operation data.

Sensitivity tests of model and tidefile time steps were done; the time steps chosen for this calibration were 15, 30, and 15 minutes for Hydro, the tidefile, and Qual, respectively (the tidefile is output by Hydro and contains hydrodynamic data for use in Qual).

The Hydro calibration period was from October 1, 2001 to October 1, 2002 and October 1, 2007 to October 1, 2008, and validation period from October 1, 2006 to October 1, 2007 and October 1, 2009 to October 1, 2009. The calibration stations are listed in Table 3-1 and shown in Figure 3-1.

Table 3-1 Hydrodynamics Calibration Locations

Location	Short Name	CDEC_ID	Flow	Stage
Grant Line Canal at Tracy Bridge	CHGRL009	GCT		x
Victoria Canal near Byron	CHVCT000	VCU	x	*
Cross Channel	DLC	DLC	x	x
False River	FAL	FAL	x	*
Grant Line Canal	GLC	GLC	x	x
Georgiana Slough at Sacramento R	GSS	GSS	x	x
Holland Cut	HOL	HOL	x	*
Miner Slough at Hwy84 Bridge	HWB	HWB	x	x
Little Potato Sough	LPS	LPS	x	*
Mokelumne R at San Joaquin R	MOK	MOK	x	*
Old River at Quimbey	ORQ	ORQ	x	x
Old River at Frank's Tract	OSJ	OSJ	x	x
Middle River near Holt	RMID005	HLT	x	*
Middle River	RMID015	MDM	x	x
Middle River at Tracy Blvd	RMID027	MTB		x
Old River at Bacon Island	ROLD024	OBI	x	x
Old River at hwy4	ROLD034	OH4	x	x
Old River below dam	ROLD046	OBD		x
Old River above dam	ROLD047	OAB	x	x
Old River near Tracy	ROLD059	OLD		x
Old River at Head	ROLD074	OH1	x	x
Martinez	RSAC054	MRZ		x
Rio Vista	RSAC101	SRV	x	x
Sacramento R below Georgiana Sl	RSAC123	GES	x	x
Sacramento R above Cross Ch	RSAC128	SDC	x	x
Freeport	RSAC155	FPT	x	x
San Joaquin at Antioch	RSAN007	ANH		x
Jersey Point	RSAN018	JER	x	x
Prisoner's Point near terminous	RSAN037	PRI	x	*
Rough and Ready Island	RSAN058	RRI	x	x
San Joaquin at Garwood Bridge	RSAN063	SJG	x	x
Brandt Bridge	RSAN072	BDT	x	x
San Joaquin at Mossdale Bridge	RSAN087	MSD	x	
Cache Slough at Ryer Island	RYI	RYI	x	x
San Joaquin near Lathrop	SJL	SJL	x	x
Dutch Sl at Jersey Isle	SLDUT007	DSJ	x	x
Beldon Landing	SLMZU011	BDL		x
Montezuma Slough at National Steel	SLMZU025	NSL	x	x
Threemile Sl at San Joaquin R	SLTRM004	TSL	x	x
Steamboat Slough	SSS	SSS	x	x
Sutter Slough at Courtland	SUT	SUT	x	x
Turner Cut near Holt	TRN	TRN	x	*

*Datum inconsistency at some stations not resolved.

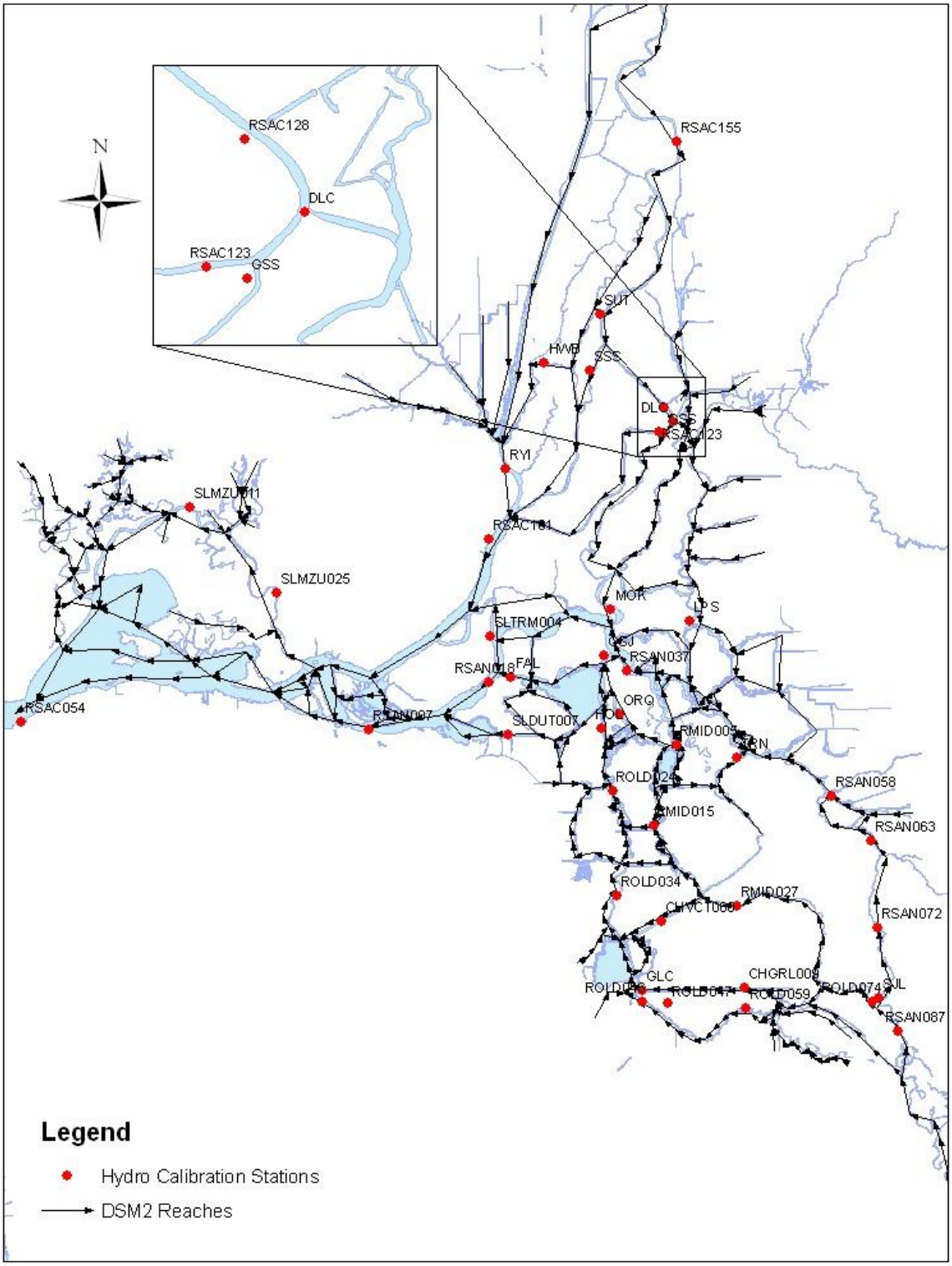

Figure 3-1 Hydro Calibration Stations

The model was primarily calibrated to match observed flows. Manning's coefficient values were adjusted for Hydro calibration. Stage was also compared to observed data in the same format as flow comparison. The calibration metrics are composed of five figures for each station:

- Timeseries comparison of instantaneous flow. This plot compares modeled and observed instantaneous flow. We show only 5 days in order to be able to see the tidal process and comparison clearly.
- Timeseries comparison of tidally-filtered daily-averaged flow. This plot compares modeled and observed tidally averaged flow, or net flow. Net flow is critical for flow distribution and for salt transport.
- Linear regression analysis of tidally-filtered daily-averaged flow. This scatter plot with a linear regression trend line shows statistically the comparison of the simulated vs. observed daily averaged flow. R^2 value gives information about the goodness of fit of the model. The trend line shows over- or under-predicting of the model.
- Linear regression analysis of instantaneous flow. This analysis followed a similar procedure described in the "Flooded Islands Pre-Feasibility Study" report (Resource Management Associates, 2005). The phase difference between the modeled and measured time series was determined using a cross-correlation procedure, and the modeled time series was shifted with the calculated phase lag before doing the regression analysis. The phase difference is noted in the figure. A positive value indicates that the simulated tidal process lags behind the observed record, while a negative value indicates a faster response by the model. The slope of the regression line approximates the amplitude ratio for modeled vs. observed tidal process. R^2 value gives information about the goodness of fit of the model. This plot was generated using data from May 15, 2008 to July 15, 2008. This short period of low flow was selected to better represent the tidal process. It is difficult to use the whole calibration period since the high flow period may have bigger net flow errors, which may be difficult to portray in a figure.
- Daily Maximum, Average, Minimum comparison. This plot compares modeled and observed daily maximum, average, minimum flow over the entire calibration period. It is easy to see how the model is doing overall in the entire calibration period.

Since overall the calibrated flow in 2009 BDCP Calibration matched observed data reasonably well, the 2009 calibration was used as a reference. Manning's n values were adjusted by groups. 26 adjustments and runs were made to reach a satisfactory result.

Due to the bug fixes of channel area interpolation, Manning's n values changed significantly in some areas, as summarized in Table 3-2. For example, in Sutter Slough and Steamboat Slough, Manning's n changed from 0.024 to 0.029; Lower San Joaquin River channels 48 through 51 changed from 0.022 to 0.026; channels in the Montezuma Slough area changed from 0.018 to 0.021.

Table 3-2 Recalibrated Manning's Coefficient

GroupName	Channel Number	2009 BDCP Calibration	Recalibrated
SUTTER_SL	375--382	0.024	0.029
STEAMBOAT_SL	383--387	0.024	0.029
LOWER_SJR	48--53, 282--301	0.019--0.037, most 0.022	0.026
THREE MILE SL	307--310	0.033	0.032
FALSE_RIVER	276--279	0.027	0.025
DUTCH_SL	215, 260, 273--275	0.027	0.025
OLD_RIVER	81--124, 214--278	0.027	0.025
MOK	334-344,348--349	0.019, 0.022	0.028
MONTEZUMA_SL	455--542	0.018	0.021

Flow results at a few locations are shown in Figure 3-2 through Figure 3-7. In summary, stations in the North Delta showed moderately improved results comparing to 2009 BDCP Calibration, e.g. Rio Vista, RSAC123 (Figure 3-2 and Figure 3-3). Stations in the South Delta showed little or no improvement, e.g., ROLD024 (Figure 3-4). A few stations showed dramatic improvements, e.g., RSAN087, LPS, and DLC (Figure 3-5 through Figure 3-7). The flow coefficients of the Delta Cross Channel gate were changed to 2.0, to allow enough flow through the gate.

Stage comparisons at a few selected stations, i.e. CHGRL009, RMID027, and DLC, are shown in Figure 3-8 through Figure 3-10. Simulated stages in this calibration compared with field data are much better than the 2009 calibration results, mainly due to the conversion to NAVD88. Maximum stages in tidal cycles match much better with field record. Minimum stages tend to be lower than observed data (e.g., Figure 3-10 Stage at Delta Cross Channel); as a result, simulated tidal ranges tend to be larger than field data.

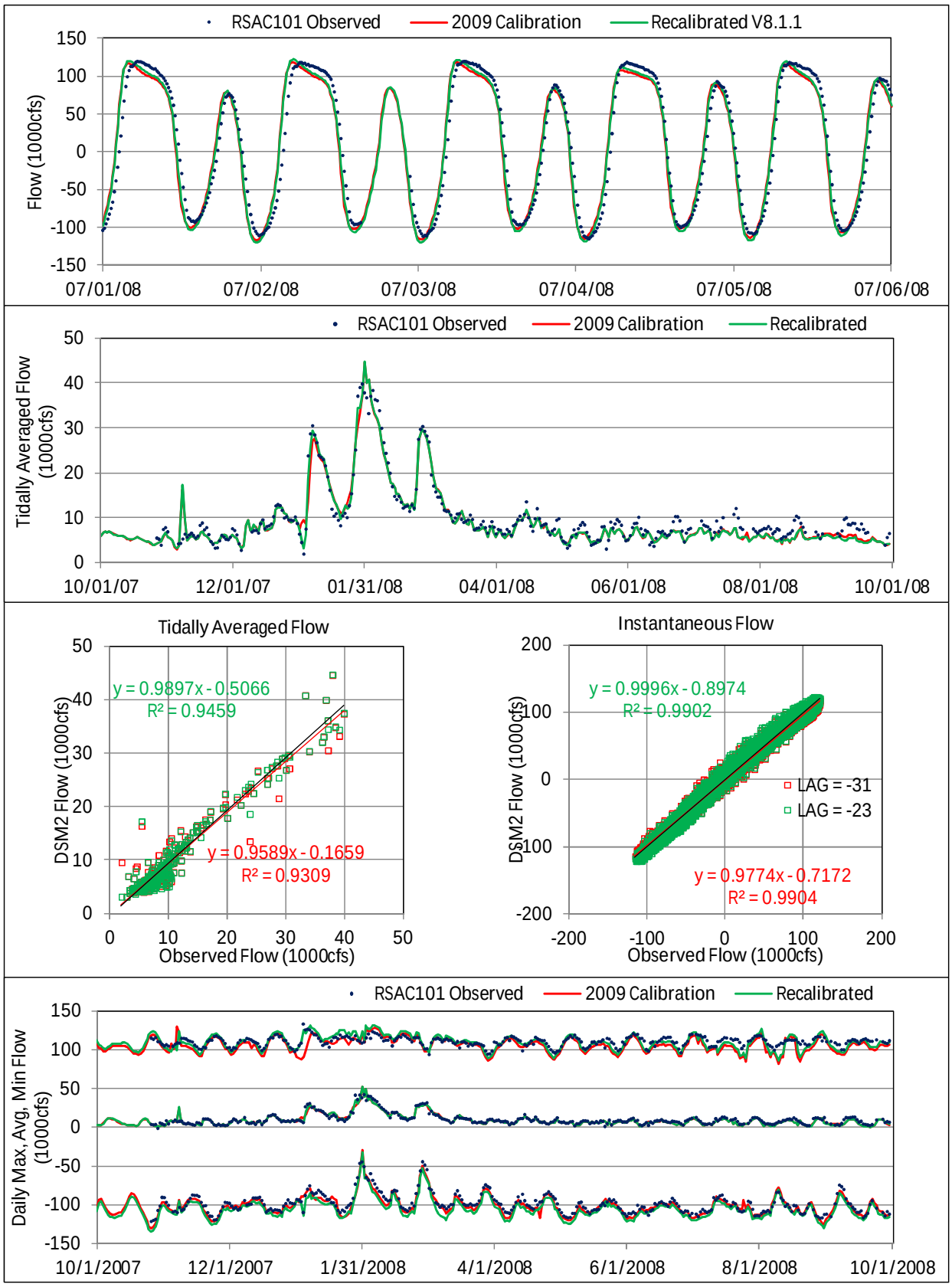

Figure 3-2 Sacramento River at Rio Vista

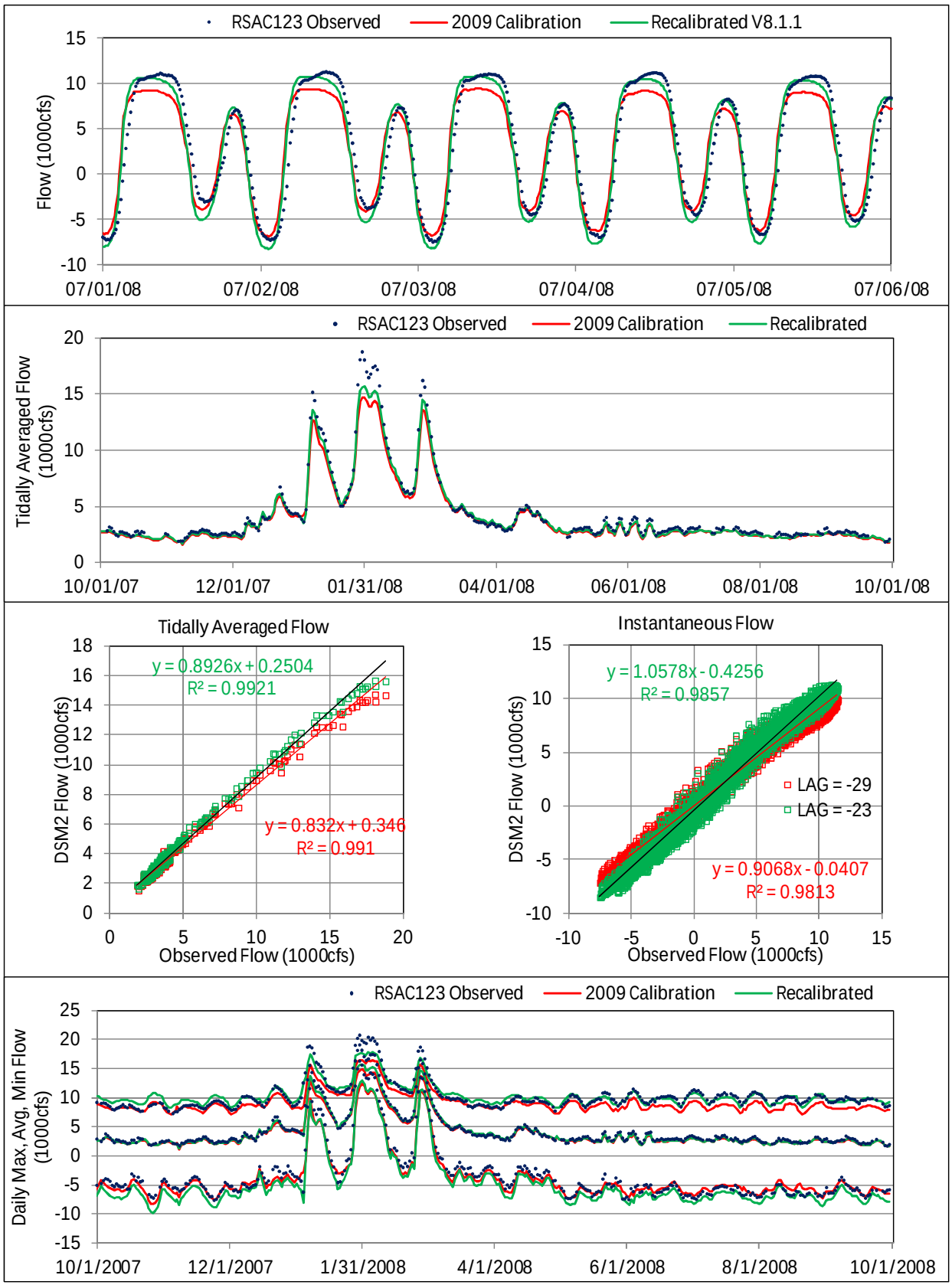

Figure 3-3 Sacramento River downstream of Georgiana Slough

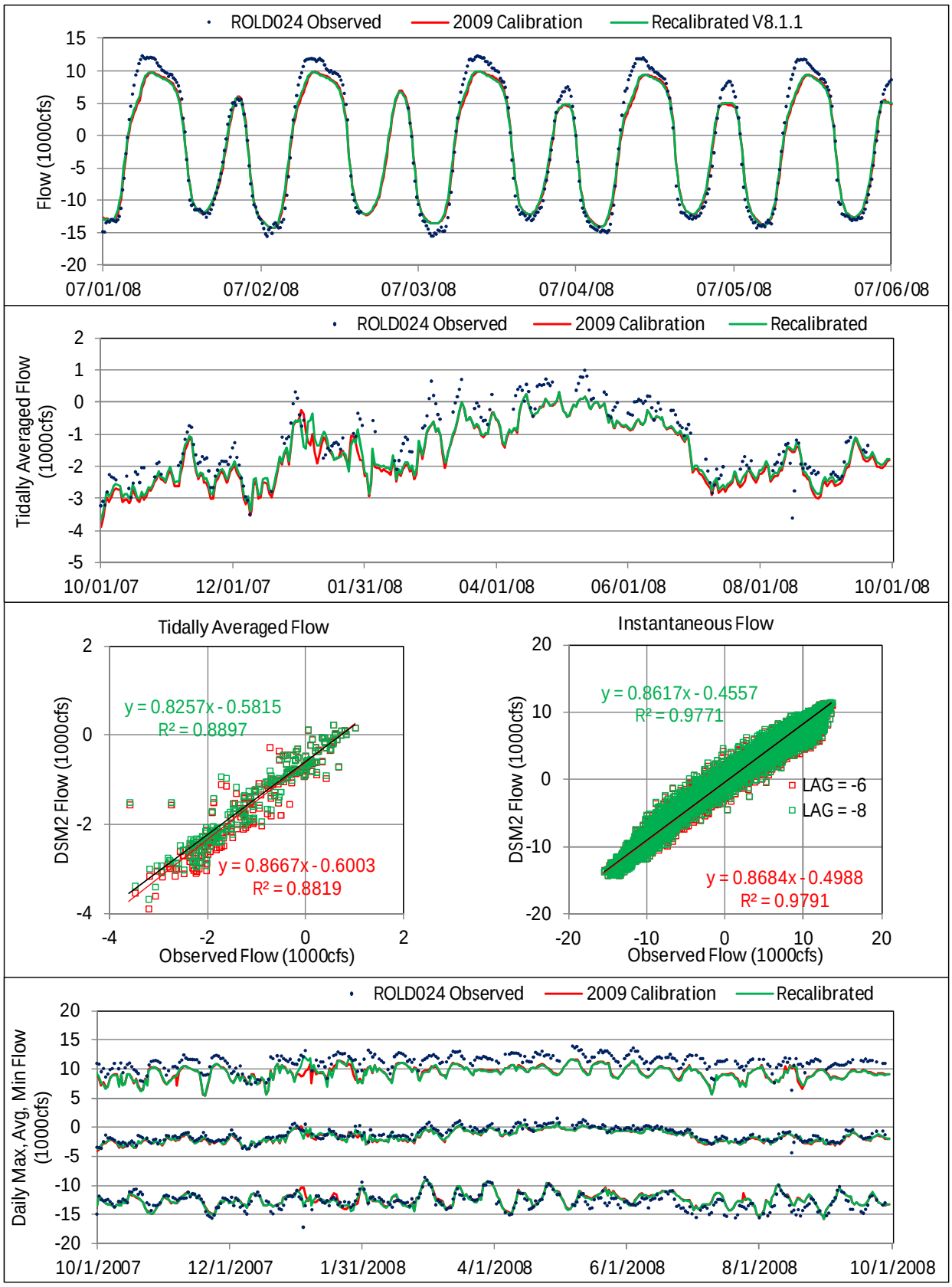

Figure 3-4 Old River at Bacon Island

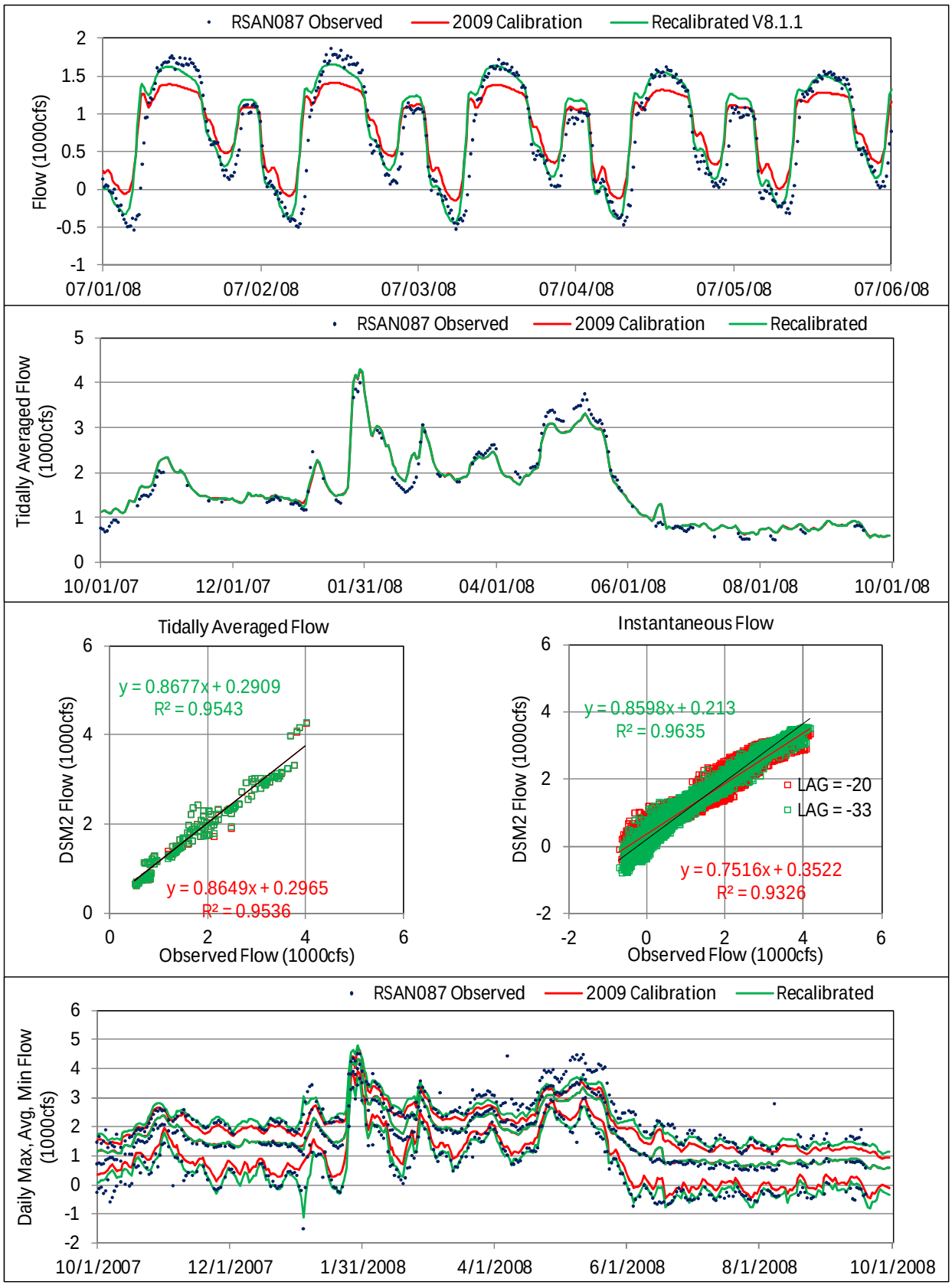

Figure 3-5 San Joaquin River at Mossdale

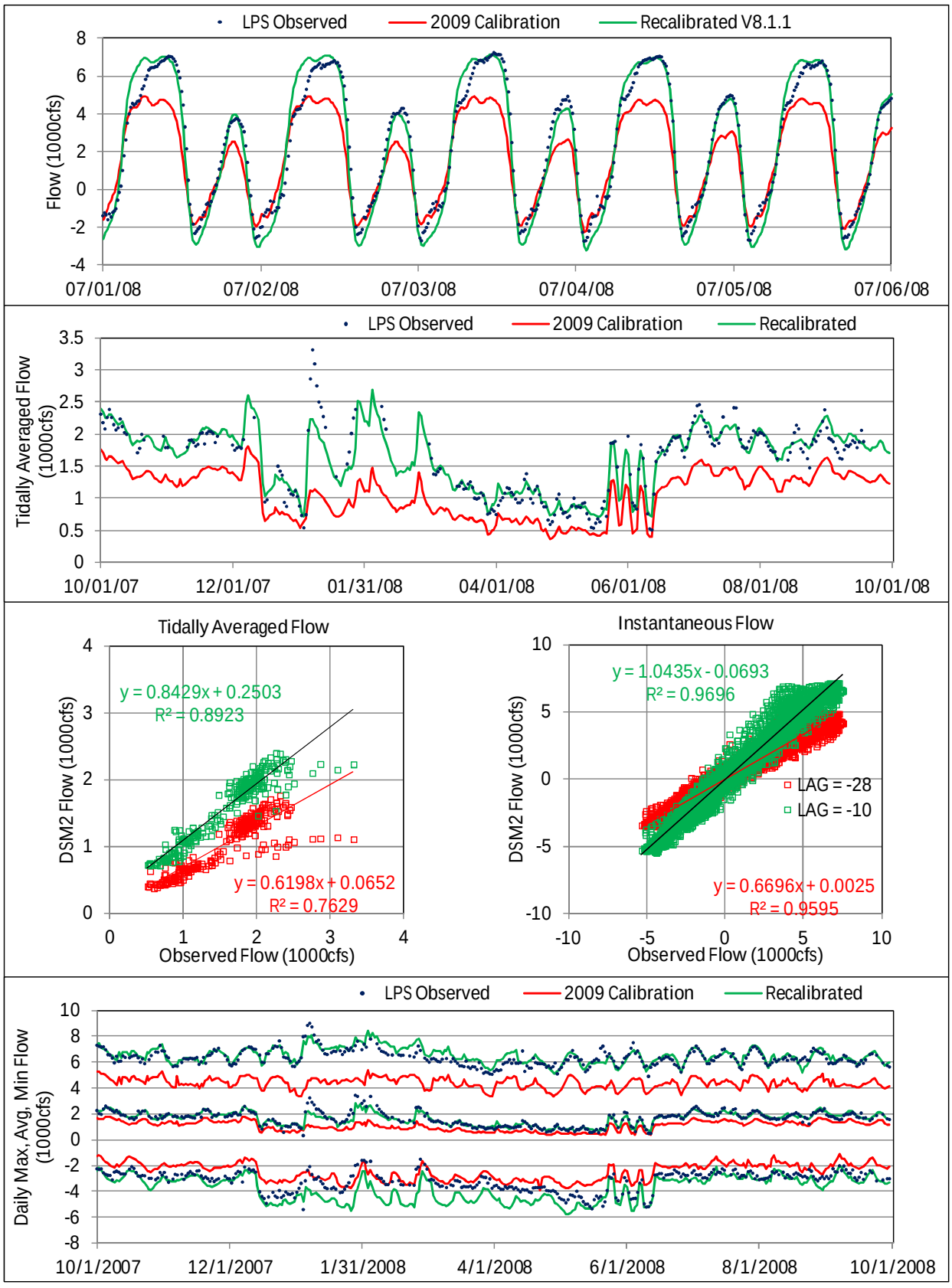

Figure 3-6 Little Potato Slough

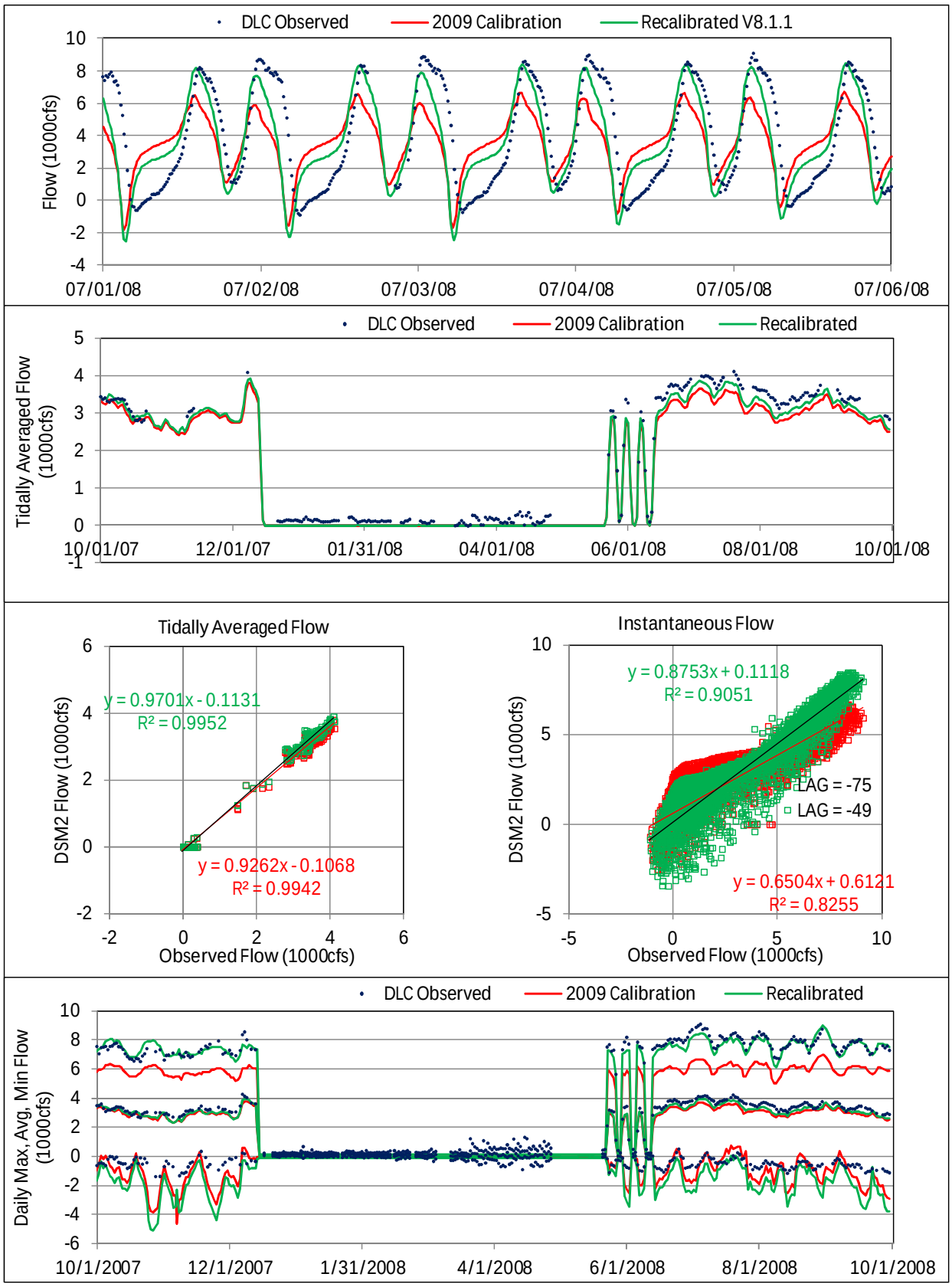

Figure 3-7 Delta Cross Channel

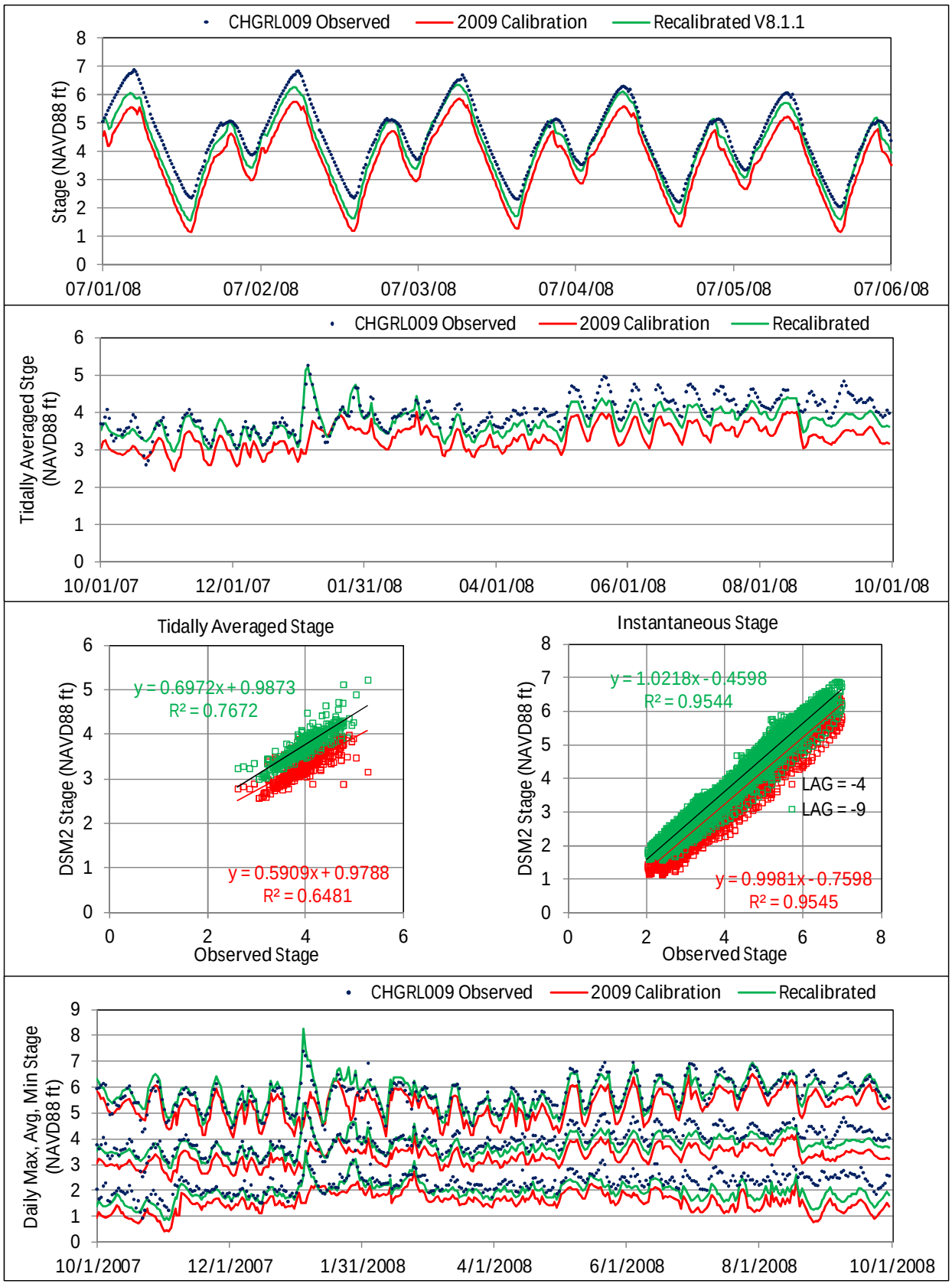

Figure 3-8 Stage at Grant Line Canal

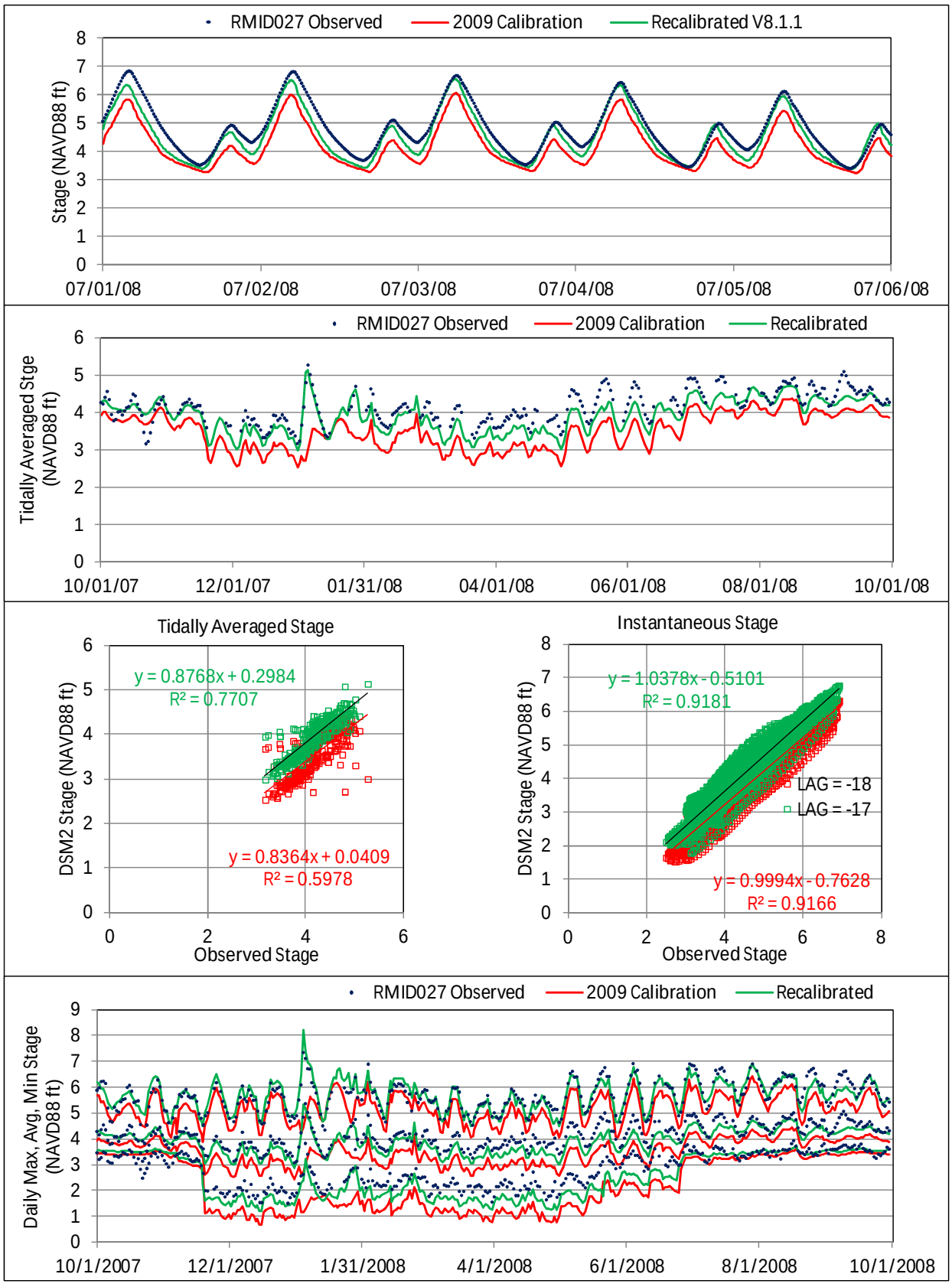

Figure 3-9 Stage at Middle River at Tracy Blvd

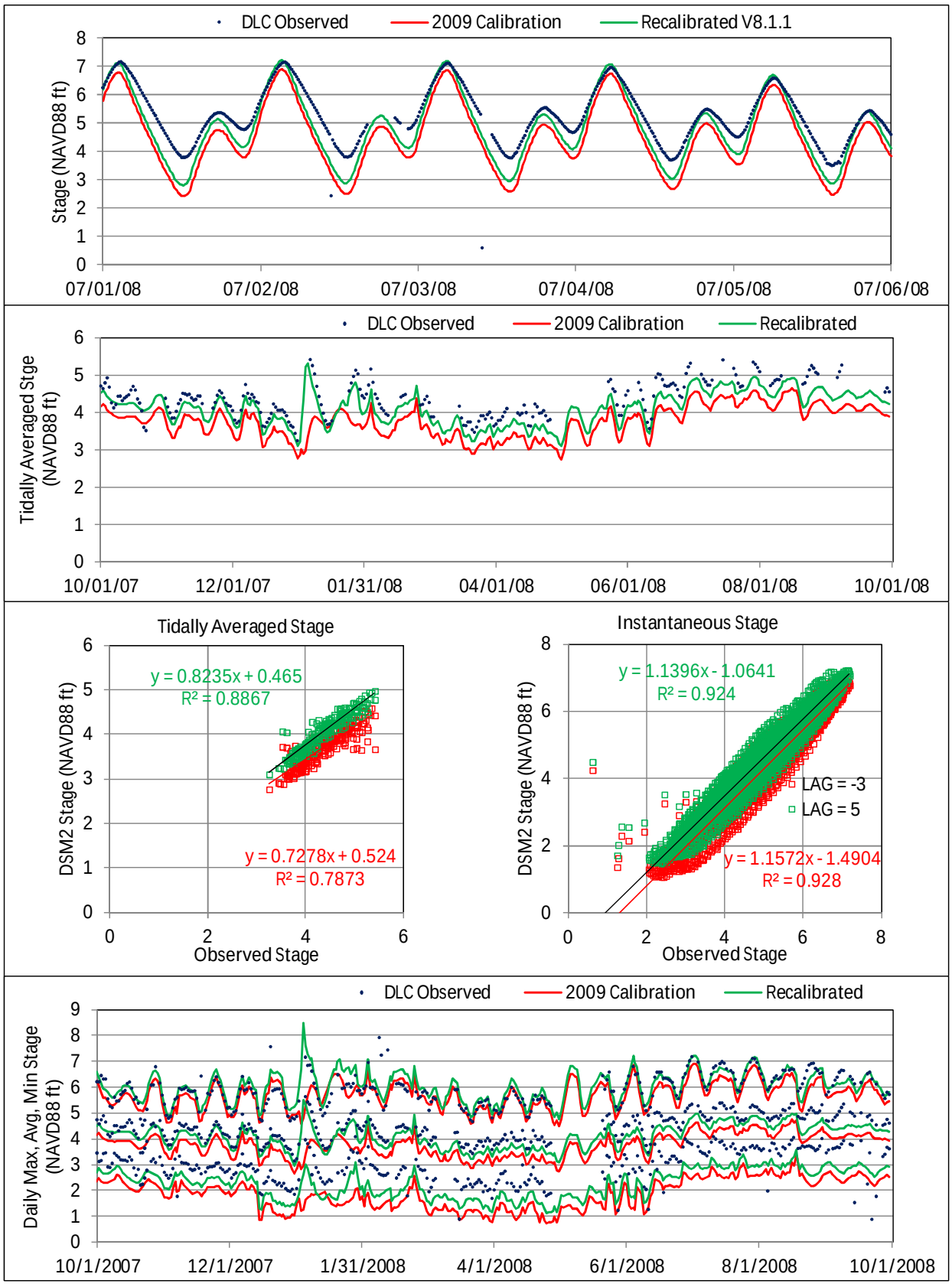

Figure 3-10 Stage at Delta Cross Channel

3.3 EC Calibration

Version 8.1 improved the dispersion formulation for model convergence (Liu & Ateljevich, Improvements to DSM2-Qual: Part 1, 2011). A new dispersion coefficient (DC) was introduced. The calibration period was from October 1, 2000 to October 1, 2008. We try to use all the stations with good data. The calibration stations are listed in Table 3-3, and shown on the map (Figure 3-11).

Some corrections were made for Martinez boundary EC. It was found, before October 1, 2002, the data were from IEP, they were indeed hourly averaged data. But after October 1, 2002, CDEC hourly data were used, which were instantaneously sampled, not hourly averaged. They were converted to hourly averaged values using HEC-DSSVue (US Army Corps of Engineers, Hydrologic Engineering Center), and the property was changed to **PER-AVER**. It is recommended to always use **PER-AVER** data at boundaries for Qual. It is more accurate for Qual to take **PER-AVER** data at boundaries because of the nature of its numerical scheme. If we start to use 15 minute data for Martinez boundary EC, it is still recommended to convert to period average. A sensitivity test showed that the differences between using 15 minute data and 1 hour data for Martinez boundary were around 0.1% in the Delta, so we used hourly-averaged for Martinez EC in this calibration.

The metrics used to evaluate model performance include:

- Linear regression analysis of monthly-averaged EC. This scatter plot with a linear regression trend line shows the simulated vs. observed monthly averaged EC. The intercept is set to zero so that the slope shows the bias of the model for higher EC. The model is over-predicting when the slope is higher than 1, and under-predicting when the slope is smaller than 1. R^2 value gives information about the goodness of fit of the model. A high R^2 value close to 1 means best fit, which usually means high quality data and good model prediction.
- Timeseries comparison of monthly-averaged EC. This plot compares modeled and observed EC month by month, easy to see directly which months the model is doing well or bad.
- Timeseries comparison of daily-averaged EC. This plot compares modeled and observed EC on a daily basis, making it easier to see how the model is doing over all.
- Mean Error (ME) and Percent Mean Error (PME). The mean values of observed and modeled EC for the entire calibration period are calculated. Percent Mean Error is calculated using Mean Error divided by the observed mean and expressed as a percentage. This gives a normalized percentage of how much the model is over-predicting or under-predicting.
- Root Mean Squared Error (RMSE) and Relative RMSE. RMSE is calculated based on daily averaged data. It is a good indicator of model prediction error and representative of the size of a "typical" error. Originally, we proposed the relative RMSE (also called normalized RMSE, or percent RMSE), calculated as RMSE divided by the range of the data and expressed as a percentage. A more mathematically sound parameter called RMSE-observed standard deviation ratio (RSR) may give better scaling and normalization, so we changed to RSR (Moriasi, Arnold, Van Liew, Bingner, Harmel, & Veith, 2007). It was recommended to be satisfactory for RSR ≤ 0.70 for watershed models with a monthly time step, and very good for RSR ≤ 0.5, while Percent Bias (PBIAS, same as PME) is also satisfactory.

Table 3-3 EC Calibration Stations

Location	Short Name	CDEC_ID
Three Mile Slough	3MILE_SL	TMS
DMC Headworks	CHDMC006	DMC
Grant Line Canal at Tracy Bridge	CHGRL009	GCT
Harvey O Banks PP	CLIFTON_C	HBP
Middle River near Holt	RMID005	HLT
Victoria Island	RMID023	VIC
Middle River at Tracy Blvd	RMID027	MTB
Union Island	RMID040	UNI
Holland Cut	ROLD014	HOL
Bacon Island at Old River	ROLD024	BAC
Old River near Tracy	ROLD059	OLD
Martinez	RSAC054	MRZ
Port Chicago	RSAC064	PCT
Mallard Island	RSAC075	MAL
Pittsburg	RSAC077	PTS
Collinsville	RSAC081	CLL
Emmaton	RSAC092	EMM
Rio Vista	RSAC101	RIV
Hood	RSAC139	SRH
San Joaquin at Antioch	RSAN007	ANH
Jersey Point	RSAN018	JER
San Andrea's Landing	RSAN032	SAL
Rough and Ready Island	RSAN058	RRI
San Joaquin at Mossdale Bridge	RSAN087	MSD
Vernalis	RSAN112	SJR
Brandt Bridge	SAN072	BDT
Farrar Park	SLDUT009	FRP
Beldon Landing	SLMZU011	BDL
Montezuma Slough at National Steel	SLMZU025	NSL
Bethel Island	SLPPR003	BET
Threemile Sl at San Joaquin R	SLTRM004	TSL

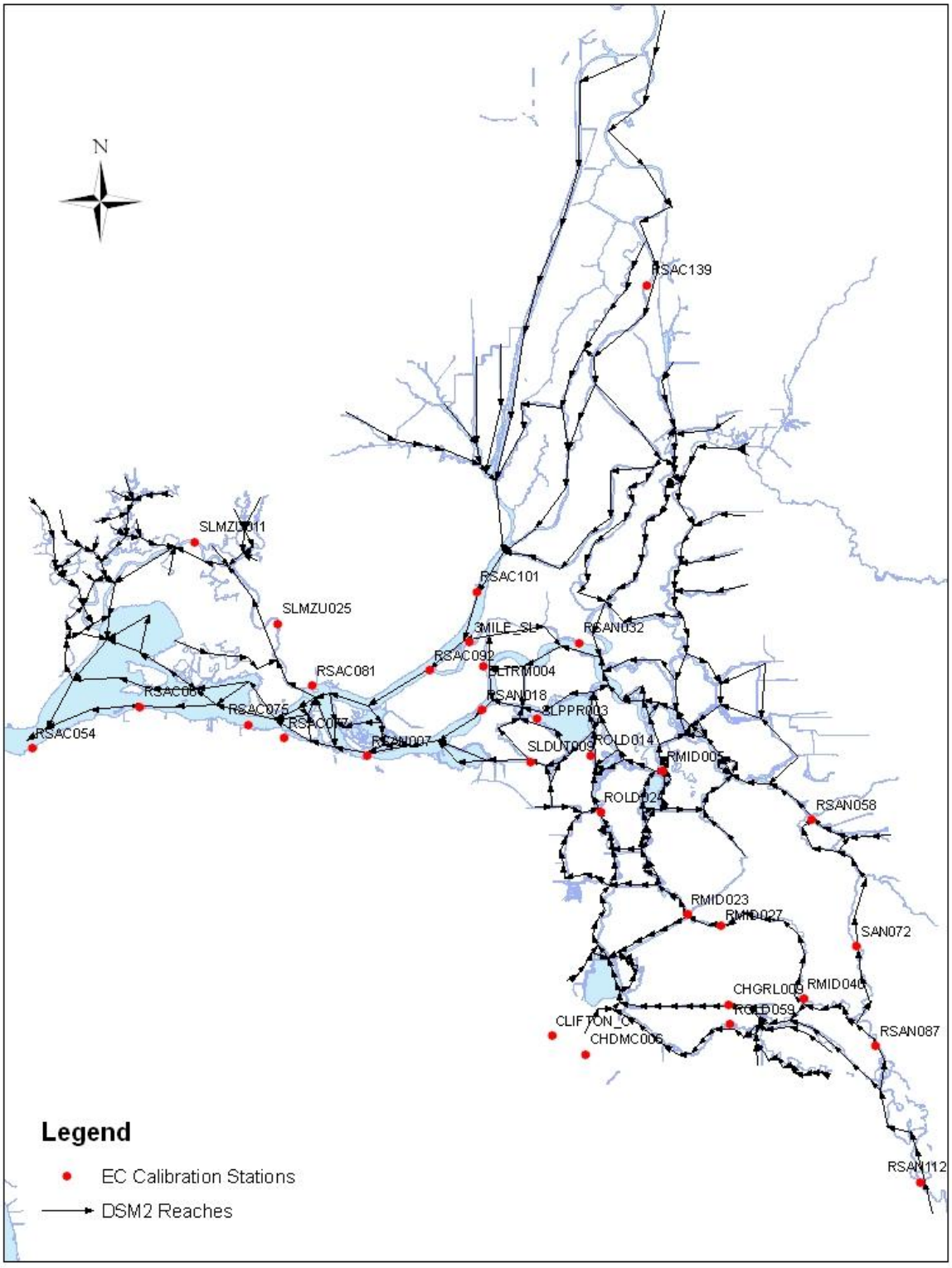

Figure 3-11 EC Comparison Stations

The calibration started by scaling the 2009 BDCP calibration dispersion coefficients by 1200, i.e., $DC = DQQ \times 1200$, where DQQ is the old dispersion coefficient, since previous experience showed this approach gave reasonable results. Then we calibrated the coefficients in groups from the West Delta to the South Delta in the trial runs. 11 adjustments and runs were taken to reach the satisfactory results, as described in the calibration notes.

30 stations with good data were selected and plotted. Mean Error, Percent Mean Error, RMSE and RSR are calculated and listed in Table 3-4 (the same metrics were calculated for 2009 calibration run and listed in Table 3-5 for comparison). Figure 3-12 through Figure 3-17 show the calibration metrics plots (including the 2009 calibration for comparison) at key stations: Collinsville, Emmaton, Jersey Point, Old River at Bacon Island, Clifton Court Forebay, and Montezuma Slough at Beldons. Some outlier data points for monthly EC were taken out for regression analysis for some South Delta stations (Clifton Court, ROLD024, SLDUT009), including December 2000, 2002, 2003, 2004, 2005, and January 2001, when the model failed to predict the EC peaks, as seen in Figure 3-15 and Figure 3-16. The reasons for these missing peaks are not clear. By taking out these outliers, the statistical analyses are more meaningful and represent the model performance in other months better.

From Table 3-4, key stations including Collinsville, Emmaton, Antioch, Jersey Point, and Old River at Bacon Island have the smallest Percent Mean Errors (PME) within 3% and RSR values less than 0.5. The model consistently under-predicts San Joaquin River stations (RSAN072, RSAN058) and South Delta stations (ROLD059, CHGRL009, RMID027, CLIFTON COURT), where the PMEs are larger than -10%. The worst is Old River at Tracy Road (ROLD059) with percent mean error -22%. The RSR values of most of the stations are less than or close to 0.5 except RMID027, ROLD059, RSAC101, and RSAN032, which may need to be further improved. The predicted EC at Montezuma Slough stations (SLMZU011, SLMZU025) are much lower than observed, although the predicted EC matches the timing of salinity intrusion well. These biases are similar to the 2000, 2009 calibrations.

Figure 3-18 shows Martinez EC comparison was improved compared to the 2009 calibration, due to the correction of the Martinez boundary EC input data.

A lot of reasons might contribute to the errors in predicted EC, e.g. bathymetry, DICU, boundary flow and water quality measurement errors, over-simplification of the model formulation, etc. A 1D model such as DSM2 may be inadequate to accurately model areas that are highly two dimensional (e.g., shallow bays, such as Grizzly Bay, Suisun Bay, and Franks Tract) or three dimensional (e.g., stratification in West Delta). Further investigations are needed to improve the model calibration.

Table 3-4 Summary of Error Estimates at Selected Stations

Location	DSM2 Station	CDEC Station	Mean (umhos)				RMSE (umhos)	STDEV	RSR
			Observed	Simulated	Error	%			
Three Mile Sl at Sac River	3MILE_SL	TMS	471	448	-22	-4.7	182	397	0.46
Jones Pumping Plant	CHDMC006	DMC	445	421	-24	-5.4	65	135	0.48
Grant Line Canal at Tracy Blvd Bridge	CHGRL009	GCT	595	522	-74	-12.4	102	243	0.42
Banks Pumping Plant	CLIFTON COURT	HBP	394	362	-32	-8.2	58	136	0.42
Middle River near Holt	RMID005	HLT	314	322	8	2.5	28	79	0.35
Middle River at Borden Hwy	RMID023	VIC	351	342	-9	-2.5	61	110	0.56
Middle River at Tracy Blvd	RMID027	MTB	513	442	-71	-13.9	145	184	0.79
Middle River at Mowery Bridge	RMID040	UNI	615	586	-30	-4.8	76	226	0.33
Old River at Holland Cut	ROLD014	HOL	456	408	-49	-10.6	69	214	0.32
Old River at Bacon Island	ROLD024	BAC	367	357	-10	-2.6	86	173	0.50
Old River at Tracy Road	ROLD059	OLD	640	500	-140	-21.9	173	264	0.65
Martinez	RSAC054	MRZ	17557	16374	-1183	-6.7	1304	8049	0.16
Sac River at Port Chicago	RSAC064	PCT	7856	8950	1095	13.9	3032	5707	0.53
Sac River at Mallard	RSAC075	MAL	4697	4665	-32	-0.7	824	4230	0.19
Sac River at Pittsburg	RSAC077	PTS	4110	4366	256	6.2	1371	3674	0.37
Sac River at Collinsville	RSAC081	CLL	2912	2917	6	0.2	789	2828	0.28
Sac River at Emmaton	RSAC092	EMM	644	637	-7	-1.1	298	705	0.42
Sac River at Rio Vista	RSAC101	RIV	187	201	14	7.6	57	48	1.19
Sac River at Hood	RSAC139	SRH	156	157	1	0.7	13	31	0.42
SJR at Antioch	RSAN007	ANH	1860	1863	2	0.1	568	1839	0.31
SJR at Jersey Point	RSAN018	JER	678	695	17	2.5	229	569	0.40
SJR at San Andreas Landing	RSAN032	SAL	223	252	29	12.9	65	91	0.72
Stockton Ship Channel	RSAN058	RRI	596	529	-67	-11.3	120	204	0.59
SJR at Brandt Bridge	RSAN072	BDT	529	490	-39	-7.3	75	234	0.32
SJR at Mossdale	RSAN087	MSD	527	506	-21	-3.9	69	231	0.30
SJR at Mossdale	RSAN112	SJR	573	573	0	0.0	2	214	0.01
Dutch Slough	SLDUT009	FRP	569	527	-42	-7.4	149	381	0.39
Montezuma Slough at Beldons	SLMZU011	BDL	6856	5122	-1734	-25.3	2130	4712	0.45
Montezuma Slough at National Steel	SLMZU025	NSL	5286	3756	-1530	-28.9	2114	4164	0.51
Piper Slough at Bethel Island	SLPPR003	BET	459	382	-77	-16.7	145	287	0.50

Table 3-5 Summary of Error Estimates Calculated for 2009 Calibration

Location	DSM2 Station	CDEC Station	Mean (umhos)				RMSE (umhos)	STDEV	RSR
			Observed	Simulated	Error	%			
Three Mile Sl at Sac River	3MILE_SL	TMS	471	452	-19	-4.0	188	397	0.47
Jones Pumping Plant	CHDMC006	DMC	445	412	-34	-7.5	67	135	0.50
Grant Line Canal at Tracy Blvd Bridge	CHGRL009	GCT	595	520	-76	-12.7	103	243	0.42
Banks Pumping Plant	CLIFTON COURT	HBP	394	354	-40	-10.2	65	136	0.48
Middle River near Holt	RMID005	HLT	314	331	17	5.4	38	79	0.48
Middle River at Borden Hwy	RMID023	VIC	351	344	-7	-2.1	64	110	0.58
Middle River at Tracy Blvd	RMID027	MTB	513	471	-42	-8.2	159	184	0.87
Middle River at Mowery Bridge	RMID040	UNI	615	586	-30	-4.8	76	226	0.34
Old River at Holland Cut	ROLD014	HOL	456	380	-76	-16.7	96	214	0.45
Old River at Bacon Island	ROLD024	BAC	367	335	-31	-8.6	93	173	0.54
Old River at Tracy Road	ROLD059	OLD	640	498	-142	-22.1	173	264	0.65
Martinez	RSAC054	MRZ	17557	15785	-1771	-10.1	1913	8049	0.24
Sac River at Port Chicago	RSAC064	PCT	7856	8610	754	9.6	2886	5707	0.51
Sac River at Mallard	RSAC075	MAL	4697	4601	-95	-2.0	878	4230	0.21
Sac River at Pittsburg	RSAC077	PTS	4110	4371	261	6.4	1408	3674	0.38
Sac River at Collinsville	RSAC081	CLL	2912	2964	53	1.8	811	2828	0.29
Sac River at Emmaton	RSAC092	EMM	644	592	-52	-8.1	316	705	0.45
Sac River at Rio Vista	RSAC101	RIV	187	190	3	1.4	46	48	0.97
Sac River at Hood	RSAC139	SRH	156	157	1	0.5	8	31	0.25
SJR at Antioch	RSAN007	ANH	1860	1887	27	1.4	598	1839	0.33
SJR at Jersey Point	RSAN018	JER	678	682	4	0.5	251	569	0.44
SJR at San Andreas Landing	RSAN032	SAL	223	252	28	12.6	68	91	0.75
Stockton Ship Channel	RSAN058	RRI	596	541	-55	-9.2	104	204	0.51
SJR at Brandt Bridge	RSAN072	BDT	529	487	-42	-7.9	68	234	0.29
SJR at Mossdale	RSAN087	MSD	527	504	-23	-4.3	84	231	0.36
SJR at Mossdale	RSAN112	SJR	573	573	0	0.0	2	214	0.01
Dutch Slough	SLDUT009	FRP	569	507	-62	-10.8	165	381	0.43
Montezuma Slough at Beldons	SLMZU011	BDL	6856	5227	-1629	-23.8	2049	4712	0.43
Montezuma Slough at National Steel	SLMZU025	NSL	5286	4065	-1222	-23.1	1758	4164	0.42
Piper Slough at Bethel Island	SLPPR003	BET	459	368	-90	-19.7	161	287	0.56

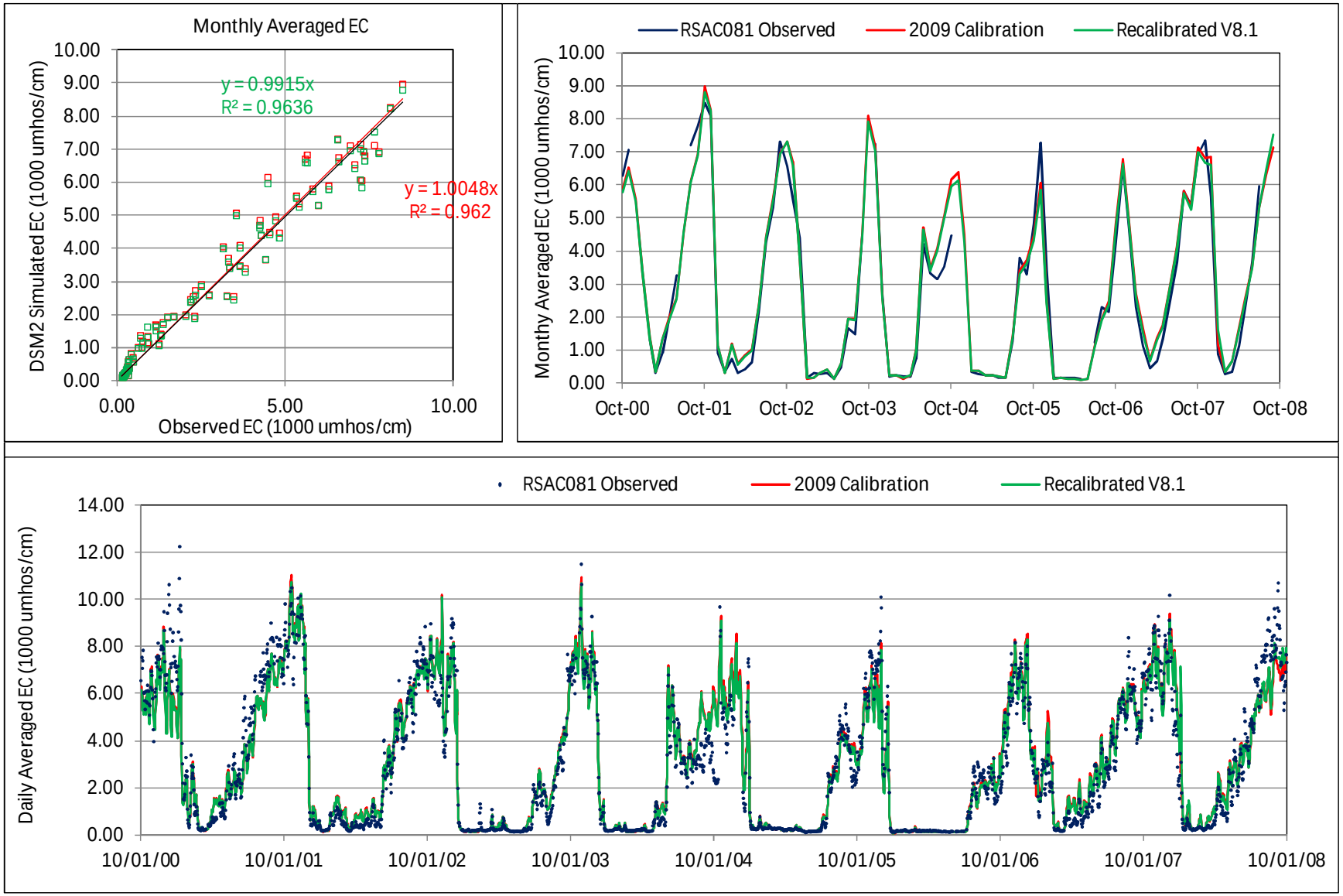

Figure 3-12 Sacramento River at Collinsville (RSAC081)

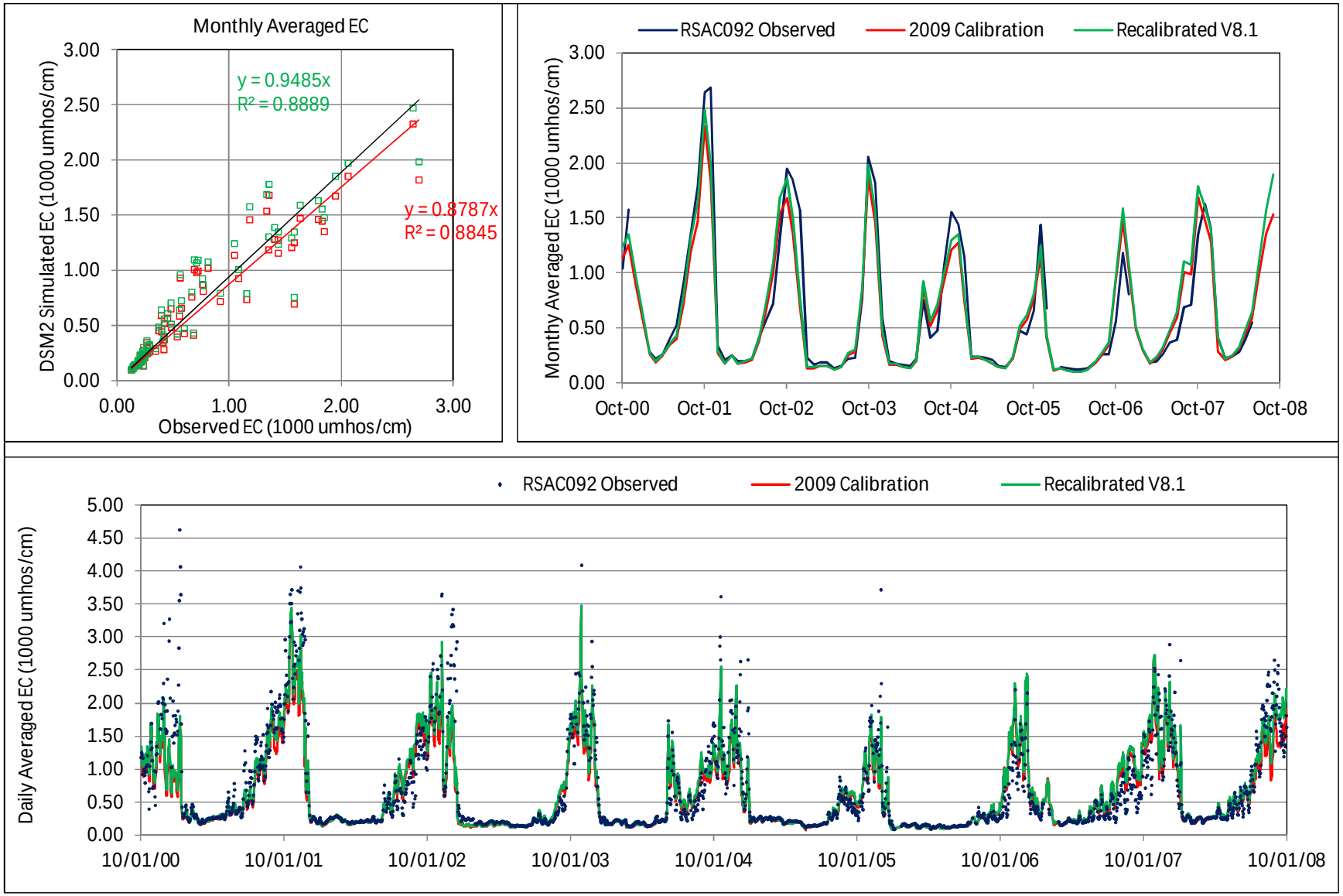

Figure 3-13 Sacramento River at Emmaton (RSAC092)

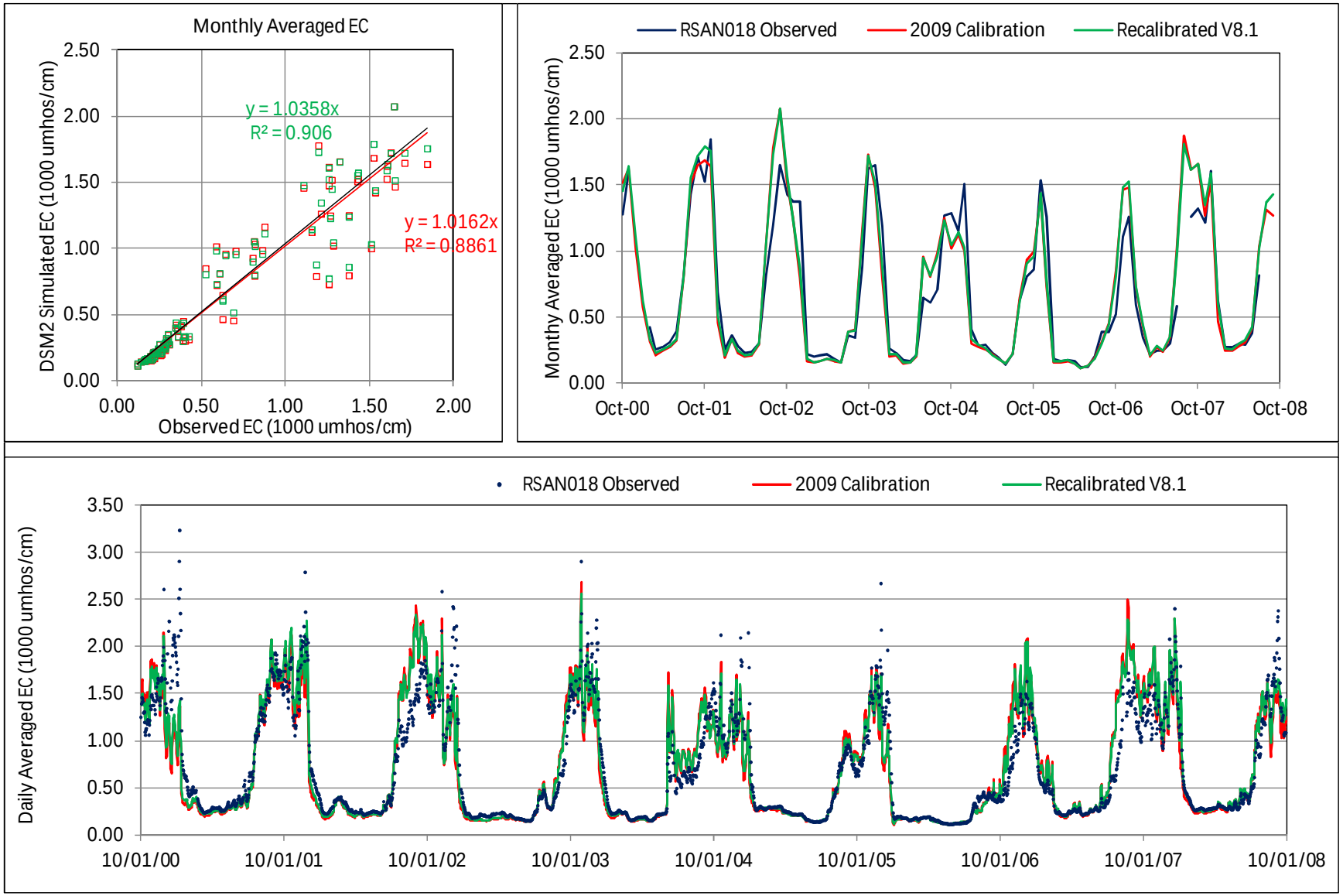

Figure 3-14 San Joaquin River at Jersey Point (RSAN018)

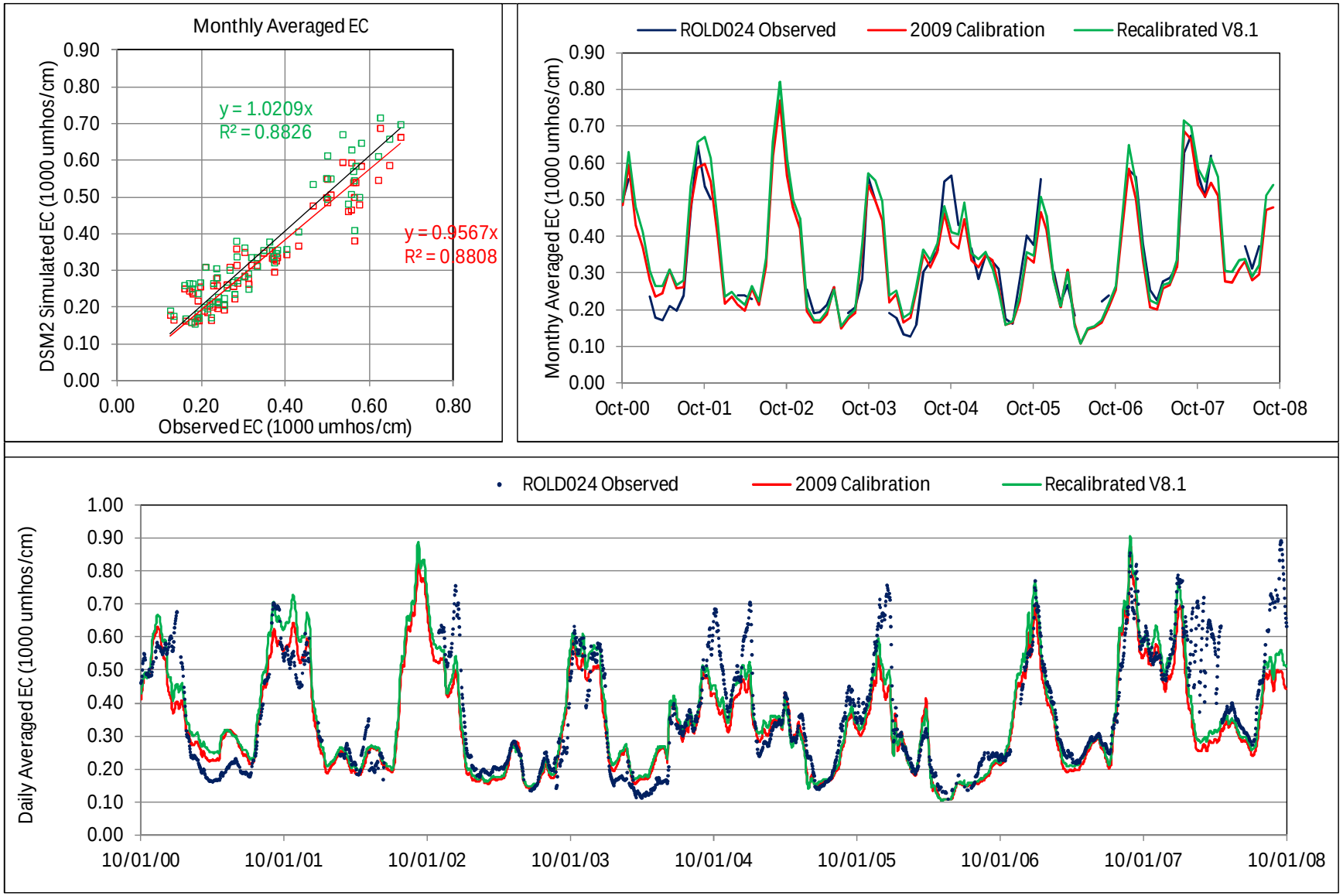

Figure 3-15 Old River at Bacon Island (ROLD024)

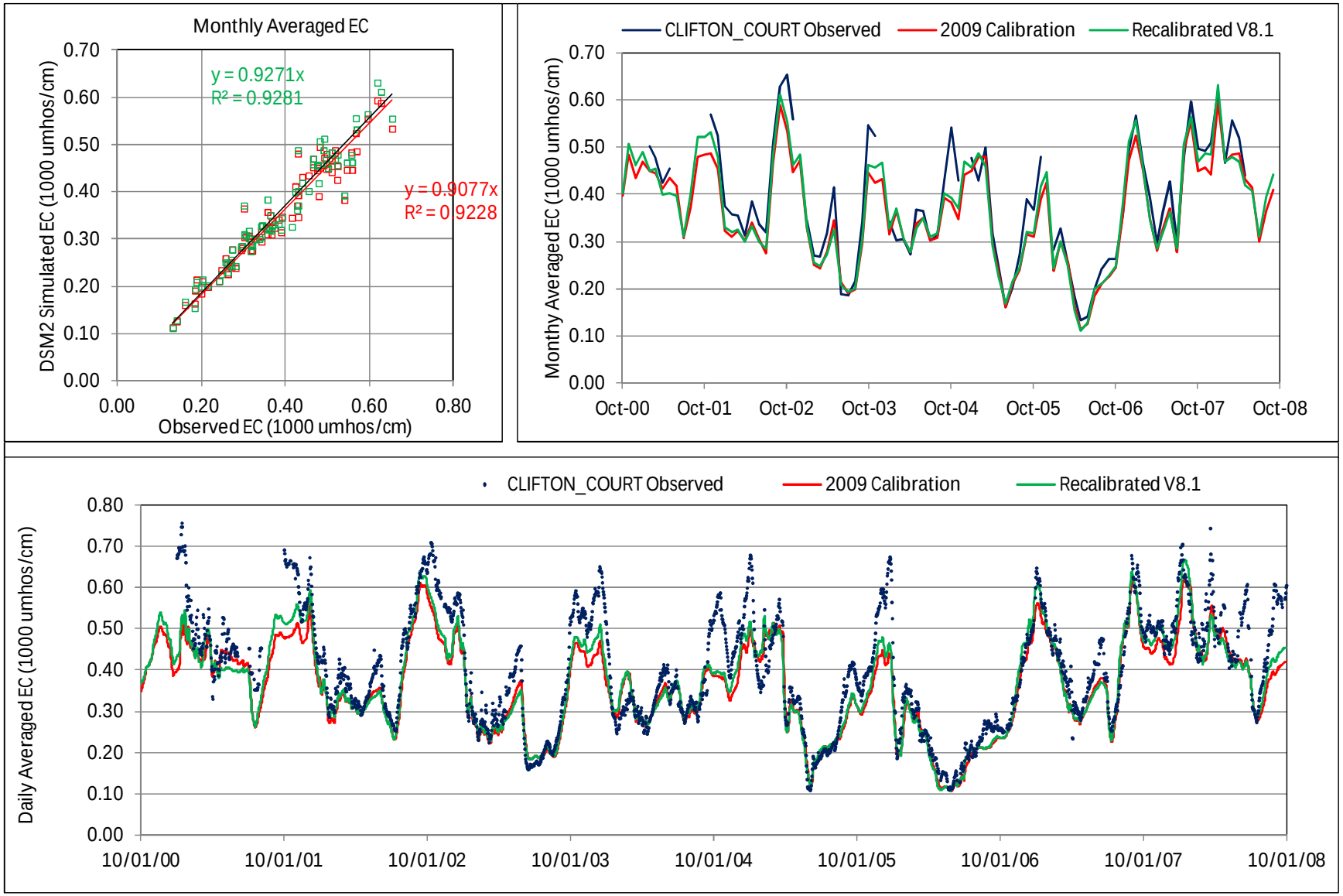

Figure 3-16 Clifton Court Forebay

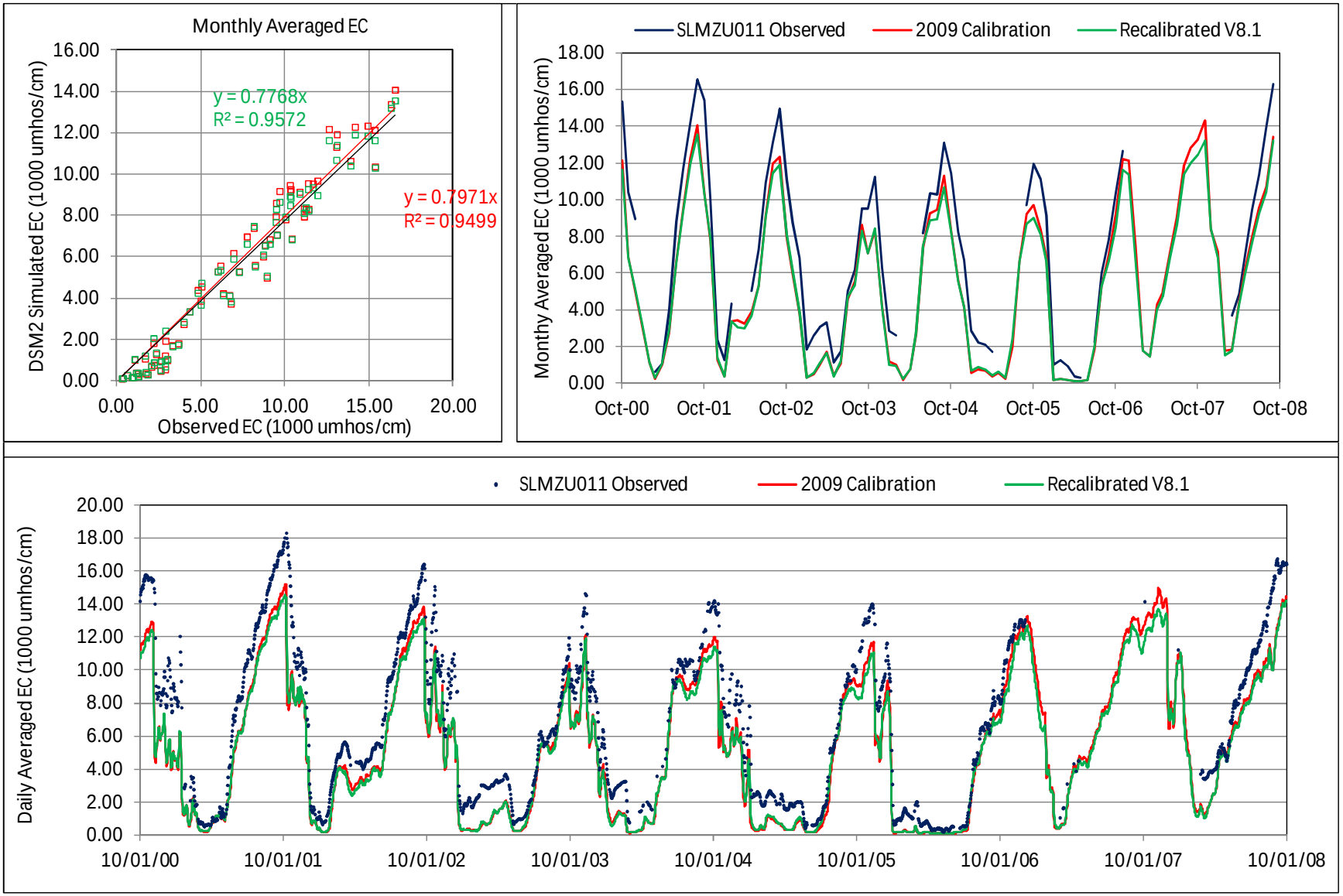

Figure 3-17 Montezuma Sl at Beldons (SLMZU011)

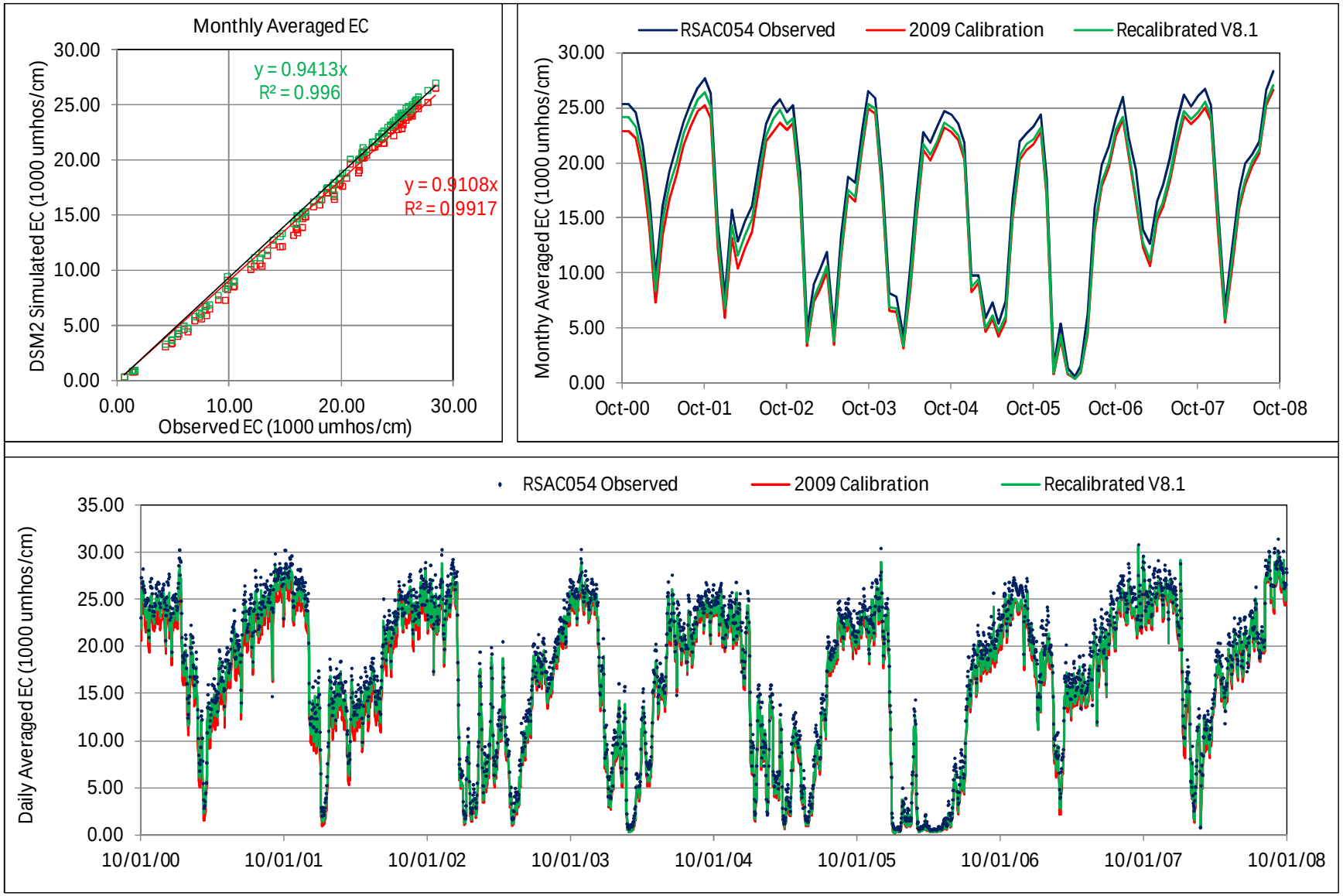

Figure 3-18 Martinez Boundary

3.4 Summary

DSM2 Version 8.1 incorporates the latest improvements to the DSM2 code and a new calibration with NAVD88 datum. The modifications of channel geometry interpolation and dispersion formulation in Version 8.1 improved the model reliability and convergence. Mass conservation was checked for both Hydro and Qual. Sensitivity and convergence tests were done to determine appropriate time steps to use. The conversion to NAVD88 stage datum improved the comparison of predicted and observed stages in the Delta. Errors in Clifton Court Gate operation data, Martinez stage data, and Martinez EC data were corrected.

The model predicted EC at key stations in Central Delta fairly well (Collinsville, Emmaton, Antioch, Jersey Point). The new calibrated model results are generally very close to the 2009 BDCP calibration results, although there are significant changes of Manning's n values and dispersion coefficients. Improvements were seen in a few places in Hydro and Qual, but not as big as we hoped. Flow around Franks Tract area and EC at South Delta are the most desirable to be improved.

This recalibration was done mainly by adjusting Manning's coefficients and dispersion coefficients. Further improvements would involve bigger changes, e.g., improve the channel schematic; regenerate cross sections based on better bathymetry data; improve flow around Franks Track area; improved estimates of diversions, return flows, and return flow water quality; Clifton Court gate modeling improvement; etc.

3.5 Acknowledgement

We would like to acknowledge Ralph Finch (DWR) for providing quality controlled data for the calibration, Lan Liang (DWR) for updating the historical run to 2012 and corrections made to Martinez stage and Clifton Court Gate operation data, Qiang Shu for help with VTools and writing some of the scripts used in the data analysis, and Parviz Nader-Tehrani for valuable suggestions.

3.6 References

CH2M Hill. (October 2009). *DSM2 Recalibration.* Sacramento.

Liu, L., & Ateljevich, E. (2011). Improvements to DSM2-Qual: Part 1. *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh*, p. Chapter 1.

Liu, L., & Ateljevich, E. (2012). Improved Geometry Interpolation in DSM2-Hydro. *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh*, p. Chapter 2.

Liu, L., & Sandhu, N. (2011, August). Dispersion Recalibration with DSM2 Version 8.1.1. *DSM2 Users Group Newsletter*. (M. Yu, Ed.) Sacramento, California, USA: California Department of Water Resources, Delta Modeling Section.

Liu, L., & Sandhu, N. (2011). Improvements to DSM2-Qual: Part 2. *In Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh*, p. Chapter 2.

Liu, L., & Sandhu, N. (2012). DSM2 Version 8.1 Recalibration. *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh*, p. Chapter 3.

Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., & Veith, T. L. (2007). Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations. *Transactions of the ASABE, 50(3)*, pp. 885-900.

Resource Management Associates. (2005). *Flooded Islands Pre-Feasibility Study.* Sacramento, CA.

US Army Corps of Engineers, Hydrologic Engineering Center. (n.d.). *HEC-DSSVue*. Retrieved 2013, from US Army Corps of Engineers, Hydrologic Engineering Center: http://www.hec.usace.army.mil/software/hec-dssvue/


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