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

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Chapter 2
New Reservoir Implementation in DSM2 V8.1.3

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2 New Reservoir Implementation in DSM2 V8.1.3

2.1 Introduction

This chapter describes a modification in the Delta Simulation Model 2 (DSM2) open water areas algorithm to include changing bathymetry with elevations. Previously, open water areas were treated as a constant area with a bottom elevation. This change will help to better model Liberty Island in addition to other open water areas in the Delta. The elevation-area-storage curves for reservoirs can be calculated using geographic information system (GIS) tools like ArcMap. The model has been tested and new results have been evaluated.

2.2 Description

Originally, DSM2 implemented reservoirs with constant area and bottom elevation; a reservoir volume can be easily calculated as a product of area and depth. A more realistic implementation of reservoirs using elevation against area and volume relationship is described here and added to version 8.1.3,

$$\frac{dV}{dt} = \sum Q = Q_s - Q_c,$$

Where

V is the reservoir volume,

t is time,

dV/dt is the derivative of Volume with respect to time,

Qs is external (source) flow into or out of a reservoir, including transfer flow, Delta Island Consumtive Use (DICU), or pumping,

Qc is the (connection) flow between the reservoir and connected channel (out of reservoir is positive).

Following the FourPt hydrodynamic model procedures, numerical integration in time can be written as

$$V_{t_2} - V_{t_1} = \left(\theta(Q_s)_{t_2} + (1-\theta)(Q_s)_{t_1}\right)\Delta t - \left(\theta(Q_c)_{t_2} + (1-\theta)(Q_c)_{t_1}\right)\Delta t.$$

with the numerals 1 and 2 indicating the volumes and flows at two different points in time and Δt representing the difference in time. Linearization with truncated Taylor series, in terms of incremental changes of variables *Q* and *Z,* can be written as

$$V_{t_2}^* + \frac{\partial V_{t_2}^*}{\partial Z}\Delta Z - V_{t_1} = \left(\theta(Q_s)_{t_2} + (1-\theta)(Q_s)_{t_1}\right)\Delta t - \left(\theta Q_{c_{t_2}}^* + \theta\Delta Q_c + (1-\theta)(Q_c)_{t_1}\right)\Delta t,$$

where the superscript "*" indicates values from the preceding iteration, Z is the water surface elevation, and θ is a time-weighted paramenter, which varies from 0.5 to 1.0 in the four point implicit scheme. Rearranging the equation by moving terms known from the preceding iteration to the right-hand side is

$$\theta\Delta Q_c + \frac{1}{\Delta t}\frac{\partial V_{t_2}^*}{\partial Z}\Delta Z = \frac{-(V_{t_2}^* - V_{t_1})}{\Delta t} + \left(\theta(Q_s)_{t_2} + (1-\theta)(Q_s)_{t_1}\right) - \left(\theta Q_{c_{t_2}}^* + (1-\theta)(Q_c)_{t_1}\right).$$

In the old model, a constant area was used, then

$$\frac{\partial V_{t_2}^*}{\partial Z} = A = constant.$$

When using the new elevation-area-storage curve,

$$\frac{\partial V_{t_2}^*}{\partial Z} = A_{t_2}^*.$$

$A_{t_2}^*$ is the area, which varies with elevation.

Reservoir elevation-area-volume curves can be generated using the 3D Analyst Tools in ArcMap. Table 2-1 shows the calculated reservoir elevations areas, and volumes of Liberty Island at roughly a 0.5 meter interval. The table shows the inundated area of Liberty Island changes greatly from low elevation to high elevation, about 3,032 acres at 1.64 ft. North American Vertical Datum of 1988 (NAVD) and 5,190 acres at 6.562 ft. NAVD. This calculation included some storage areas outside Liberty Island (Figure 2-1), e.g., Little Holland Tract, as shown in the Figure 2-1. Channels were kept out of the storage area calculation.

Liberty Island		
Elevation(ft. NAVD)	Area(acre)	Volume(acre-feet.)
-61.975	0.000	0.000
-32.808	2.478	12.020
-16.404	16.220	114.969
-3.281	272.328	1154.224
-1.640	1017.270	2023.584
0.000	1999.522	4448.286
1.640	3031.999	8456.815
3.281	4209.851	14598.662
4.921	4584.028	21795.491
6.562	5190.456	29734.639
8.202	6359.679	39288.629
9.843	6636.050	50043.149
13.123	6731.118	72015.036
16.404	6830.894	94276.839
19.685	6876.916	116780.976
22.966	6890.138	139391.916

Table 2-1 Calculated Reservoir Elevation-Area-Volume at Liberty Island

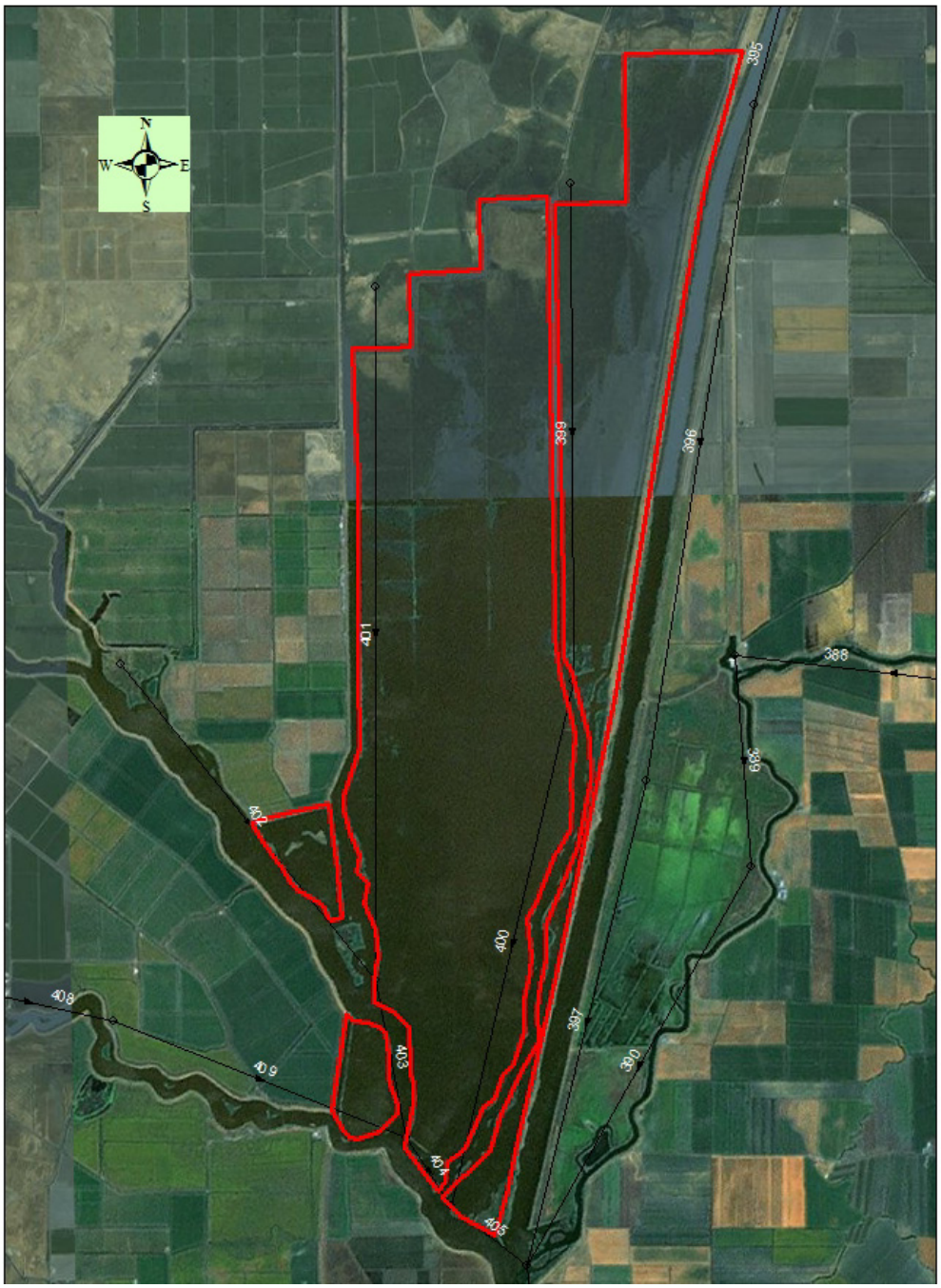

Figure 2-1 Liberty Island Storage Area Map

2.2.1 Calculation of $A^*_{t_2}$ and $V^*_{t_2}$

Within each layer, between two specified elevations in the Table 2-2, if we assume the area changes linearly from the bottom to the top, the volume can be calculated as

$$\Delta V = \frac{1}{2}(A_1 + A_2)(Z_2 - Z_1).$$

Where A is area, Z is the elevation, and ΔV is the calculated volume between specified (designated as 1 and 2) areas and elevations.

But this calculated volume is not equal to the real volume as defined in the elevation-area-volume table (Table 2-1 or Table 2-2), i.e.,

$$\Delta V \neq V_2 - V_1.$$

A correction factor is defined as

$$\alpha = \frac{V_2 - V_1}{\Delta V}.$$

At any elevation *Z*, the area (A) and volume (V) can be calculated as

$$A = \frac{A_2 - A_1}{Z_2 - Z_1}(Z - Z_1) + A_1$$

$$V = \alpha \frac{A + A_1}{2}(Z - Z_1) + V_1$$

and

$$\frac{\partial V}{\partial Z} = \alpha \cdot A.$$

This way, the calculated volume using area exactly matches the specified volumes in the elevation-area-volume in tables 2-3, 2-4, 2-5, 2-6, and 2-7.

The only change for the input files is a new table added to the original reservoir input file. In the new RESERVOIR_VOL table (Table 2-2), the area unit is acre and volume unit is acre-feet. No change was made to the original RESERVOIR table, which used million square feet for the area. The new executable V8.1.3 (not released yet) is backward compatible with V8.1.2 so that V8.1.2 input files can still run using V8.1.3 without any changes. If no elevation-area-volume values were specified for a reservoir, the original constant area would be used.

```
RESERVOIR_VOL
RES_NAME        ELEV        AREA       VOLUME
liberty       -61.975       0.000       0.000
liberty       -32.808       2.478      12.020
liberty       -16.404      16.220     114.969
liberty        -3.281     272.328    1154.224
liberty        -1.640    1017.270    2023.584
liberty         0.000    1999.522    4448.286
liberty         1.640    3031.999    8456.815
END
```

Table 1-2 New RESERVOIR_VOL Table

2.2.2 Other Reservoir Elevation-Area-Volume Tables

Clifton Court Forebay		
Elevation(ft. NAVD)	Area(acre)	Volume(acre-feet)
-41.864	0.000	0.000
-32.808	0.232	0.685
-16.404	2.641	19.749
-3.281	1721.648	3634.879
-1.640	2060.266	6766.577
0.000	2167.212	10261.804
1.640	2189.206	13837.950
3.281	2202.368	17439.877
4.921	2213.733	21063.314
6.562	2222.305	24701.898
8.202	2228.793	28350.774
9.843	2233.958	32007.171
13.123	2243.772	39346.372
16.404	2255.195	46730.970
19.685	2258.395	54155.385
22.966	2258.395	61564.824

Table 2-2 Calculated Reservoir Elevation-Area-Volume at Clifton Court Forebay

Franks Tract		
Elevation(ft. NAVD)	Area(acre)	Volume(acre-feet)
-37.664	0.000	0.000
-32.808	0.077	0.097
-16.404	15.458	81.712
-3.281	2863.623	6347.693
-1.640	3053.221	11229.356
0.000	3108.659	16289.292
1.640	3135.313	21414.532
3.281	3148.853	26569.405
4.921	3157.061	31739.000
6.562	3162.805	36920.426
8.202	3167.736	42112.172
9.843	3173.686	47313.134
13.123	3179.422	57750.586
16.404	3179.431	68181.904
19.685	3179.431	78613.118

Table 2-3 Calculated Reservoir Elevation-Area-Volume at Franks Tract

Bethel		
Elevation(ft. NAVD)	Area(acre)	Volume(acre-feet)
-10.433	0.000	0.000
-3.281	220.520	386.621
-1.640	274.450	804.670
0.000	286.141	1264.891
1.640	293.217	1740.520
3.281	296.166	2224.650
4.921	297.149	2712.450
6.562	297.198	3199.959
8.202	297.230	3687.516
9.843	297.252	4175.117
13.123	297.268	5150.659
16.404	297.268	6125.948

Table 2-4 Calculated Reservoir Elevation-Area-Volume at Bethel

Mildred		
Elevation(ft. NAVD)	Area(acre)	Volume(acre-feet)
-27.592	0.000	0.000
-16.404	30.433	43.056
-3.281	955.409	7648.080
-1.640	960.074	9217.757
0.000	964.188	10794.926
1.640	967.400	12377.913
3.281	969.247	13966.830
4.921	971.128	15559.504
6.562	972.641	17157.774
8.202	973.281	18755.206
9.843	973.874	20353.688
13.123	974.667	23553.121
16.404	974.977	26754.369
19.685	974.979	29953.415
22.966	974.979	33152.168

Table 2-5 Calculated Reservoir Elevation-Area-Volume at Mildred

Discovery Bay		
Elevation(ft. NAVD)	Area(acre)	Volume(acre-feet)
-7.612	0.000	0.000
-3.281	379.378	855.693
-1.640	409.827	1494.922
0.000	436.020	2180.971
1.640	460.503	2909.906
3.281	485.850	3683.030
4.921	516.216	4499.517
6.562	588.874	5395.956
8.202	649.454	6408.017
9.843	696.445	7502.144
13.123	906.898	10038.752
16.404	1134.594	13533.369
19.685	1141.429	17278.161
22.966	1141.429	21023.010

Table 2-6 Calculated Reservoir Elevation-Area-Volume at Discovery Bay

From the tables, it can be seen that other reservoir areas are fairly constant over the tidal range, and are very close to the constant area values used in V8.1.2.

2.3 Results Comparison

Historical simulations from 2000 to 2008 were done with the new reservoir specifications and results were compared with the V8.1.2 calibration. The change of the Liberty Island storage affected flow around the lower Sacramento River and even the San Joaquin River. Small adjustments of Manning's coefficients were made to a few channels for calibration. The recalibrated flow and stage results were generally very close to the V8.1.2 calibration. Obvious differences were seen only at Rio Vista; the phase difference for flow changed from 25 to 35 minutes (Figure 2-2), and stage amplitude became larger (Figure 2-3). There were almost no differences at Jersey Point and the entire South Delta (Figures 2-4 to 2-5). Electrical Conductivity (EC) results are almost identical to the V8.1.2 calibration. EC results at key stations: RSAC081, RSAN018, ROLD024 are shown in Figures 2-6 to 2-8 and at Clifton Court in Figure 2-9.

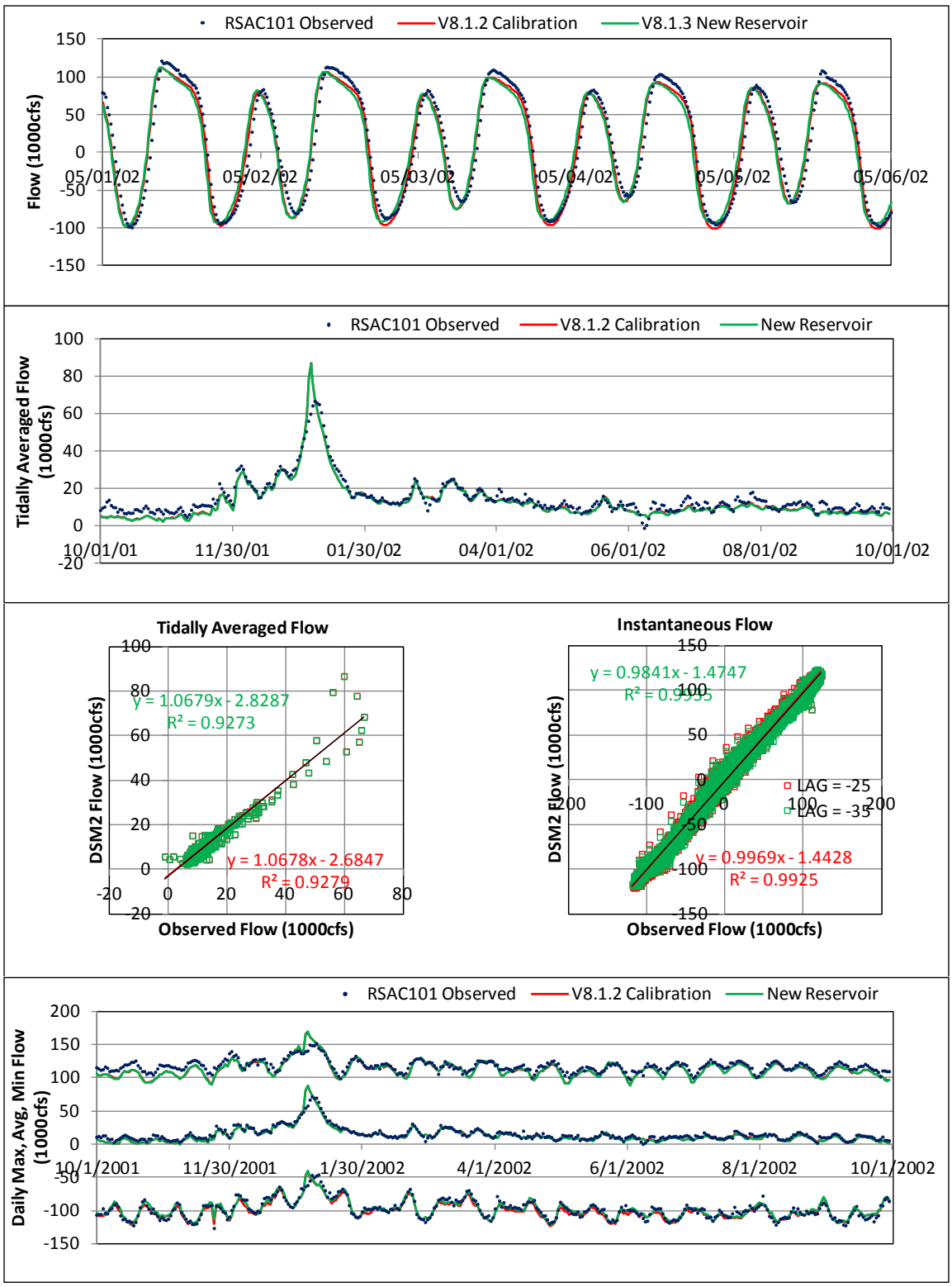

Figure 2-2 Flow at Sacramento River at Rio Vista

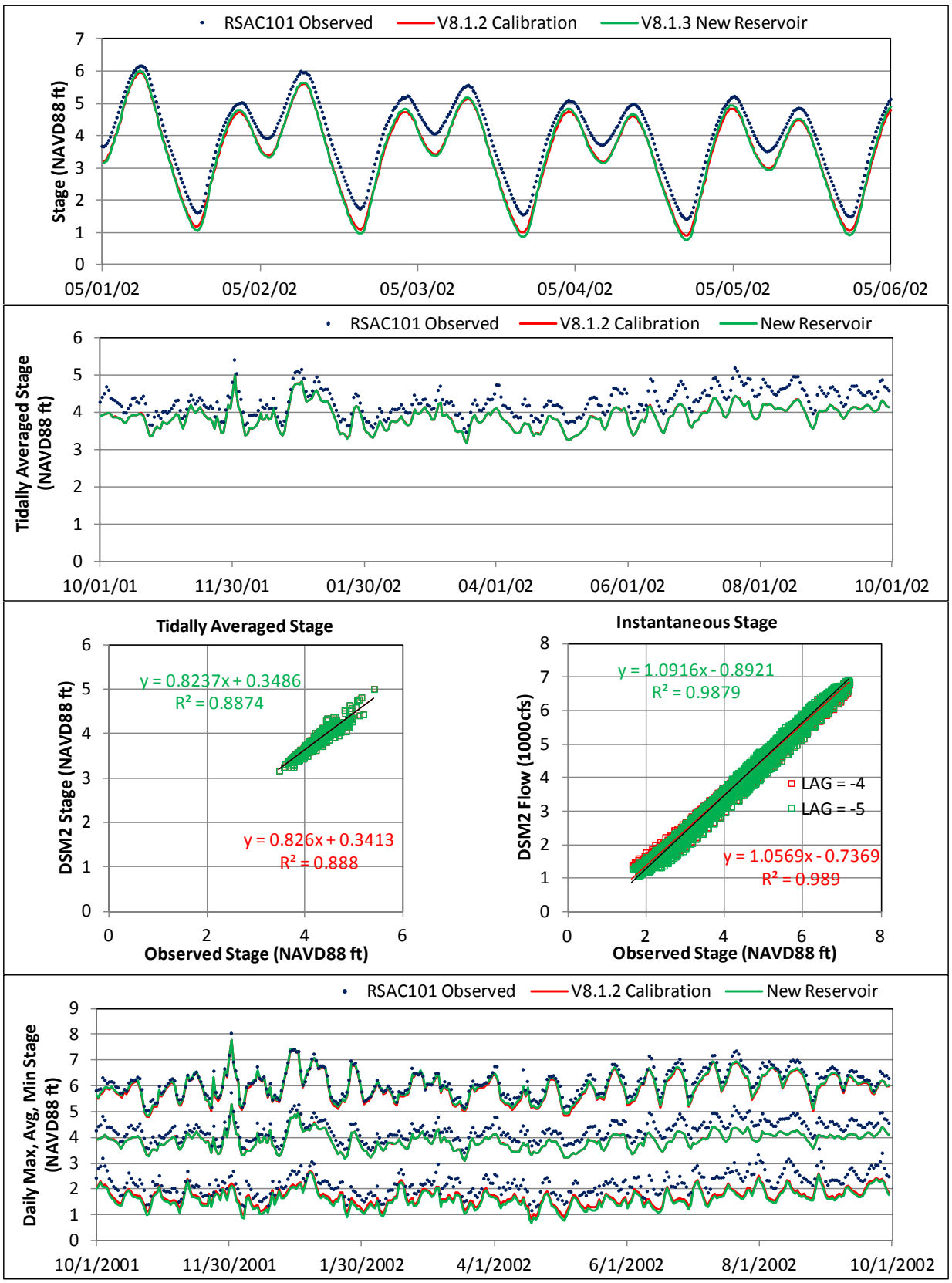

Figure 2-3 Stage at Sacramento River at Rio Vista

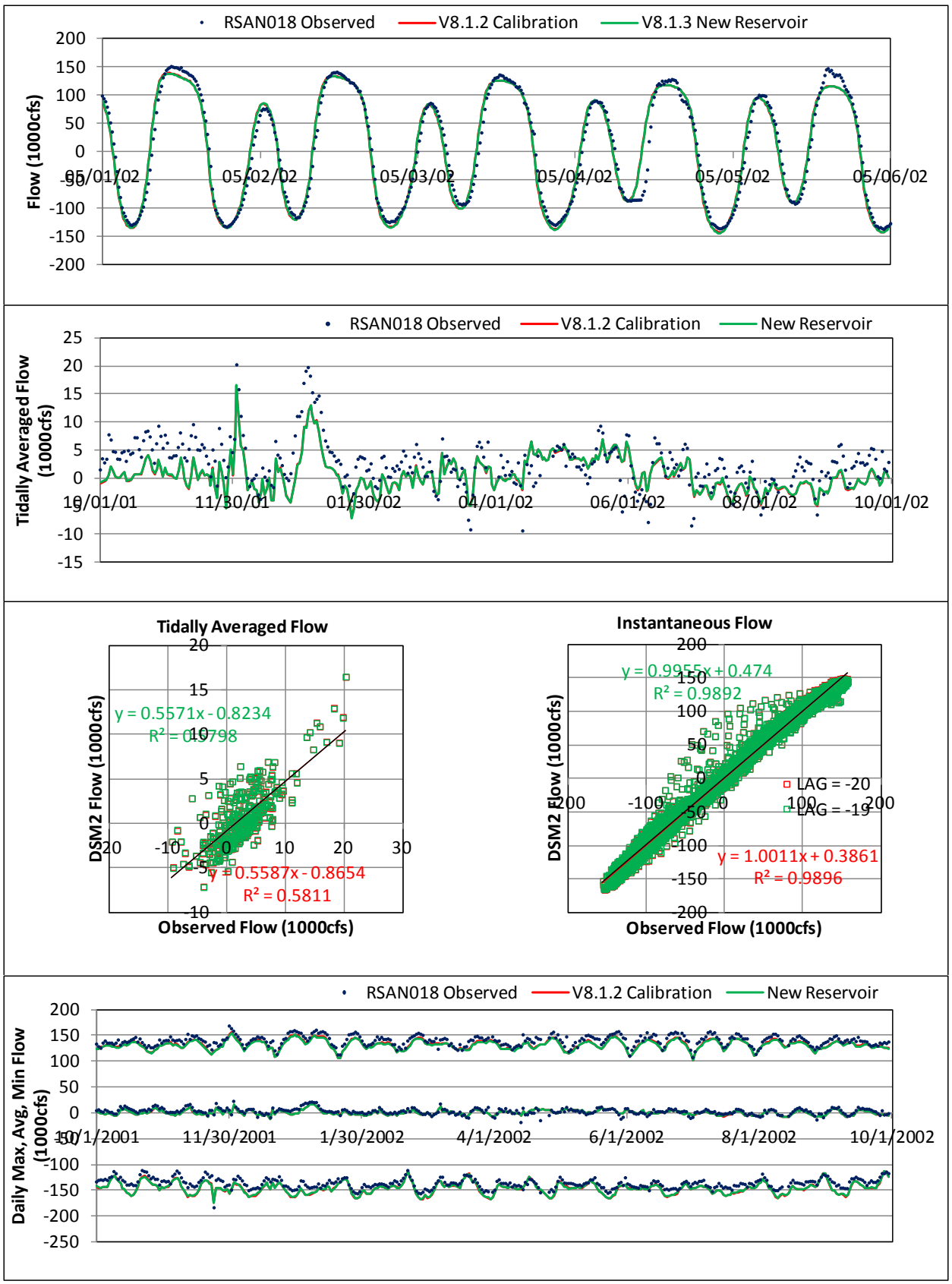

Figure 2-4 Flow at San Joaquin River at Jersey Point (RSAN018)

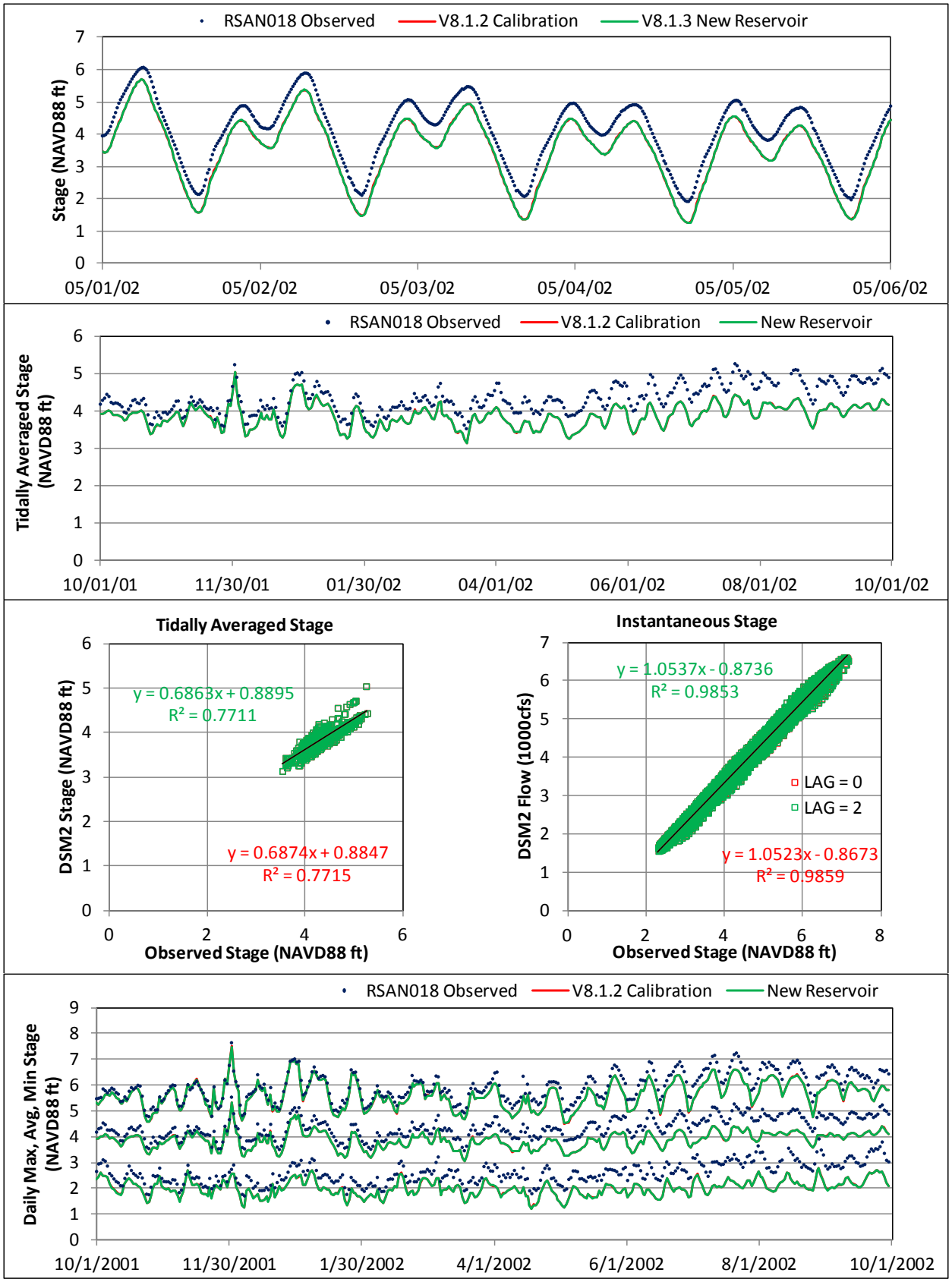

Figure 2-5 Stage at San Joaquin River at Jersey Point (RSAN018)

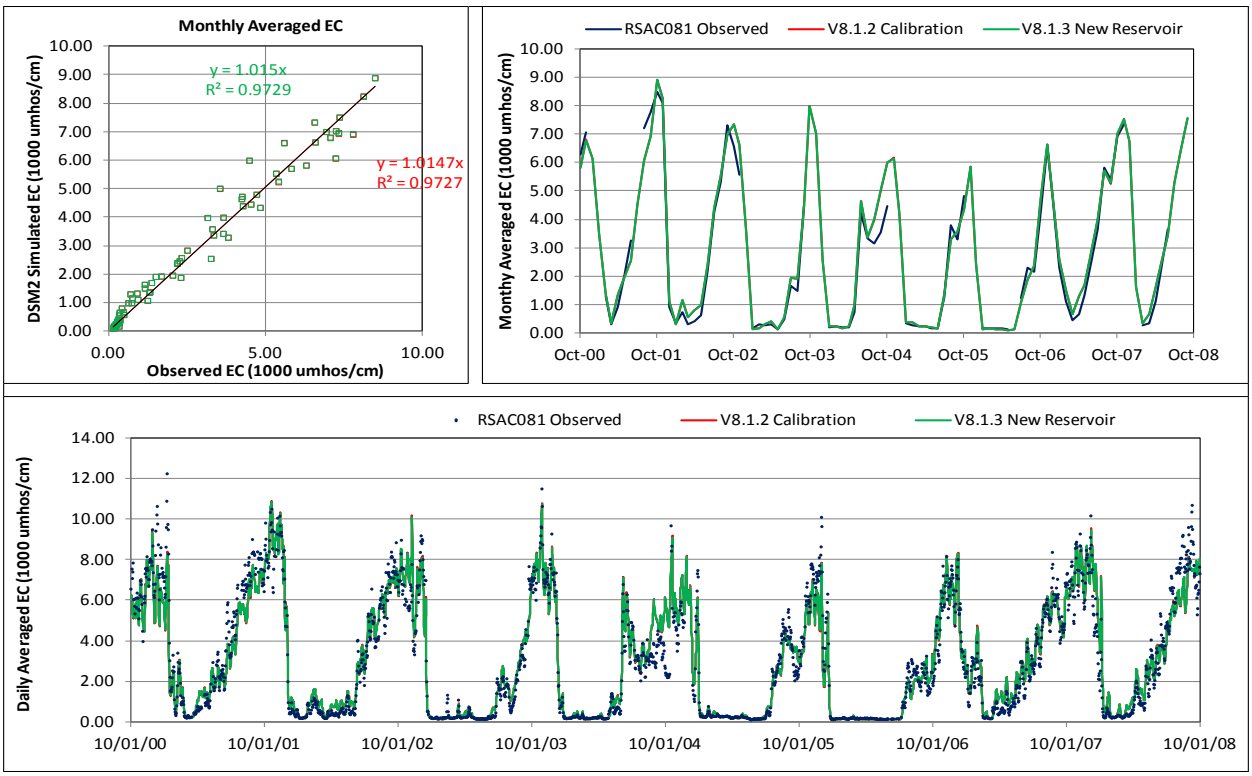

Figure 2-6 Stage at San Joaquin River at Jersey Point (RSAN018)

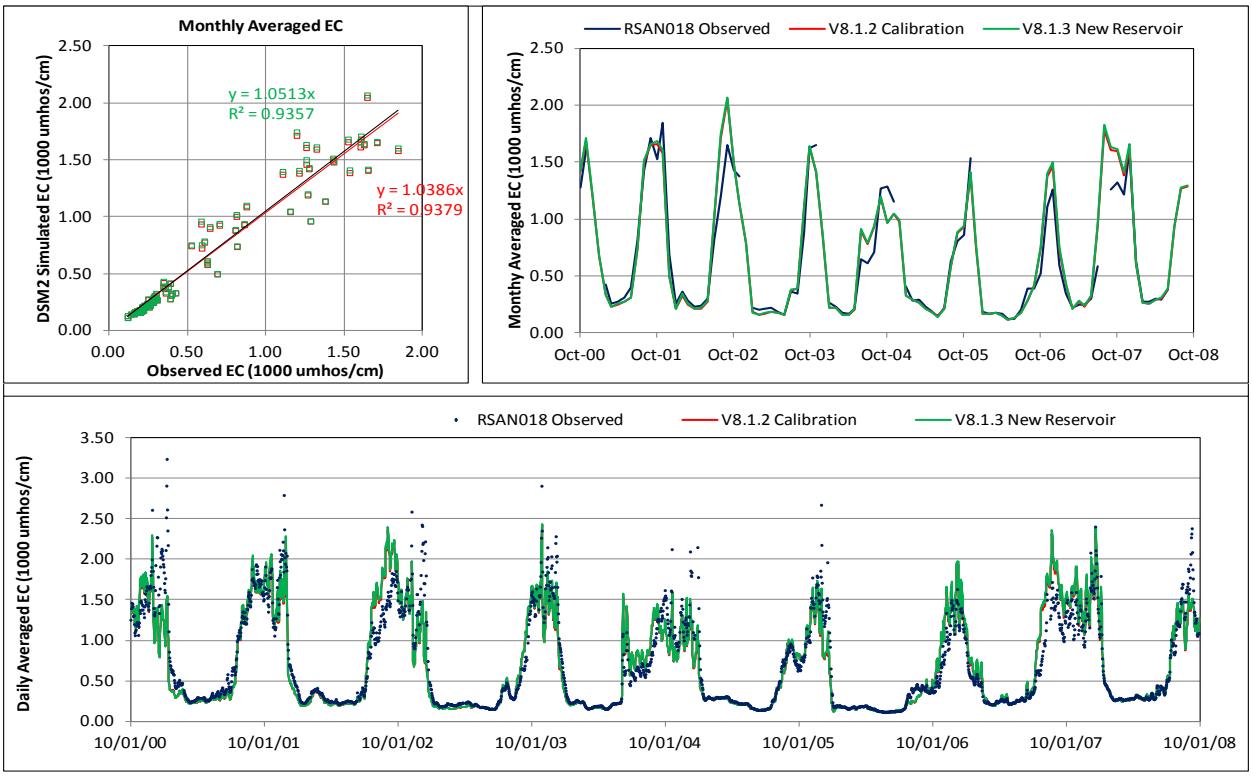

Figure 2-7 Simulated EC at San Joaquin River at Jersey Point (RSAN018)

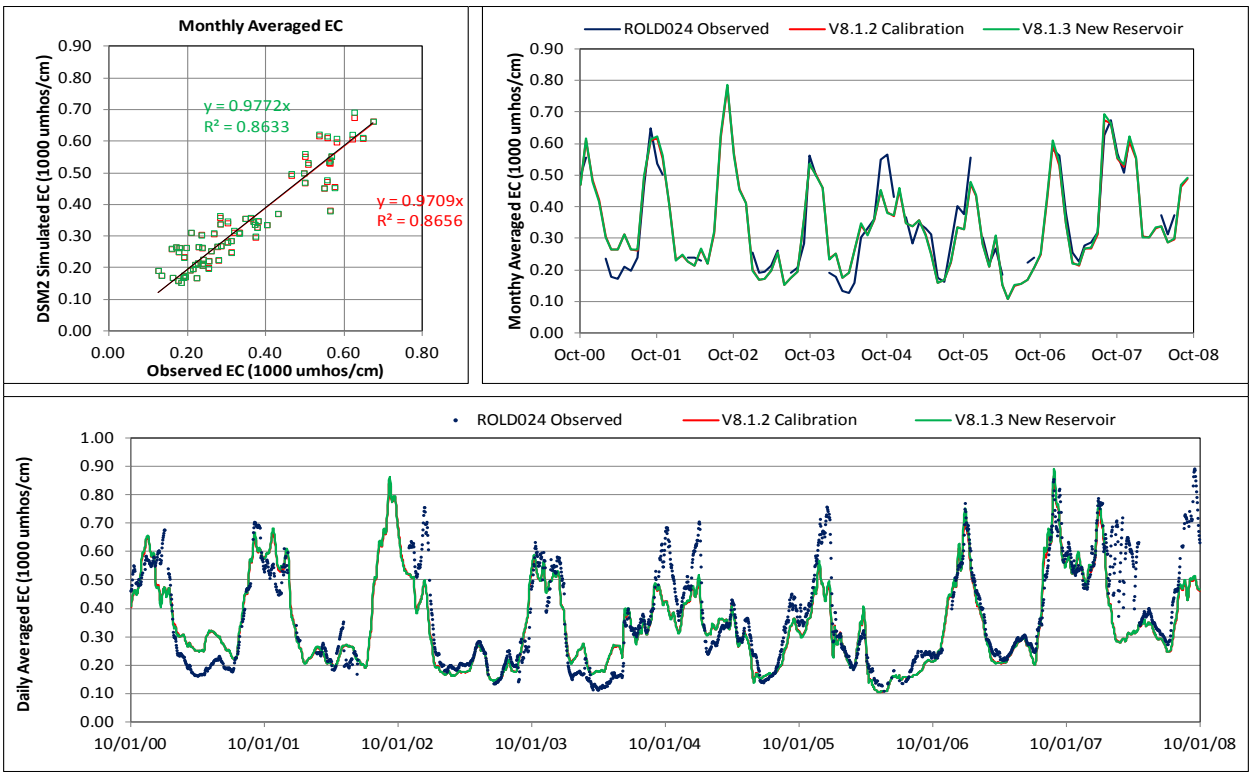

Figure 2-8 Simulated EC at Old River at Bacon Island (ROLD024)

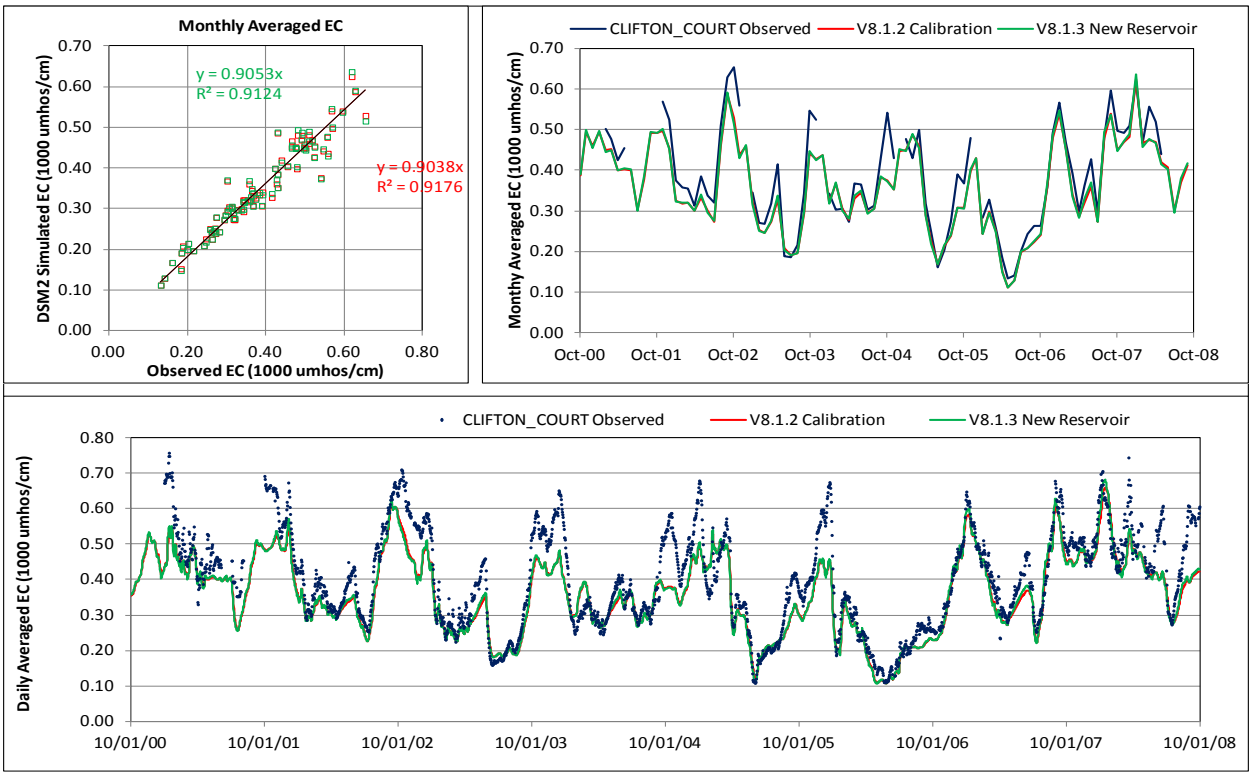

Figure 2-9 Simulated EC at Clifton Court Forebay

2.4 Summary

A new input table to use elevation-area-volume curve for reservoirs was added. The modifications were tested for stability and accuracy. This feature is useful to better model Liberty Island and other potential tidal-marsh restoration areas where the inundated area changes significantly with tidal elevations. This change prompted a recalibration in the region of Liberty Island, and the resulting differences using the new reservoir specifications were not significant.

A new information message was added for accumulated volume balance errors of reservoirs at the end of a Qual run and those errors are listed in the end of the output file (*.qof).