MBK ENGINEERS

Water Resources ◆ Flood Control ◆ Water Rights

# TECHNICAL MEMORANDUM

**DATE:** August 31, 2016

**TO:** North Delta Water Agency

**FROM:** Shankar Parvathinathan, and Gary Kienlen

**SUBJECT:** Technical Comments on California Water Fix Biological Assessment Modeling

## Introduction

This technical memorandum is a summary of MBK Engineers' findings based on our review of the hydrodynamic modeling performed by the California Department of Water Resources (DWR), and the United States Bureau of Reclamation (Reclamation or USBR), for the California Water Fix Biological Assessment (CWF BA) No Action Alternative (NAA ELT) and the Preferred Alternative, Alternative 4A, under Early Long Term climate change (Alt4A ELT). This review of the California Water Fix (CWF or Project) modeling focuses on water quality, stage, flow, and velocity at the following locations within the North Delta Water Agency (NDWA):

- Sacramento River at Emmaton
- Sacramento River at Three Mile Slough
- Steamboat Slough at Sutter Slough

This memorandum is focused on additional information and statistical measures that would help the decision makers and the legal users of water understand the extent and variability of impacts at a higher resolution, in particular, at the locations which are of importance to water users within NDWA.

### No Action Alternative

Assumptions used in CalSim II water operations modeling and DSM2 Delta hydrodynamic modeling for the CWF No Action Alternative are defined in the January 2016 WaterFix

Modeling Appendix[1]. Those assumptions include changes to hydrology caused by climate change.

### Proposed Action

The Proposed Action is defined as the CWF Alternative 4A that Reclamation and DWR modeled for the CWF BA under Section 7 of the Endangered Species Act.

### Review of DWR/Reclamation Modeling for Biological Assessment

This review focuses on Delta hydrodynamics and water quality modeling using the Delta Simulation Model II (DSM2). Hydrodynamics and water quality modeling are essential to understanding the impacts of proposed modifications to the Delta and the operations of the CVP/SWP with CWF. Changes to the configuration of the Delta and Project operations will influence the tidal hydrodynamics and water quality conditions in the Delta. Analyses and an understanding of hydrodynamics and water quality changes as a result of these complex changes are critical in understanding the impacts to legal users of water, habitat, species, as well as other water users that depend on the Delta.

This review focuses on effects of Delta hydrodynamics under the Alt4A ELT, as determined by DSM2 Models used in the CWF BA modeling. The review involves two Alternatives: 1) NAA ELT (No Action Alternative with Early Long Term Climate Change), and 2) Alt4A ELT (Proposed Action with Early Long Term Climate Change). Early Long Term Climate Change is intended to represent projected climate changes in 2025. The overall analytical framework used for the CWF BA effects analysis is summarized in Appendix 5A of the *CalSim II Modeling and Results of the Water Fix Biological Assessment* report. A detailed report of the hydrodynamic modeling used in the CWF BA can be found in Appendix 5B.

Outputs were extracted from the DSM2 modeling, and stage and salinity values for the Alt4A ELT, which were then compared against the No Action Alternative (i.e. Alt 4A ELT compared to the NAA ELT). The CWF BA DSM2 modeling simulates the hydrologic period from October 1974 to September 1991 and produces output at 15-minute intervals. Daily maximums, minimums, and averages were then calculated from the 15-minute DSM2 output. Hydrodynamics and salinity were reviewed at key locations within NDWA such as the Sacramento River at Emmaton, Sacramento River at Three Mile Slough and Steamboat Slough at Sutter Slough.

## Summary of Findings

This section summarizes the results from the CWF BA DSM2 modeling for the NAA ELT and Alt4A ELT. Daily and monthly average values of EC, flows, and stage are presented to show the effect of Alt4A ELT on Delta conditions.

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[1] The detailed assumptions are stated in Biological Assessment for the California WaterFix Appendix 5A (CalSim II) and Appendix 5B (DSM2).

## Sacramento River at Emmaton

**Figure 1** compares monthly average EC values in the Sacramento River at Emmaton under Alt4A ELT and NAA ELT. The change in EC values fluctuate in both directions, positive and negative. There are months (e.g. October, November) when the EC values are lower, and months (e.g. July, August, September) when the EC values are higher under the Alt4A ELT, compared to the NAA ELT. On average, the EC increases under the Alt4A ELT by 2 percent in comparison to the NAA ELT. It is important to note that the monthly average EC values in July, August, and September are higher under the Alt4A ELT by 16 percent, 17 percent, and 23 percent, respectively. Additionally, there are months in the period of simulation when the changes in EC are higher than reflected in these average values. The opposite phenomenon is observed during October and November when the EC is lower by nearly 15 percent under Alt4A ELT. The improvement in EC at Emmaton, in particular during October, can be attributed to a simulated increase in Delta outflows under Alt4A ELT to meet the proposed flow requirements at Rio Vista. These flows improve EC not only at Rio Vista, but also at Emmaton and Three Mile Slough.

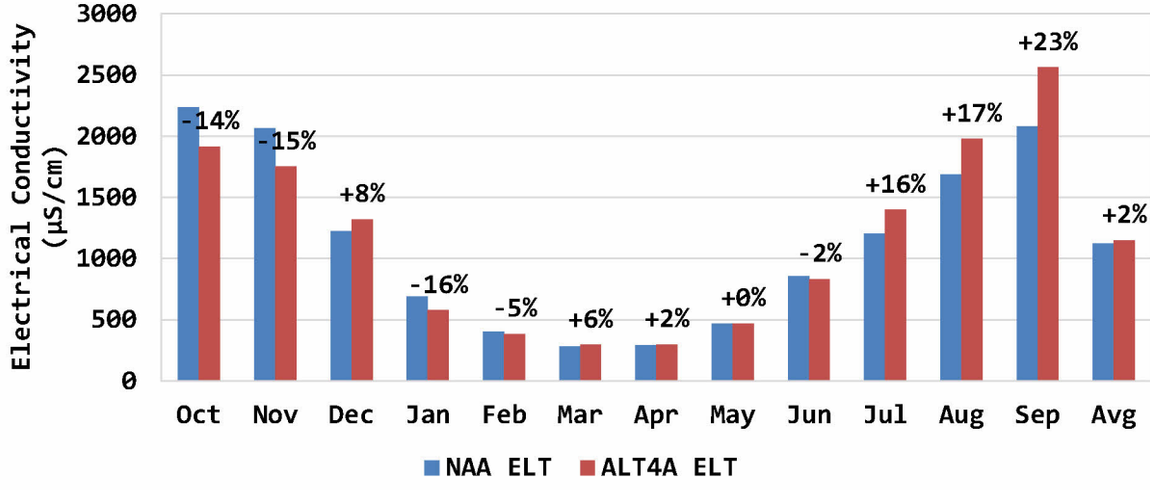


**Figure 1. Monthly Average Electrical Conductivity and Percent Change in the Sacramento River at Emmaton**

To provide for the detail on the temporal changes in EC, **Table 1** shows monthly changes in EC values at Emmaton under the Alt4A ELT, relative to the NAA ELT. This table shows cells highlighted in color for the months with changes greater than 5 percent. A review of the changes in individual months confirm that EC values during the months of July, August, and September are consistently greater under the Alt4A ELT in comparison to the NAA ELT. There are months when the increases in EC values are significantly greater than the average, such as during September 1989 when the EC values increased by nearly 78 percent (1,717 microSiemens per centimeter [µS/cm]) from a NAA ELT value of 2,194 µS/cm to 3,911 µS/cm under the Alt4A ELT.

**Table 1. Monthly Changes in Average Electrical Conductivity in the Sacramento River at Emmaton**

| WY Type | Water Year | Change in Electrical Conductivity (µS/cm)[1] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| C | 1976 | 23(+8%) | 32(+13%) | 101(+22%) | -389(-40%) | -364(-50%) | -30(-10%) | 5(+1%) | -18(-4%) | 10(+1%) | 297(+17%) | 167(+8%) | 564(+19%) |
| C | 1977 | -485(-14%) | -417(-14%) | -88(-3%) | -158(-8%) | 87(+8%) | 10(+1%) | -1(-0%) | 10(+1%) | 56(+2%) | 36(+1%) | 44(+1%) | 430(+11%) |
| AN | 1978 | -456(-9%) | -768(-15%) | 20(+1%) | 9(+4%) | 11(+6%) | 11(+6%) | 11(+6%) | 1(+1%) | -57(-18%) | -55(-10%) | 185(+17%) | 83(+15%) |
| BN | 1979 | 53(+8%) | 1(+0%) | 361(+43%) | 18(+3%) | -1(-0%) | 13(+7%) | 9(+4%) | 5(+2%) | 8(+3%) | 280(+33%) | 589(+36%) | 1272(+52%) |
| AN | 1980 | -776(-24%) | 135(+8%) | 264(+29%) | -1(-1%) | 3(+2%) | 1(+1%) | 4(+2%) | 11(+5%) | -50(-15%) | 5(+1%) | 156(+15%) | 86(+13%) |
| D | 1981 | -38(-6%) | 72(+12%) | 86(+12%) | -19(-3%) | 7(+4%) | 22(+11%) | 16(+7%) | 7(+2%) | -14(-2%) | 396(+34%) | 158(+9%) | 804(+30%) |
| W | 1982 | -485(-15%) | -420(-27%) | -1(-1%) | 3(+2%) | 4(+2%) | 5(+2%) | 1(+0%) | 0(+0%) | 1(+1%) | 68(+16%) | 287(+23%) | 13(+4%) |
| W | 1983 | 30(+13%) | 7(+3%) | 3(+2%) | 7(+4%) | 1(+0%) | 0(+0%) | 1(+0%) | 1(+1%) | 3(+1%) | 18(+9%) | 120(+43%) | 33(+16%) |
| W | 1984 | 31(+13%) | 12(+6%) | 0(+0%) | 4(+2%) | 4(+2%) | 6(+3%) | 9(+5%) | 3(+1%) | -63(-14%) | 131(+34%) | 426(+50%) | 34(+10%) |
| D | 1985 | 17(+6%) | 38(+10%) | -2(-1%) | -99(-28%) | -51(-19%) | -4(-2%) | 12(+5%) | 9(+2%) | 0(-0%) | 399(+69%) | 575(+50%) | 792(+32%) |
| W | 1986 | -835(-26%) | -900(-27%) | 78(+11%) | 76(+23%) | 1(+1%) | 2(+1%) | 1(+1%) | 1(+0%) | -175(-36%) | 178(+44%) | 458(+60%) | 37(+8%) |
| D | 1987 | 17(+6%) | 1(+0%) | 41(+5%) | -253(-34%) | -46(-17%) | 9(+4%) | 55(+20%) | -53(-12%) | -17(-2%) | 32(+2%) | 88(+4%) | 560(+18%) |
| C | 1988 | -1032(-32%) | -1265(-35%) | -59(-7%) | 21(+9%) | 150(+69%) | 125(+22%) | -46(-9%) | 7(+1%) | -19(-2%) | 161(+9%) | 123(+5%) | 526(+14%) |
| D | 1989 | -693(-16%) | -114(-3%) | 53(+2%) | -54(-5%) | 1(+0%) | 15(+6%) | 4(+2%) | 0(+0%) | -76(-13%) | 594(+53%) | 515(+38%) | 1717(+78%) |
| C | 1990 | 242(+9%) | -490(-16%) | -145(-5%) | 17(+3%) | -4(-1%) | 4(+1%) | 10(+3%) | 9(+1%) | -27(-2%) | 412(+16%) | 391(+15%) | 368(+11%) |
| C | 1991 | -736(-15%) | -972(-20%) | 839(+25%) | -992(-41%) | -138(-14%) | 83(+30%) | 11(+4%) | 17(+2%) | 123(+7%) | 206(+9%) | 413(+14%) | 355(+9%) |
| Average | | -320(-14%) | -315(-15%) | 97(+8%) | -113(-16%) | -21(-5%) | 17(+6%) | 6(+2%) | 1(+0%) | -18(-2%) | 198(+16%) | 293(+17%) | 480(+23%) |

**Note**

[1] Change is calculated as difference in monthly Electrical Conductivity values between the Project and the baseline (Alt4A ELT minus NAA ELT). Values in parenthesis indicate percent change, calculated as ([Alt4A ELT minus NAA ELT]/ NAA ELT)*100.

Colored cells indicate months when the changes under Alt4A ELT are greater than 5 percent.

**Figure 2** shows two scatter plots comparing monthly average EC values in the Sacramento River at Emmaton, between NAA ELT and Alt4A ELT. The first scatter plot presents monthly average EC values for the entire period of simulation, whereas the second plot only shows data in the period of simulation that corresponds to the agricultural irrigation season, defined here as April through September. The scatter plots show a line (Alt4A=NAA line) that represents a hypothetical condition where the Alt4A ELT EC values (y axis) exactly equal the NAA ELT EC values (x axis). If there were no changes in EC between Alt4A ELT and NAA ELT all points would plot on this line. The EC plotted points above the Alt4A=NAA line indicate EC values under Alt4A ELT are greater than the NAA ELT. When the EC plotted points are below the line, the EC values under the NAA ELT are lower than the Alt4A ELT. The vertical distance of the plotted points from the Alt4A=NAA line defines the magnitude of the change in EC between the two alternatives: the greater the distance, the greater the difference in EC between the two alternatives. The difference in EC values between the two alternatives tend to be smaller in the EC range below 1,000 µS/cm, and the increases in EC occur more frequently than the decreases in EC under the Alt4A ELT. The EC values under the Alt4A ELT are higher than the NAA ELT, by up to 1,717 µS/cm in a month. During the irrigation season, between April and September, the EC values under Alt 4A ELT are consistently higher than the NAA ELT.

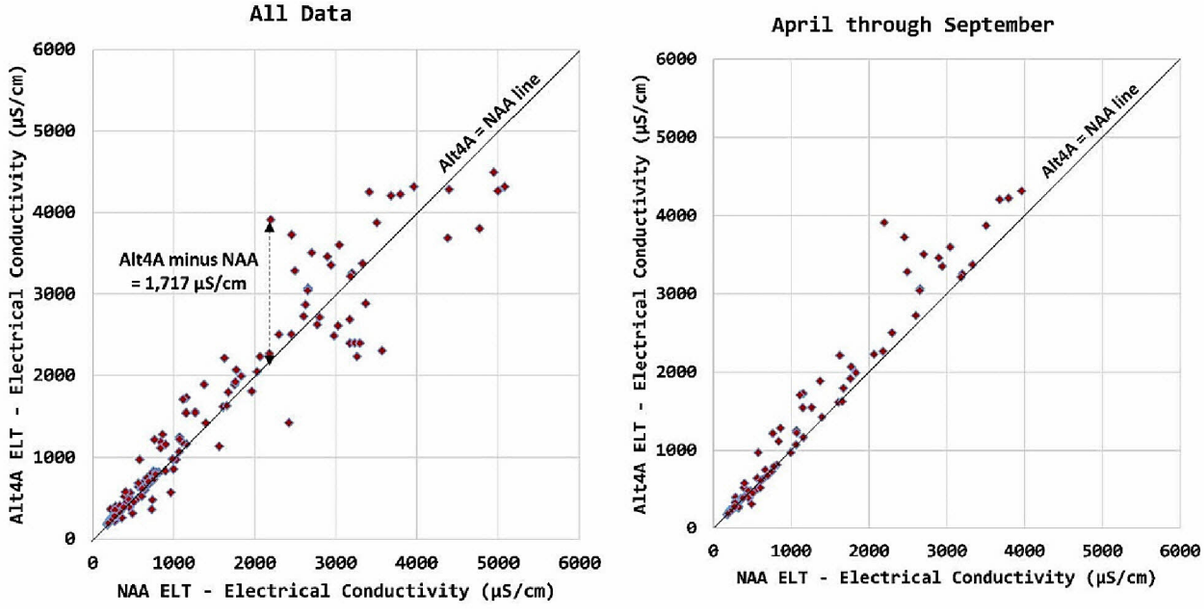


**Figure 2. Scatter Plot Showing Average Monthly EC Values between Alt4A ELT and NAA ELT in the Sacramento River at Emmaton**

## Sacramento River at Three Mile Slough

**Figure 3** shows a comparison of monthly average EC values between Alt4A ELT and NAA ELT in the Sacramento River at Three Mile Slough. On a monthly average basis, the change in EC values fluctuate in both directions, there are months (e.g. October, November) when the EC values are lower under the Alt4A ELT and there are also months (e.g. July, August, September) when the EC values are higher under the Alt4A ELT, similar to changes at Emmaton. On an average basis, the EC decreases under the Alt4A ELT by 1 percent, in comparison to the NAA

ELT. The annual average EC values in July, August, and September, are higher under the Alt4A ELT than the NAA ELT by 8 percent, 13 percent, and 20 percent respectively, similar to changes at Emmaton.

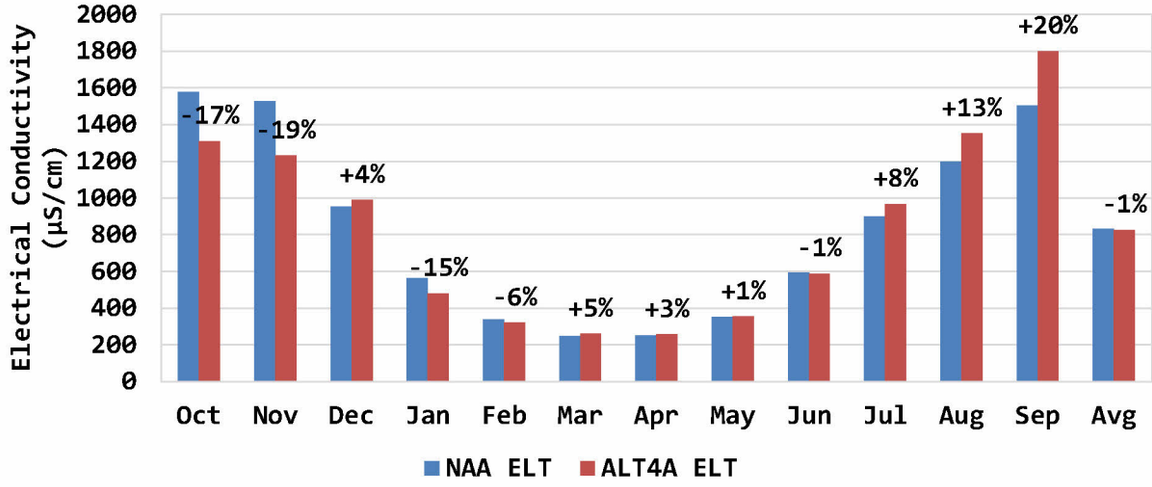


**Figure 3. Monthly Average Electrical Conductivity and Percent Change in the Sacramento River at Three Mile Slough**

**Table 2** contains monthly changes in EC values at Three Mile Slough under the Alt4A ELT relative to the NAA ELT. This table shows cells highlighted in color for the months with changes greater than 5 percent. Overall, the EC values during the months of July, August and September are consistently greater under the Alt4A ELT in comparison to the NAA ELT. There are months when the increases in EC values are significantly greater than the average increase, such as during September 1989 when the EC values increase by nearly 62 percent (1,057 µS/cm) from a NAA ELT value of 1,712 µS/cm to 2,769 µS/cm under the Alt4A ELT. A comparison of simulated EC values under Alt4A ELT against the water quality standards for Three Mile Slough under the 1981 Contract show an increase in the violation of the 1981 Contract standards 20 days during simulation period.

**Table 2. Monthly Changes in Average Electrical Conductivity in the Sacramento River at Three Mile Slough**

| WY Type | Water Year | Change in Electrical Conductivity (µS/cm)[1] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| C | 1976 | 10(+4%) | 37(+18%) | 56(+15%) | -297(-40%) | -287(-50%) | -36(-13%) | 1(+0%) | -8(-2%) | 11(+1%) | 140(+11%) | 151(+11%) | 444(+23%) |
| C | 1977 | -370(-16%) | -414(-19%) | -155(-8%) | -81(-6%) | 70(+9%) | 10(+2%) | 1(+0%) | 5(+1%) | 48(+2%) | 36(+2%) | 88(+4%) | 334(+13%) |
| AN | 1978 | -383(-11%) | -603(-16%) | 3(+0%) | 11(+4%) | 21(+10%) | 33(+16%) | 21(+10%) | 1(+1%) | -15(-6%) | -89(-20%) | -11(-1%) | -56(-11%) |
| BN | 1979 | 6(+1%) | -79(-15%) | 108(+15%) | -54(-9%) | 5(+2%) | 16(+8%) | 10(+5%) | 9(+4%) | 7(+3%) | 85(+13%) | 297(+25%) | 717(+39%) |
| AN | 1980 | -645(-29%) | -28(-2%) | 153(+18%) | -5(-2%) | 7(+4%) | 2(+1%) | 5(+3%) | 11(+5%) | -7(-3%) | -8(-2%) | -15(-2%) | -5(-1%) |
| D | 1981 | -21(-5%) | 30(+7%) | 0(-0%) | -64(-10%) | 6(+3%) | 15(+8%) | 19(+9%) | 9(+3%) | -8(-2%) | 118(+13%) | 51(+4%) | 507(+26%) |
| W | 1982 | -421(-19%) | -567(-40%) | -7(-4%) | 7(+3%) | 12(+7%) | 14(+7%) | 2(+1%) | 0(+0%) | 11(+6%) | 44(+14%) | 95(+10%) | -62(-17%) |
| W | 1983 | 19(+9%) | 4(+2%) | 5(+3%) | 14(+7%) | 3(+2%) | 0(+0%) | 1(+0%) | 1(+1%) | 4(+2%) | 17(+8%) | 73(+32%) | 20(+10%) |
| W | 1984 | 16(+7%) | 12(+6%) | 1(+1%) | 9(+5%) | 7(+4%) | 12(+6%) | 12(+6%) | 6(+3%) | -31(-9%) | 48(+14%) | 196(+30%) | -97(-24%) |
| D | 1985 | 4(+1%) | -23(-6%) | -11(-5%) | -66(-22%) | -26(-11%) | 3(+1%) | 12(+6%) | 5(+2%) | -1(-0%) | 159(+32%) | 297(+36%) | 466(+26%) |
| W | 1986 | -664(-30%) | -865(-35%) | -36(-5%) | 57(+18%) | 5(+3%) | 6(+3%) | 1(+1%) | 1(+0%) | -85(-24%) | 52(+15%) | 216(+37%) | -9(-2%) |
| D | 1987 | 18(+8%) | 16(+6%) | 27(+5%) | -179(-32%) | -35(-14%) | 8(+4%) | 30(+13%) | -30(-9%) | -10(-2%) | 13(+1%) | 125(+9%) | 446(+21%) |
| C | 1988 | -745(-34%) | -961(-39%) | -74(-10%) | 12(+5%) | 75(+35%) | 65(+16%) | -24(-7%) | 5(+1%) | -10(-2%) | 67(+5%) | 138(+8%) | 440(+17%) |
| D | 1989 | -556(-18%) | -107(-3%) | 0(+0%) | -92(-11%) | -16(-2%) | 8(+3%) | 6(+3%) | 2(+1%) | -52(-13%) | 174(+17%) | 246(+23%) | 1057(+62%) |
| C | 1990 | 39(+2%) | -410(-20%) | -126(-7%) | -5(-1%) | -9(-3%) | 2(+1%) | 8(+3%) | 7(+1%) | -20(-2%) | 187(+9%) | 239(+13%) | 273(+11%) |
| C | 1991 | -603(-17%) | -780(-23%) | 667(+27%) | -588(-35%) | -149(-20%) | 50(+19%) | 13(+5%) | 13(+2%) | 70(+6%) | 71(+4%) | 277(+13%) | 279(+10%) |
| Average | | -269(-17%) | -296(-19%) | 38(+4%) | -83(-15%) | -19(-6%) | 13(+5%) | 7(+3%) | 2(+1%) | -6(-1%) | 70(+8%) | 154(+13%) | 297(+20%) |

**Note**

[1] Change is calculated as difference in monthly Electrical Conductivity values between the Project and the baseline (Alt4A ELT minus NAA ELT). Values in parenthesis indicate percent change, calculated as ([Alt4A ELT minus NAA ELT]/ NAA ELT)*100.

Colored cells indicate months when the changes under Alt4A ELT are greater than 5 percent.

**Figure 4** shows two scatter plots comparing monthly average EC values in the Sacramento River at Three Mile Slough between NAA ELT and Alt4A ELT. Overall, the seasonality and pattern of changes in EC values under the Alt4A ELT at Three Mile Slough are similar to those observed at Emmaton, with fewer exceptions between the two locations during isolated months. The difference in EC values between the two alternatives tend to be lower in the EC range below 1,000 µS/cm and the increases in EC are more frequent than the decreases in EC under the Alt4A ELT, similar to the reported changes in EC at Emmaton. The EC values under the Alt4A ELT are higher than the NAA ELT by up to 1,057 µS/cm in a month during the simulation. During the April through September irrigation season, the EC values under Alt4A ELT are consistently higher than the NAA ELT.

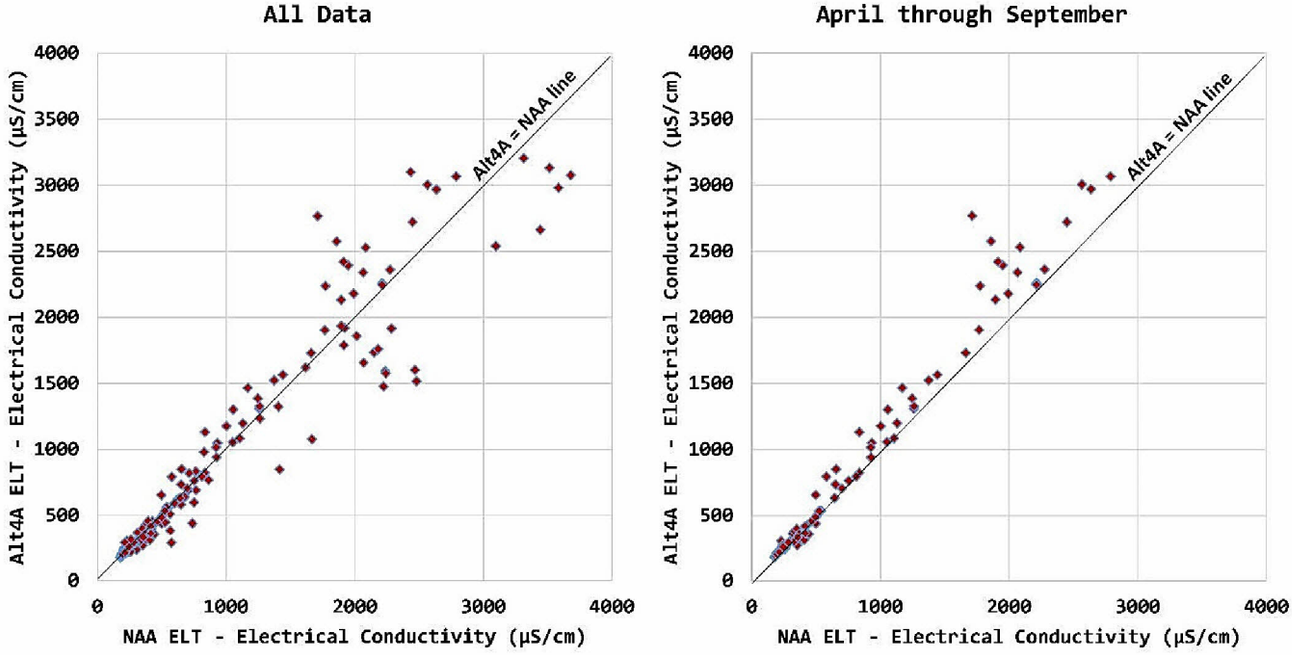


**Figure 4. Scatter Plot Showing Average Monthly EC Values between Alt4A ELT and NAA ELT in the Sacramento River at Three Mile Slough**

## Sacramento River at Rio Vista

**Figure 5** and **Figure 6** present simulated EC results in the Sacramento River at Rio Vista. These results are similar to the analysis presented for changes in EC in the Sacramento River at Emmaton and Three Mile Slough. Results indicate that the pattern of changes in EC at Rio Vista are similar to at Emmaton and Three Mile Slough except that the EC values at Rio Vista are smaller as Rio Vista is farther away from the tidal influence than the other two locations. Overall, there is an increase in EC on an average basis under the Alt4A ELT relative to the NAA ELT. Rio Vista also has a consistent increase in EC during July, August, and September similar to Emmaton and Three Mile Slough. **Table 3** contains monthly changes in EC under Alt4A ELT at Rio Vista. As noted earlier in the analysis for Emmaton and Three Mile Slough, there are months when the increases in EC values are greater than the average, such as during September 1989 when the EC values increase by nearly 80 percent (277 µS/cm) from a NAA ELT value of 348 µS/cm to 625 µS/cm under the Alt4A ELT. A comparison of simulated EC values under Alt

4A ELT against the water quality standards for Rio Vista under the 1981 Contract show that there is an increase in the violation of the 1981 Contract standards of nearly 12 days during the simulation period.

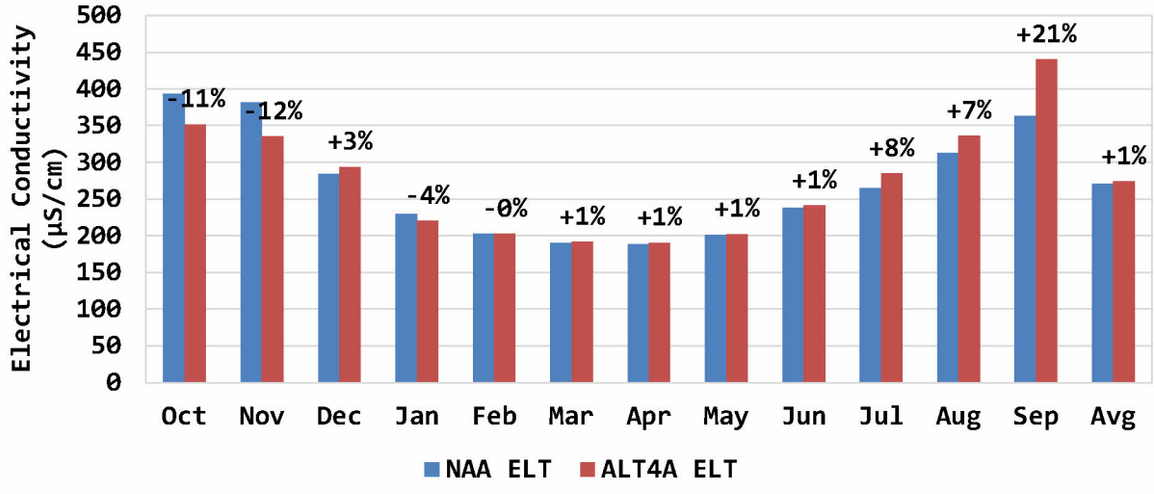


**Figure 5. Monthly Average Electrical Conductivity and Percent Change in the Sacramento River at Rio Vista**

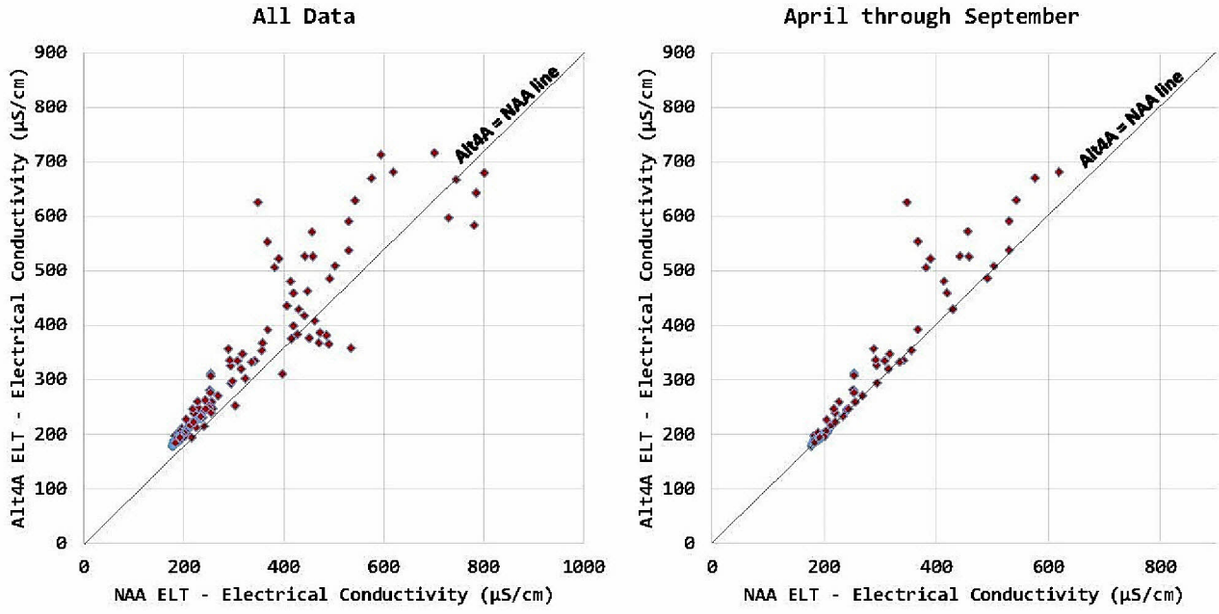


**Figure 6. Scatter Plot Showing Average Monthly EC Values between Alt4A ELT and NAA ELT in the Sacramento River at Rio Vista**

**Table 3. Monthly Changes in Average Electrical Conductivity in the Sacramento River at Rio Vista**

| WY Type | Water Year | Change in Electrical Conductivity (µS/cm)[1] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| C | 1976 | 5(+3%) | 8(+5%) | 8(+4%) | -26(-11%) | -22(-10%) | -2(-1%) | 1(+1%) | 1(+0%) | 4(+1%) | 32(+11%) | -7(-2%) | 85(+19%) |
| C | 1977 | -55(-12%) | -40(-10%) | -21(-5%) | -21(-6%) | 13(+5%) | 3(+1%) | 1(+1%) | -1(-0%) | 7(+1%) | 6(+1%) | -6(-1%) | 87(+16%) |
| AN | 1978 | -78(-10%) | -143(-18%) | 11(+3%) | 3(+2%) | 4(+2%) | 1(+1%) | 2(+1%) | 1(+1%) | 6(+3%) | -3(-2%) | 3(+1%) | -2(-1%) |
| BN | 1979 | 3(+1%) | 2(+1%) | 19(+8%) | -3(-1%) | 3(+1%) | 5(+2%) | 3(+2%) | 3(+1%) | 2(+1%) | 18(+8%) | 68(+24%) | 186(+51%) |
| AN | 1980 | -74(-16%) | 0(-0%) | 19(+8%) | 1(+0%) | 1(+0%) | 1(+0%) | 1(+1%) | 3(+2%) | 6(+3%) | 5(+3%) | 3(+1%) | 0(+0%) |
| D | 1981 | 2(+1%) | 16(+8%) | 2(+1%) | -4(-2%) | 2(+1%) | 3(+2%) | 3(+2%) | 3(+1%) | 0(+0%) | 29(+12%) | 5(+1%) | 132(+34%) |
| W | 1982 | -44(-10%) | -51(-17%) | 0(+0%) | 1(+1%) | 1(+0%) | 1(+1%) | 0(+0%) | 1(+0%) | 6(+3%) | 13(+7%) | 23(+9%) | 0(+0%) |
| W | 1983 | 7(+4%) | 4(+2%) | 1(+1%) | 2(+1%) | 0(+0%) | 0(-0%) | 0(+0%) | 0(+0%) | 1(+1%) | 8(+4%) | 14(+8%) | 4(+2%) |
| W | 1984 | 5(+3%) | 3(+2%) | 0(+0%) | 1(+0%) | 1(+0%) | 1(+1%) | 2(+1%) | 2(+1%) | -2(-1%) | 5(+3%) | 32(+14%) | 6(+3%) |
| D | 1985 | 5(+3%) | 3(+2%) | 0(+0%) | -4(-2%) | 0(-0%) | 2(+1%) | 2(+1%) | 0(+0%) | 0(-0%) | 22(+11%) | 58(+23%) | 124(+33%) |
| W | 1986 | -103(-22%) | -104(-21%) | -3(-1%) | 6(+3%) | 0(+0%) | 0(+0%) | 1(+0%) | 0(+0%) | -4(-2%) | 13(+7%) | 28(+13%) | 0(-0%) |
| D | 1987 | 7(+4%) | 7(+4%) | 6(+3%) | -13(-6%) | -1(-1%) | 2(+1%) | 3(+2%) | -3(-1%) | 4(+2%) | 2(+1%) | -2(-1%) | 115(+25%) |
| C | 1988 | -124(-25%) | -177(-33%) | -6(-3%) | 3(+2%) | 12(+6%) | 4(+2%) | -1(-1%) | 2(+1%) | -2(-1%) | 30(+9%) | 0(+0%) | 94(+16%) |
| D | 1989 | -133(-18%) | 15(+2%) | 15(+3%) | -10(-4%) | -3(-1%) | 2(+1%) | 1(+0%) | 1(+0%) | -5(-3%) | 54(+21%) | 44(+15%) | 277(+80%) |
| C | 1990 | 29(+7%) | -86(-18%) | -24(-5%) | 1(+0%) | 1(+0%) | 1(+1%) | 1(+1%) | 2(+1%) | -3(-1%) | 67(+16%) | 39(+9%) | 61(+12%) |
| C | 1991 | -122(-15%) | -197(-25%) | 119(+20%) | -86(-22%) | -14(-6%) | 6(+3%) | 2(+1%) | 3(+1%) | 27(+9%) | 24(+7%) | 68(+15%) | 62(+10%) |
| Average | | -42(-11%) | -46(-12%) | 9(+3%) | -9(-4%) | 0(-0%) | 2(+1%) | 1(+1%) | 1(+1%) | 3(+1%) | 20(+8%) | 23(+7%) | 77(+21%) |

**Note**

[1] Change is calculated as difference in monthly Electrical Conductivity values between the Project and the baseline (Alt4A ELT minus NAA ELT). Values in parenthesis indicate percent change, calculated as ([Alt4A ELT minus NAA ELT]/ NAA ELT)*100.

Colored cells indicate months when the changes under Alt4A ELT are greater than 5 percent.

### Steamboat Slough at Sutter Slough

The following results show a comparison of minimum daily water levels or stage between Alt4A ELT and NAA ELT in Steamboat Slough at Sutter Slough. The minimum daily stage is calculated from 15-minute model results in any given day. **Figure 7** shows two scatter plots comparing minimum daily stage in Steamboat Slough at Sutter Slough between NAA ELT and Alt4A ELT. **Figure 7** also shows a line (Alt4A = NAA line) that represents a hypothetical condition when the minimum daily stage values (y axis) equals exactly the NAA ELT stage values (x axis). When the plotted points are below the line, it indicates that the minimum daily stage under Alt4A ELT is lower than under the NAA ELT. In **Figure 7**, it is notable that the minimum daily stage under Alt4A ELT are consistently lower than the NAA ELT. The vertical distance of the plotted points from the Alt4A = NAA line defines the magnitude of the difference between the two alternatives; the greater the distance, greater the difference between the two alternatives. Overall, the minimum daily stage in Steamboat Slough and Sutter Slough is lower under the Alt4A ELT in comparison to NAA ELT with an approximate reduction of up to nearly 1.0 feet.

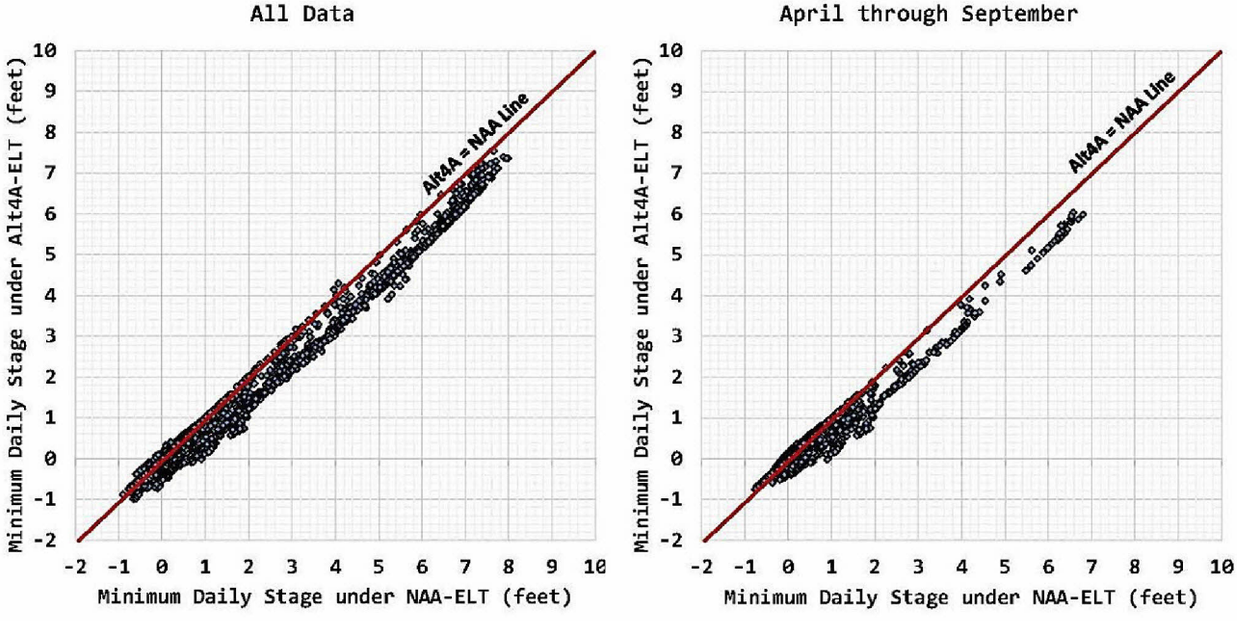


**Figure 7. Scatter Plot Showing Minimum Daily Stage between Alt4A ELT and NAA ELT at Steamboat Slough at Sutter Slough**

## Conclusions

This modeling review focused on evaluating changes in EC at the key locations of interest to NDWA: the Sacramento River at Emmaton, Rio Vista, and Three Mile Slough. However, in certain months average monthly EC can increase by nearly 80 percent, and also can decrease by nearly 70 percent, thus indicating both positive and negative changes due to the Project. The results also reveal a consistent pattern of increased EC in the months of July, August, and September at these Sacramento River locations. On average these fluctuations cancel each other

out, however understanding the seasonality of the changes is important in determining how they affect beneficial uses of water. The simulated minimum daily stage in Steamboat Slough at Sutter Slough is consistently lower under the Alt 4A ELT, particularly during the April through September irrigation season.