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BEFORE THE

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

HEARING IN THE MATTER OF CALIFORNIA DEPARTMENT OF WATER RESOURCES AND UNITED STATES BUREAU OF RECLAMATION REQUEST FOR A CHANGE IN POINT OF DIVERSION FOR CALIFORNIA WATER FIX	TESTIMONY OF DR. PARVIZ NADER-TEHRANI (EXHIBIT DWR-79)

I, Parviz Nader-Tehrani, do hereby declare:

I am a supervising engineer employed by the Department of Water Resources (DWR). Information on my education, experience and expertise, is provided in my Statement of Qualifications and direct testimony. [Exhibits DWR-26 and DWR-66, pp. 1:17-27.]

I. OVERVIEW OF TESTIMONY

The purpose of my testimony is to provide evidence rebutting the claims brought by a number of parties concerning two major topics on modeling: the Department of Water Resources' (DWR) modeling results analyzing California WaterFix; and the proper use of the models, CalSim II and DSM2, for the analysis.

Sections II - VII of my testimony address the first topic. I offer my opinion, mostly regarding DSM2 modeling, in response to parties opinions and analysis which I believe were either incorrect, incomplete, or needed further clarification, including:

a. The effects of Head of Old River Gate (HORG) operation on the South Delta water quality. I show how the more aggressive HORG closure requirements under the Boundary 2 scenario is the likely cause for the difference in the water quality and it is not directly related to the proposed WaterFix North Delta Diversions (NDD).

b. Effects of Fall X2 on water quality and water levels. I explain the effects of Boundary 1, which does not include Fall X2, on water quality and water levels and the result of any increase in chloride or EC or reduction in water levels is not due to WaterFix but rather due to removing the Fall X2 flow requirement.

c. Changes in frequency of reverse flows on Sacramento River near Freeport. In my opinion there will not be an increase in Significant Reverse Flow Events (SRFE) as a result of WaterFix and that the EBMUD analysis is flawed.

d. Water level changes during low flow periods. I show that the reduction in water levels are expected to be much smaller during low flow periods, since the WaterFix NDD bypass flow rules would limit the use to a minimum health and safety requirements.

e. North Delta water quality. It is my opinion that in general the water quality will continue to remain fresh at most places in North Delta under WaterFix operations.

f. Water quality at Antioch. It is my opinion that the water quality at Antioch would be similar or better under WaterFix and the salinity increase at Antioch under Boundary 1 can be mostly attributed to lack of inclusion of the Fall X2 flow requirement.

Sections VIII – X of my testimony address the second topic regarding the proper use of the models. Many parties testified on the use of the models and I offer my opinion to clarify and correct such testimony, including:

a. Several protestant's testimony showed an inappropriate use of modeling results which in my opinion provided representations that distorted results and should not be relied upon.

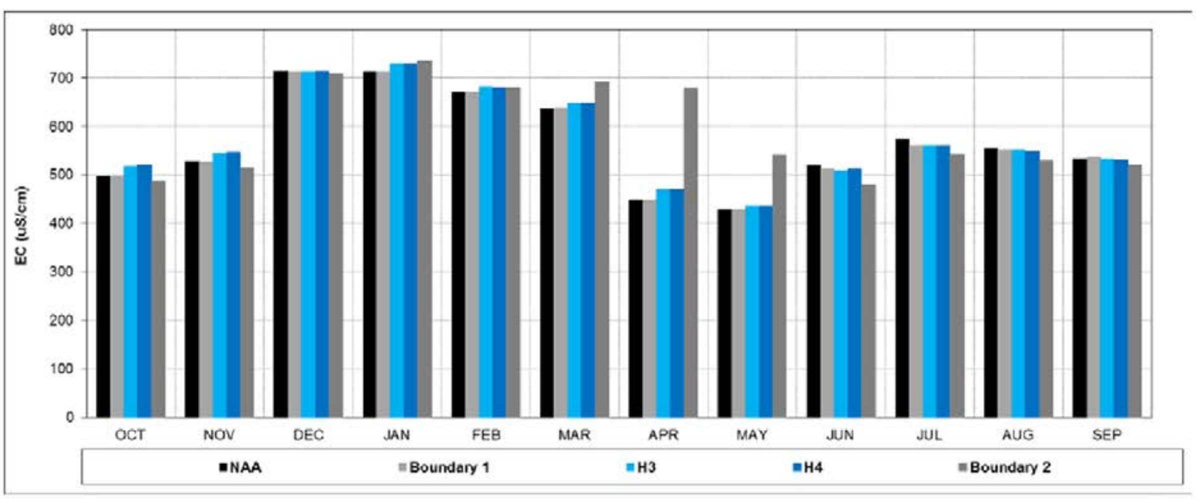
b. Modeled exceedances in results for D-1641 agricultural, municipal, and industrial water quality objectives are not real, and occur mainly due to a difference in the assumptions in DSM2 and CalSim II

c. Some parties incorrectly expressed opinions that DSM2 was not properly calibrated but DSM2 is calibrated and validated and represents the best available tool to analyze change that may occur from WaterFix.

II. EFFECTS OF HEAD OF OLD RIVER GATE OPERATION

In my direct testimony, I presented water quality results for EC and Chloride at locations throughout the Delta. [Exhibit DWR-66.] Specifically, this modeling showed DSM2 water quality results at the Old River Tracy Road, which is one of the locations in the South Delta where D-1641 agricultural water quality objectives are set, shown below in Figure EC5. [See also Exhibit DWR-513, Figure EC-5.][1]

Figure EC5: Monthly Average EC at Old River at Tracy Road



**Model results are used for comparative purposes and not for predictive purposes*

My direct testimony explained that the reason for the increase in EC for the Boundary 2 operational scenario is the installation of a complete barrier at the head of Old River for the

[1] The modeling conclusions presented in Exhibits DWR-66 and DWR-513 were generated from the modeling data contained in Exhibit DWR-500. DWR-500 is hereby incorporated by reference into this rebuttal testimony.

months of March through May. [Exhibit DWR-66, p. 6.]

For purposes of responding to protestant's comments regarding the increase in EC in the south Delta, under my direction, my staff performed two additional DSM2 runs for the Boundary 2 and H3 operational scenarios.[2] In these runs, we changed the Head of Old River gate operations to be the same as the NAA. The results are shown below in Figure 1. The results for the two new model runs, labeled H3_HORBasNAA and Boundary 2_HORBasNAA, clearly show that if the head of Old River Gate operation is operated the same way as the NAA, the EC results are expected to be very close to the NAA. This modeling result demonstrates that changes in south Delta water quality are not from operation of the NDD, but are related to closure of the proposed HOR gate.

In general, the water quality at the Old River at Tracy Road is mostly affected by the flow and water quality entering the Delta from San Joaquin River and the head of Old River Gate operation. There are no changes in San Joaquin River flows proposed under the California Water Fix. The proposed changes in the head of Old River Gate operation in CWF will be determined based on water quality and fish presence as discussed in Chapter 3, pages 3-142 and 3-267 [Table 3-7] of the FEIR[3] and Draft Partially Recirculated EIR/Supplemental EIS. [SWRCB-3, Section 4.1.2.2, Table 4.1-2.]

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[2] Additional modeling data upon which the additional analysis was performed are submitted as Exhibit DWR-900.

[3] The CWF Final EIR, dated December 2016, is publically available at the California WaterFix website https://www.californiawaterfix.com/resources/planning-process/eir-eis/. [Exhibit SWRCB-102.]

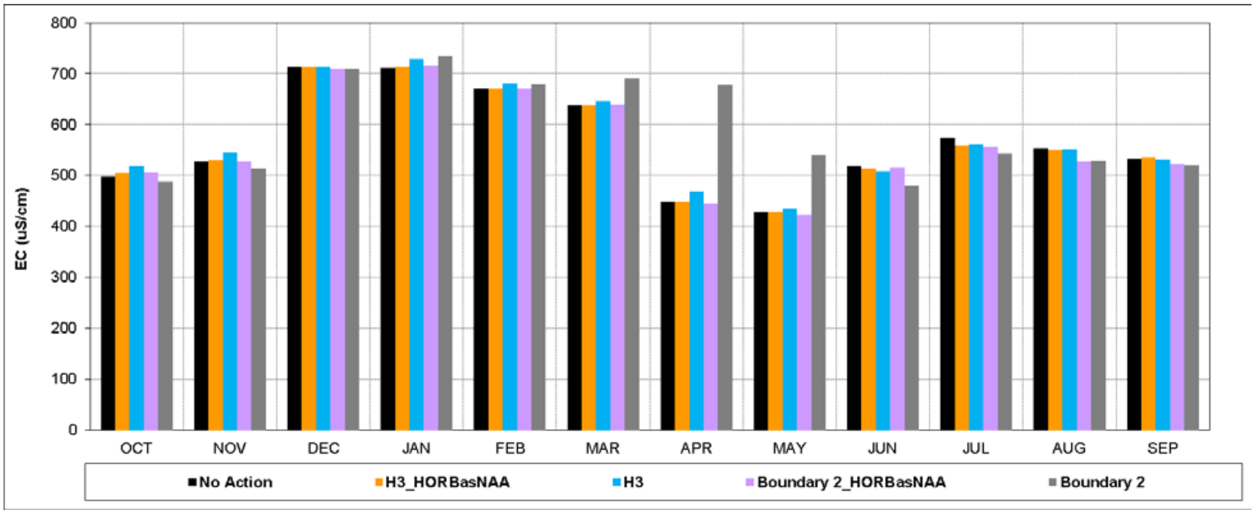

Figure 1. Monthly Average EC at Old River Tracy Road (Revised DSM2 runs)

III. IMPORTANCE OF FALL X2 WHEN INTERPRETTING MODEL RESULTS

A number of protestant's criticized an increase in the modeled observed EC, or chloride concentration, and a reduction in water levels under the Boundary 1 analysis. [Exhibits Antioch-200, pp. 5-6; Antioch-202, pp. 25-27; CSPA-2, pp. 8-9.] This section explains that because the Boundary 1 analysis does not include the existing requirement for Fall X2, which is in the NAA, it is not surprising to see an increase in EC or an effect on water levels during certain years. Even with these results, DWR can operate the SWP to meet the required water quality requirements.

The Fall X2 requirement is defined in the U.S. Fish and Wildlife Service Biological Opinion as Action 4. [SWRCB-87, p. 369.] Action 4 requires additional Delta outflow to manage X2 in the fall months following the wet and above normal years to maintain an average X2 for the months of September and October no greater (more eastward) than 74 kilometers in the fall following wet years and 81 kilometers in the fall following above normal years. In November, the inflow to CVP/SWP reservoirs in the Sacramento Basin should be added to reservoir releases to provide an added increment of Delta inflow and to augment Delta outflow up to the fall X2 target. [SWRCB-87, pp. 283, 369.]

A. Effect of Fall X2 on Water Quality

In order to meet the Fall X2 requirement, Delta outflow has to increase either by releasing more water from the reservoirs or by reducing the Delta exports. The effect of the increase in Delta outflow is a reduction in ocean salinity intrusion leading to improved water quality (EC) throughout the Delta, especially the Western and Central Delta. This would be most apparent in the fall months (September through November in wet and above normal water years). In general, meeting Fall X2 requirements requires substantial increase in Sacramento River flow especially in September and October of wet and above normal water years, all WaterFix operational scenarios considered in this petition include the Fall X2 action except for Boundary 1. As such, it is not surprising to see an increase in EC (or Chloride concentration) corresponding to the Boundary 1 operational scenario in fall months of wet and above normal years when compared to the NAA.

Some parties focused their attention on water quality associated with only the Boundary 1 operational scenario in order to show an increase in EC (or chloride concentration) caused by the CWF. [Exhibit Antioch-202.] In response to these comments, I prepared additional modeling and graphics presented here, Figures 2-4. For example, in Figure 2 below, my additional modeling and analysis shows the monthly average chloride concentration for the water years 1984 through 1987 for Boundary 1 and the NAA. This shows there is a fairly large difference in chloride concentrations in water years 1984 (wet) and 1986 (wet) mostly during September through December. However, for the rest of the period the chloride concentrations are very similar. In water years 1985 (dry) and 1987 (critical) the chloride concentrations are quite similar. This clearly demonstrates the effect of Fall X2 on water quality, and shows that the primary reason for the elevated chloride concentrations for Boundary 1 operational scenario during fall of wet and above normal water years is due to not including the Fall X2 action.

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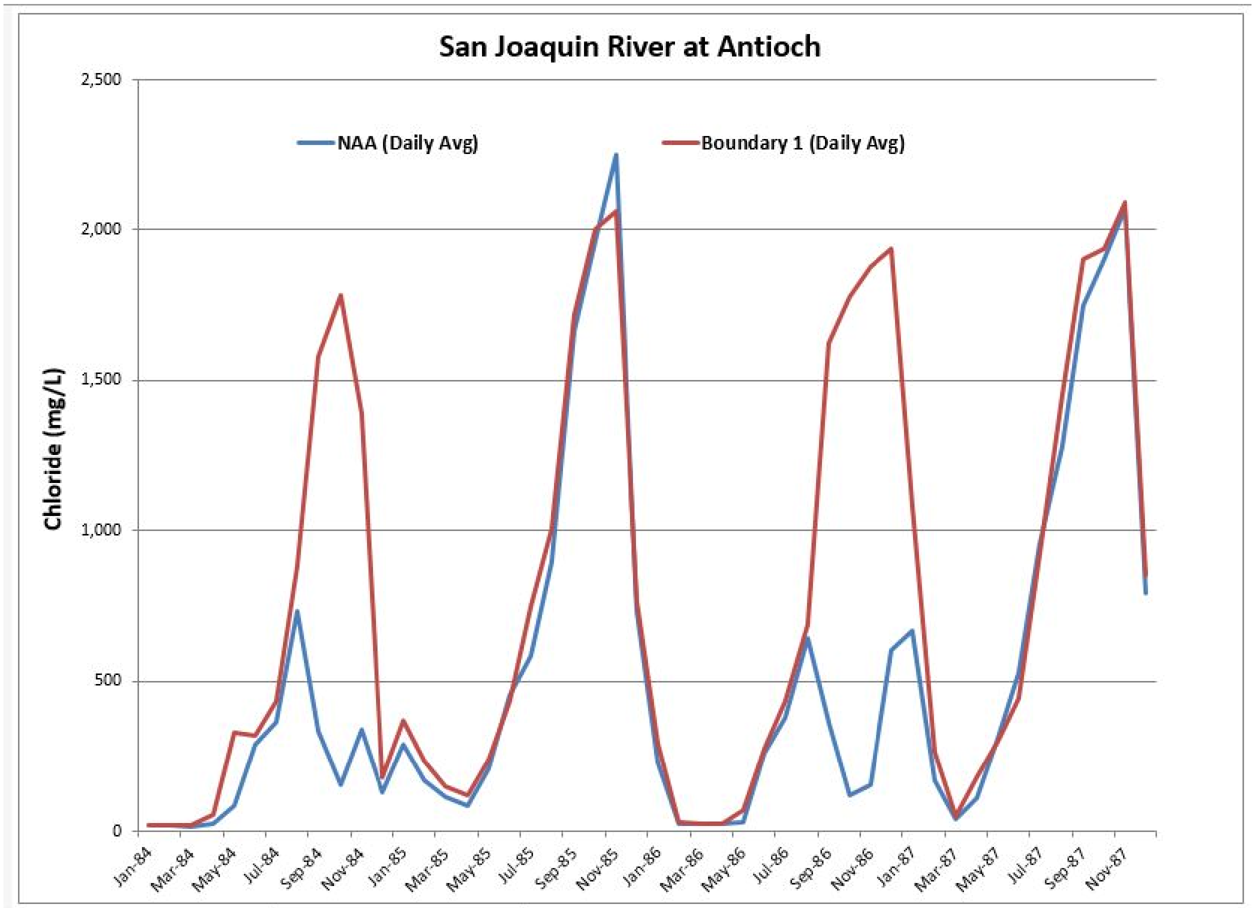

Figure 2. Monthly Average Chloride Concentration at Antioch (1984-1987)

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Figure 3, below shows the monthly average chloride concentration for the water years 1984 through 1987 for all operation scenarios as compared to the NAA. As it can be clearly seen, H3 and H4 operational scenarios result in mostly similar or lower chloride concentrations as compared to the NAA, and Boundary 2 results in the lowest chloride concentrations in all four years.

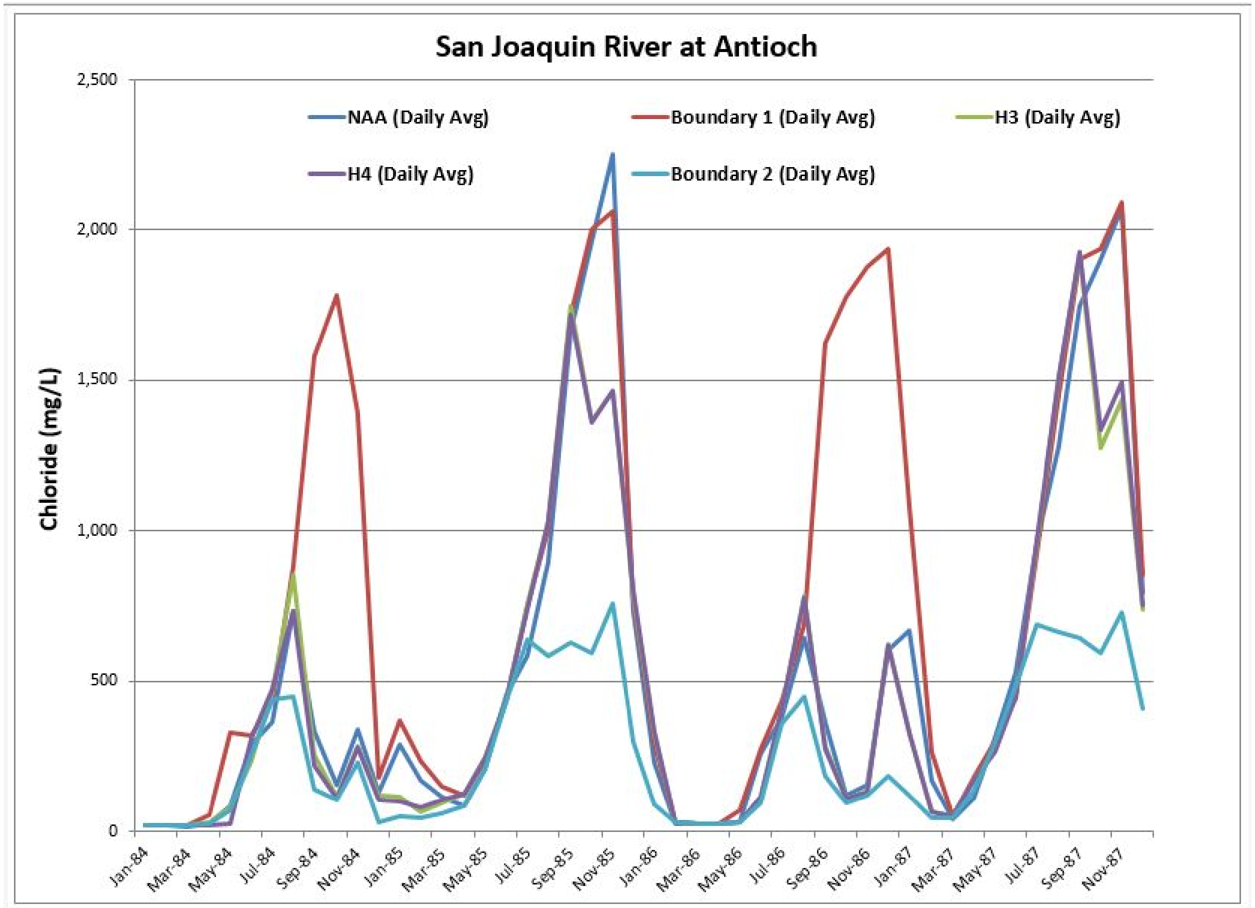

Figure 3. Monthly Average Chloride Concentration at Antioch (1984-1987)

Figure 4, below, shows the monthly average chloride concentration for the water years 1978 through 1981 for all operation scenarios as compared to the NAA. Once again, as it can be observed, there is a large increase in chloride concentrations for Boundary 1 scenario relative to NAA in water years 1978 (Above Normal) and 1980 (Above Normal) mostly during September through December. However, for the rest of the period the chloride concentrations for Boundary 1 are very similar to NAA.

Similar to the other four year period, H3 and H4 operational scenarios result in mostly similar or lower chloride concentrations as compared to the NAA, and Boundary 2 results in the lowest chloride concentrations in all four years.

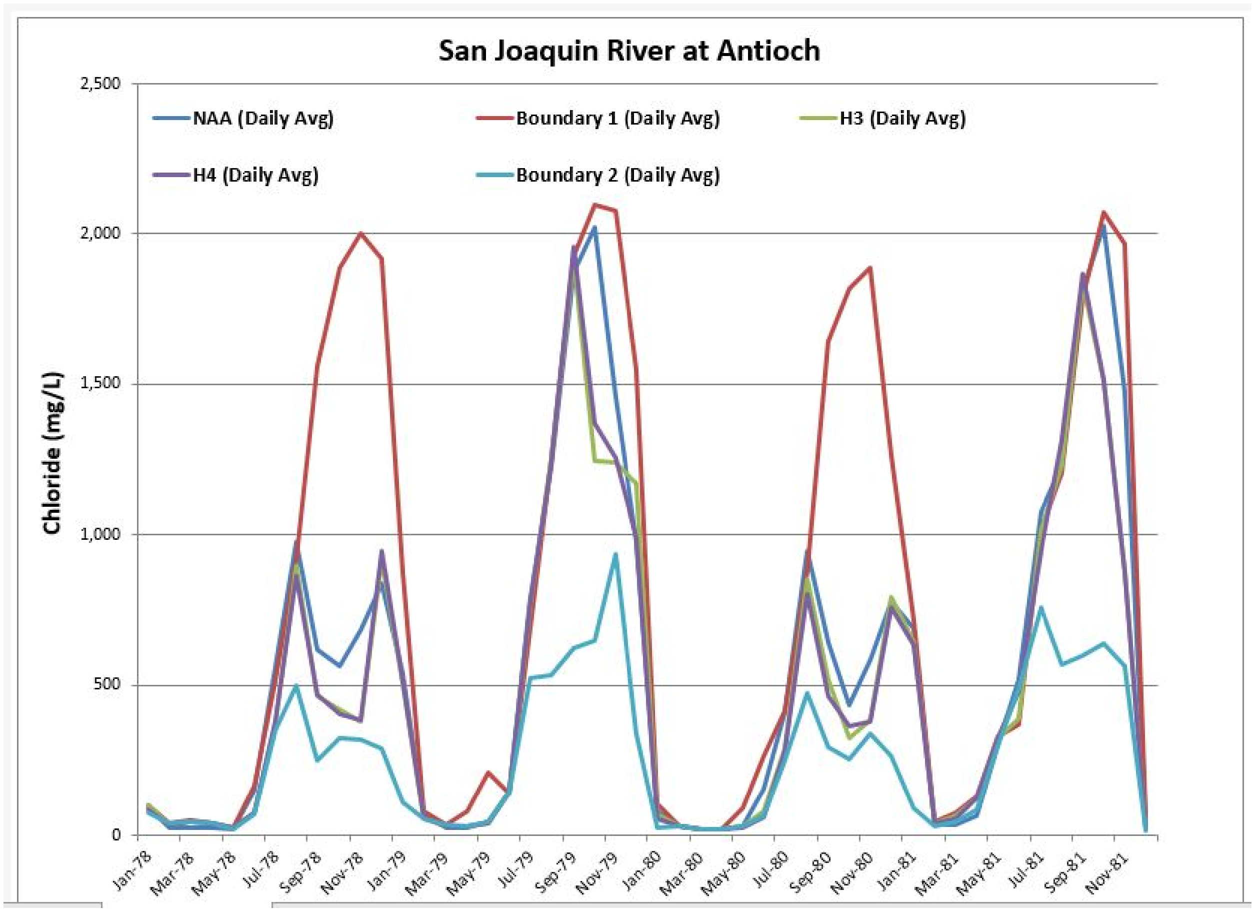

Figure 4. Monthly Average Chloride Concentration at Antioch (1978-1981)

Although Fall X2 requirements only apply to wet and above normal water years, it may affect water quality in other water year types. As an example, consider 1984, a wet water year. The Fall X2 requirements would lead to additional releases starting in September, and continuing through October and possibly November. Under the definition of the California water year, however, the months of October and November 1984 were part of 1985 water year, which was categorized as a dry year. In other words, although

1985 was considered a dry year, the effects of better water quality were associated with the higher flows in October and November 1984 which was technically part of the 1985 water year.

Conversely, there may be some water years that although may be categorized as wet or above normal, the water quality benefits associated with meeting Fall X2 requirements in October and November would not be associated with those water year types. As an example, consider 1978, which was considered an above normal water year and which would have had a Fall X2 requirement. However, October and November of the 1978 water year are really months of the 1977 calendar year, a very dry period that was near the end of a major drought. The main point here is that one may see the water quality effects of Fall X2 in selected water years (during October-November) that are not categorized as wet or above normal water years, and conversely, one may **not** see the water quality benefits associated with Fall X2 (during October-November) in select water years that are categorized as wet or above normal.

In summary, since the Boundary 1 operational scenario does not include the Fall X2 requirement, it may result in higher salinity (EC, Chloride, etc.) during the fall of wet and above normal years. As long as USFWS upholds the need for Fall X2 Action, WaterFix is expected to operate to it during wet and above normal years.

B. Effect of Fall X2 On Water Levels

Dr. Thomas Burke, representing South Delta Water Agency testified that water levels change under Boundary 1. [Exhibits SDWA-76 errata, p. 6; SDWA-77, pp. 24-26.] Dr. Burke showed the water level changes only for the Boundary 1 relative to NAA. Specifically Dr. Burke showed the reduction in water level downstream from the third proposed North Delta diversion, at the point where you expect the highest water level reduction. [Exhibits SDWA-76 errata p. 6; SDWA-78.] In doing so, it appears that Dr. Burke simply plotted the difference in the 15 minute DSM2 stage output between Boundary 1 and NAA. There are two points to be made regarding his plot of data:

1. This sort of analysis is considered an inappropriate use of DSM2 model results as described below in Section 8A of this testimony. Because DSM2 uses input from the CalSim II model which is based on monthly average hydrology, it is inappropriate to compute differences between two planning scenarios' 15 min output.
2. Dr. Burke reports reduction in water levels in excess of 4 ft. In his analysis he did not specify the time periods during which those larger differences were detected. He also did not show any analysis for reduction in water levels for any other operational scenarios.

I tried to duplicate the procedure followed by Dr. Burke. I tried to focus my attention on the largest differences in water levels and noticed that the largest reductions observed correspond to September of wet years. Specifically the three largest reductions in water levels are found for a single 15 minute time-step during September 1984, September 1986, and September 1982. I created Table 1, shown below, showing the flow at Freeport for the same three months and the corresponding maximum reduction in water level corresponding to Boundary 1 as compared to NAA. It is clear that the relatively large reduction in water levels Dr. Burke reported is directly related to a reduction in flow at Freeport for Boundary 1 operational scenario as it was not operated to meet the Fall X2 requirement. The flow at Freeport for the same months for the other CWF operational scenarios (H3, H4, and Boundary 2) are much closer to the NAA (as they all include Fall X2), and thus not expected to lead to the same magnitude of reductions in water levels as those shown in my Table 1. In short, the larger reductions in water levels reported by Dr. Burke were directly related to the lack of implementation of Fall X2 action for the Boundary 1 scenario.

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Table 1. The Effect of Flow at Freeport on the Water Level

	Freeport Flow (cfs) B1	NAA	Maximum Reduction in Water Level (ft)
Sep-84	8867	29541	4.0
Sep-86	11089	23949	3.6
Sep-82	13521	24959	2.8

It should be noted that since the issuance of USFWS Biological Opinion in Dec 2008, Fall X2 criteria had to be met only once in 2011 due to the recent droughts. Thus, with the exception of 2011, legal users of water did not necessarily experience or enjoy the water quality/level benefits associated with the increased reservoir releases to meet the Fall X2 requirement.

IV. ANALYSIS OF REVERSE FLOW AT FREEPORT

Dr. Bray used two different types of analysis to show changes in the frequency of occurrence of Significant Reverse Flow Events (SRFEs) at Freeport from CWF operations. [Exhibit EBMUD-152.] I respond to his analysis and show through my own analysis that SRFEs at Freeport would have a similar frequency at all flow levels (low to high) for all CWF operational scenarios. In my opinion, my analysis as described below shows that both approaches by Dr. Bray are flawed.

A. CalSim II Approach

Dr. Bray used historical velocity data at Freeport and observed that based on his calculations, Significant Reverse Flow Events (SRFE) typically occur when flow at Freeport is below 8,000 cfs. [Exhibit EBMUD-152, pp. 6-7.] However, on cross examination, Dr. Bray stated that there are times when the flow at Freeport is less than 8,000 cfs and

SFRE's do not occur. [October 27, 2016 Transcript Vol. 24, p. 287:2-4.] Furthermore, Dr. Bray testified that he didn't do any statistical analysis for this approach. [October 27, 2016 Transcript vol. 24 p. 260:12-17.]

Dr. Bray used the CalSim II tables and determined the number of months when flow at Freeport is below 8,000 cfs and the flow at Freeport under any of the operational scenarios is less than that for the NAA by at least 20 cfs. [Exhibit EBMUD-152, p. 8.] There are two fundamental flaws with this approach:

1. There is no evidence that there is a high degree of probability of SRFE occurring when flow at Freeport is less than 8,000 cfs. According to EBMUD witness Eilen White only four SRF events actually occurred from April 2014 through December 2015 (that is roughly about 2.3 SRFE events in a very dry year). [October 27, 2016 Transcript Vol.24, pp.214-236; 280-283.] According to CDEC, there were 371 days during this period which the daily average flow at Freeport was less than 8,000 cfs. This translates in to a one in ninety two probability (1.1%) that there would be a SRFE when the daily average flow at Freeport drops below 8,000 cfs.
2. Dr. Bray's analysis only looked at the number of months when the flow at Freeport for any one of the four CWF operational scenarios was below that of NAA. Dr. Bray did not indicate the number of months when the reverse condition was true, i.e. the flow for the CWF operational scenarios was higher than that of the NAA. Any general analysis based on CalSim II results should be based on the entire 82 years of record.

My Figure 5 below shows the frequency of exceedance for the flow at Freeport (82 years,1922-2003) for all operational scenarios including the NAA. It shows all operational scenarios have a very similar pattern, suggesting the flow at Freeport would have a similar frequency at all flow levels (low to high) for all CWF operational scenario.

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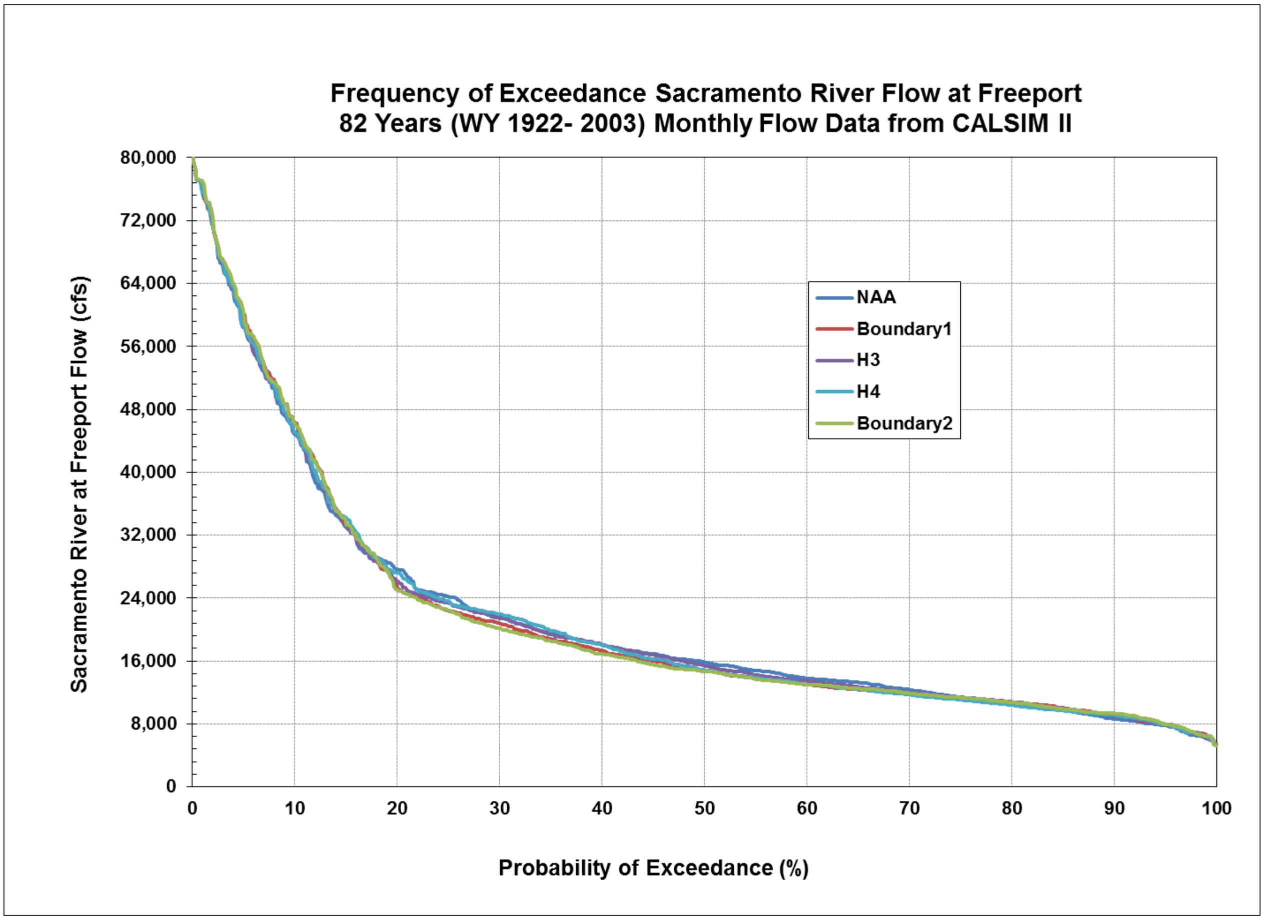


Figure 5. Frequency of Exceedance flow at Freeport

In addition, I prepared Table 2 showing the percentage of months for each of the CWF operational scenarios (including NAA) and that the flow at Freeport is below 8,000 cfs. Table 2 clearly shows that all CWF operational scenarios have about the same probability of Freeport flow being below 8,000 cfs, and in fact the NAA has a slightly higher probability of Freeport flow going below 8,000 cfs.

Table 2. Probability of low Freeport flow (< 8,000 cfs)

CWF Alternatives	Probability of Sacramento River Flow at Freeport below 8000 cfs (CALSIM II
NAA	6.20%
Boundary 1	5.30%
H3	5.60%
H4	5.60%
Boundary 2	5.30%

Therefore, based on this approach there is absolutely no evidence to indicate that CWF operational scenarios would lead to a higher number of SRFEs.

B. DSM2 Approach

Dr. Bray also used adjusted DSM2 data in considering SRFEs. However, when using his own data that is not adjusted, in all but one situation the NAA has more SRFEs than the other CWF operational scenarios. Dr. Bray first used the unmodified velocities computed by DSM2 to determine the number of expected SRFEs for each of the CWF operational scenarios including the NAA. [Exhibit EBMUD-152, pp. 14 -19.] According to Dr. Bray's testimony shown by his Table 2 copied below, the NAA in general shows a higher number of expected SRFE compared to all CWF operational scenarios. [Exhibit EBMUD-152, p. 44, Table 2.] The only exception is that during 1976-1977, the H4 scenarios showed two more SRFEs (33 vs 31) compared to NAA. With this approach, using data for 1976-77 drought, you would expect about 15 SRFEs per year. This is much higher than the 2.3 SRFE per year actually experienced during the April 2014 to Dec 2015 period.

Table 2. Significant Reverse Flow Events for California WaterFix Water Rights Hearing Modeling Studies. Period of analysis is indicated in parenthesis.

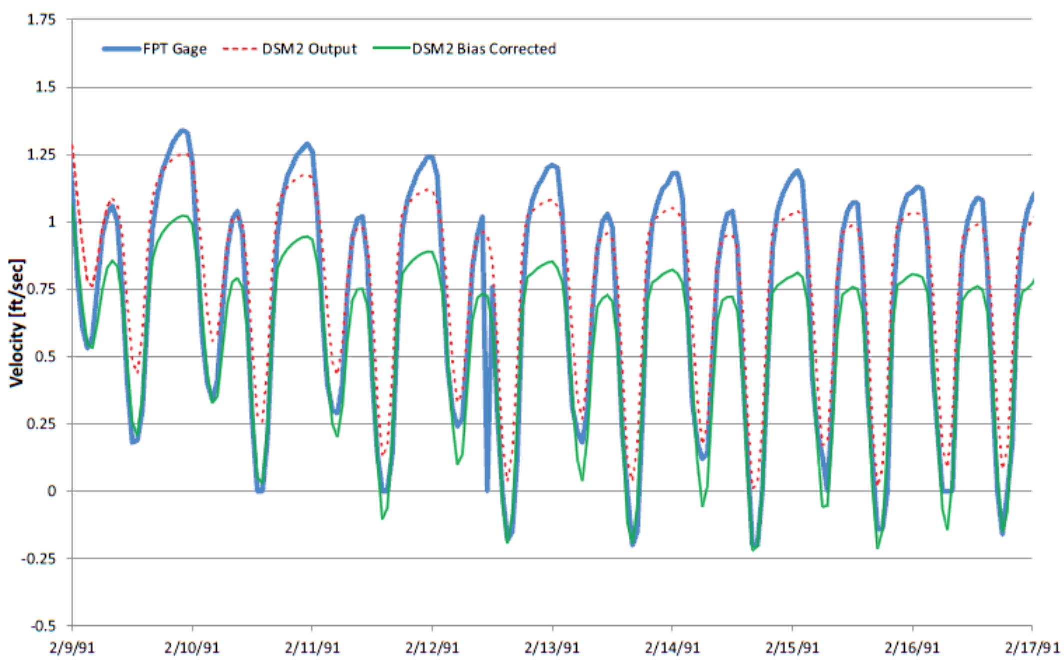
	No Action Alternative	Project Scenario H3	H4	Boundary 1	Boundary 2
1976–1977 Drought (Oct. 1975 – Oct. 1977)	31	30	33	27	28
1987–1992$^{\alpha}$ Drought (Oct. 1987 – Sep. 1990)	71	51	45	50	56
WYs 1976–1991 Total (Oct. 1975 – Sep. 1991)	113	89	86	82	96

α - Note that WY 1992 is not included in Petitioners DSM2 modeling simulation, therefore, this final year of the drought cannot be included in the analysis.

[Exhibit EBMUD-152, p. 44, Table 2.]

Dr. Bray made the point that DSM2 underrepresented the peak reverse flows. Dr. Bray developed a bias offset to the velocities computed by DSM2 by minimizing the sum of square error in order to get a better match with the observed data. [Exhibit EBMUD-152, p. 10.] Dr. Bray then attempted to show that the DSM2 bias-corrected velocities are in better agreement with the observed data as shown on his figure 7, copied below.

Figure 7. Freeport Gage Velocity with DSM2 Historical Simulated Velocity at Freeport Project Intake and DSM2 Velocity with -0.230 ft/sec Bias Correction Offset, Feb. 9 – 27, 1991.



[Exhibit EBMUD-152, p. 34, Figure 7.]

While Dr. Bray's approach may result in a better overall agreement with the observed data, it is clear that it may overestimate the number and severity of reverse flows (negative velocities) and ultimately overestimate the number of expected SRFEs. Dr. Bray's Figure 7 shows velocity at Freeport for about 8 days (2/9/91 through 2/17/91). In the same time window, the bias-corrected velocities would suggest an additional 4 days (2/11. 2/14, 2/15, and 2/16) of reverse flow events, which truly did not occur based on data from Freeport gauge. Thus the adjustment in just those 8 days created 4 reverse flow events that did not actually occur but were due to his adjustment.

Dr. Bray also showed the estimated number of SRFEs using the bias corrected velocities in his testimony at Table 3, copied below. [Exhibit EBMUD 152, p. 45, Table 3.] When the numbers in Table 3 are compared with those on Table 2 (without the bias correction), there is about a five-fold increase in the estimated number of SRFEs. Dr. Bray's revised approach indicates that there would be about 82 SRFEs (165/2) per year in the drought years 1976-77 corresponding to the NAA scenario. When comparing that number to the 2.3 SRFEs per year actually experienced in the period April 2014 through December 2015 (an almost equally dry period), it becomes quite clear that these estimated frequency of SFREs shown in Table 3 are at best extremely questionable. Further observations on values shown in Table 3 indicate that outside the 1976-1977 period, all CWF operational scenarios result in lower frequency of SRFEs compared to the NAA. This includes the extended 4 year drought period (1987-1991) and the entire 16 year period.

Table 3. Significant Reverse Flow Events for California WaterFix Water Rights Hearing Modeling Studies from Bias Corrected DSM2 Output. Period of analysis is indicated in parenthesis.

	No Action Alternative	Project Scenario H3	H4	Boundary 1	Boundary 2
1976–1977 Drought (Oct. 1975 – Oct. 1977)	165	183	183	160	176
1987–1992$^{\alpha}$ Drought (Sep. 1987 – Sep. 1991)	377	374	332	326	328
WYs 1976–1991 Total (Oct. 1975 – Sep. 1991)	596	572	541	500	504

α - Note that WY 1992 is not included in Petitioners DSM2 modeling simulation, therefore, this final year of the drought cannot be included in the analysis.

[Exhibit EBMUD-152, p. 45, Table 3.]

V. WATER LEVEL CHANGES DURING LOW FLOW PERIODS

During Part 1 of the hearing, DWR showed the expected changes in water levels using a probability of exceedance plot at several locations throughout the Delta. [Exhibits DWR-513, Figures W1-W5, and DWR-66, p. 9.] DWR showed the highest reduction in water levels is expected to occur along Sacramento River immediately downstream of the third proposed intakes. DWR also explained that the reductions in minimum daily water levels are expected to be around 1-1.2 ft during high flows and about 0.5 ft during low flows. DWR also showed that the expected reductions in water levels become smaller as you get farther away from the new proposed North Delta intakes. These results were based on the DSM2 analysis using the entire 16 years of record (1976-1991) which includes the extreme hydrologic events ranging from the very dry to the extreme wet periods.

Some parties raised concerns about the expected water level impacts during extreme dry events (similar to those occurred during 2014-2015) and how it might affect their ability to use their existing irrigation practices. [Exhibit SDWA-76 errata, p. 6.]

To get a better estimate on the expected reductions in water levels during extreme dry periods, I have prepared another graph, shown below as Figure 6, and similar to Figure W1: “Probability of Exceedance for Daily Minimum Stage At Sacramento River Downstream from the Three Proposed Intakes” in my Exhibit DWR-513 [p. 11, Figure W1], but the new graph below focuses mainly on the 1976-1977 period which is the driest two years on record within the 16 years of simulation.

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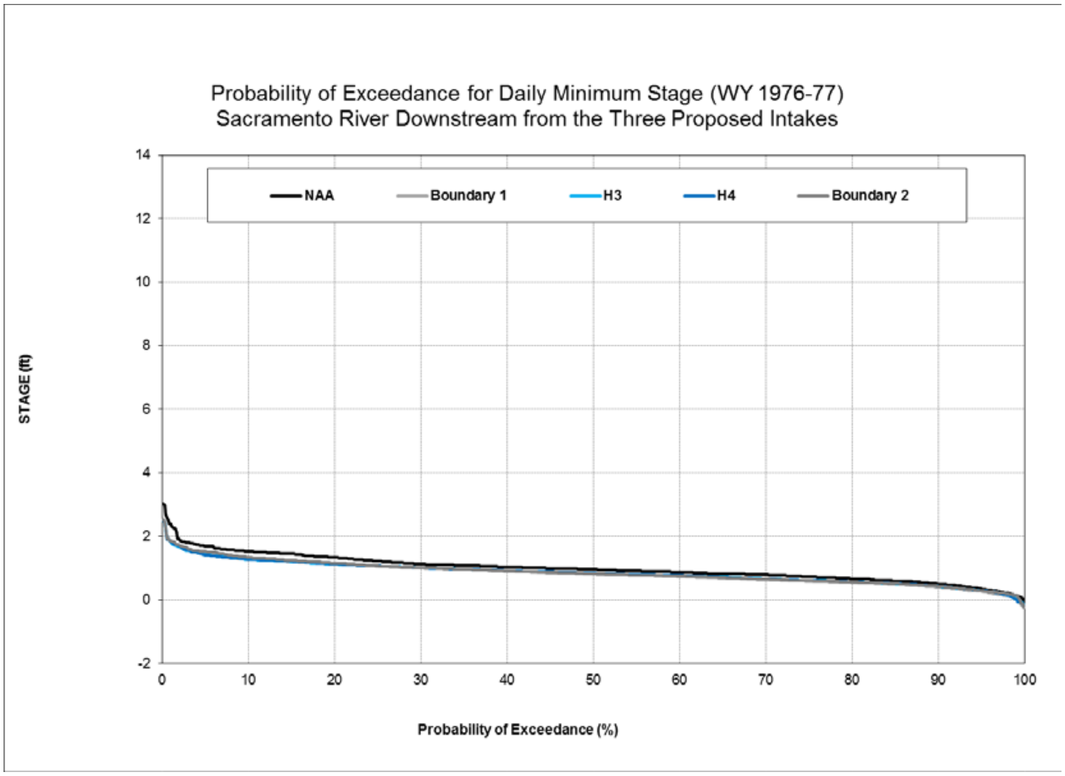

Figure 6. Probability of Exceedance for Daily Minimum Stage at Sacramento River Downstream From the Three Proposed Intakes.

Figure 6 clearly shows that during low flow periods, the expected reduction in water levels is a lot smaller during low flow periods. In fact, at higher probability levels (lowest water levels) the expected reduction in minimum daily water levels is about 0.1-0.15 ft (less than two inches). This is consistent with the fact that based on the bypass flow and other regulatory requirements, there will be little or no diversions from the three proposed North Delta intakes during the low flow periods (with the exception of the health and safety requirements). The location shown in Figure 6 represents the region with the highest expected reduction in water level. The change in water level at any other location in the Delta would be even less than that shown in Figure 6.

VI. NORTH DELTA WATER QUALITY

North Delta Water Agency (NDWA) testified that CWF would impact water users within its service area. [Exhibit NDWA-32.] However, as explained in Ms. Maureen

Sergent's rebuttal testimony, under the terms of the 1981 Contract, NDWA agreed to specific water criteria at seven stations throughout North Delta as being protective of their water quality requirements. [Exhibit DWR-77, pp. 9-16.]

The NDWA testimony by MBK consultants contains a water quality analysis at three stations (Emmaton, Three Mile Slough, and Rio Vista). [Exhibit NDWA-32.] The MBK consultants state that their analysis is based on the CWF H3+ operational scenario. It is my belief that at these three locations, the results for the H3+ operational scenario are very close to the H3 and H4 operational scenarios.

The MBK analysis showed that there are varying levels of increases in EC at these three locations, depending on the specific period reviewed. However, the MBK analysis also shows that there are only twenty additional days in the entire 16 years of DSM2 simulations where the EC exceeded the thresholds described in the NDWA contract at Three Mile Slough (an average of 1.25 days per year) relative to the NAA scenario. Correspondingly, at Rio Vista, the MBK analysis shows only twelve additional days where the EC exceeded the thresholds described in the NDWA contract (an average of 0.75 days/year).

While the modeling results show a potential exceedance of possibly a few days in any one year at Three Mile Slough, DWR historically has complied with the terms of its contract with NDWA as described in Ms. Sergent's testimony in all but the drier year types. [Exhibit DWR-77, pp. 14:25 – 15:8.] Furthermore, the NDWA Agreement includes provisions to compensate the water users in the NDWA service area from demonstrated impacts due to water quality exceedances even during extreme drought, as experienced in 2015. [Exhibit DWR-77, p. 11:23-28.]

It is also my belief that at the five other locations covered under NDWA Contract (North Fork Mokelumne River near Walnut Grove, Sacramento River at Walnut Grove, Steamboat Slough at Sutter Slough, Mokelumne River at Terminous, and San Joaquin River at San Andreas Landing), the EC levels are typically well below the thresholds described in the NDWA contract, and at these locations typically EC changes under CWF operational scenarios are typically expected to be small. The only exception is the San Joaquin River at San Andreas Landing. At this location the EC levels are generally similar or lower compared to the NAA (with the exception of the Boundary 1 operational scenario). [Exhibit DWR-513, Figure EC-3.] It is my belief that increases in EC at this location corresponding to Boundary 1 are in large part due to the lack of inclusion of the Fall X2 action, as discussed in Section III above.

VII. WATER QUALITY AT ANTIOCH

Dr. Paulsen, representing the City of Antioch, presented modeling information that suggested that CWF would remove a higher fraction of Sacramento River water from the Delta, which would change the composition and quality of water in the San Joaquin River near Antioch. [Exhibit Antioch-202, pp. 23-27.] Paulsen's testimony suggested that such a change in water composition would result in water quality impacts to the City of Antioch. However, my analysis of the relationship of the variation in flows, the San Joaquin River volumetric contribution, and EC at Antioch demonstrates that the large increases from San Joaquin River volumetric contribution under CWF operational scenarios mainly occurs when San Joaquin River flows are higher and EC values are lower, and as a result are not expected to cause substantial increases in EC at Antioch. In addition, my analysis indicates there is no correlation between an increase in San Joaquin River volumetric contribution at Antioch and any significant increase in EC at Antioch. Furthermore, with the exception of Boundary 1 which does not include the Fall X2 action, all CWF operational scenarios are generally expected to provide a similar or better water quality at Antioch.

A. Water Quality and Finger-Printing Analysis

Dr. Paulsen prepared a report evaluating CWF for the City of Antioch, focusing on changes in hydrodynamics and water quality. She claims that DWR's evaluation of CWF is inadequate and an increase in the fraction of San Joaquin River water results in degraded water quality at the City's intake. [Exhibits Antioch-200, p. 3, and Antioch-202 errata, p.33.] Dr. Paulsen's testimony includes fingerprinting analysis showing for nearly all water year types and months the fraction of Sacramento River water at the City's intake will be lower for the Boundary 1 operational scenario than for the NAA and the EBC2 scenario. [See Exhibit Antioch-202 errata, p. 33.] She reports that under the Boundary 1 operational scenario, an additional 1,200,000 acre-feet per year of exports will occur, on average; as shown in Figure 6 of her report [see Exhibit Antioch-202 errata, p. 34.], the fraction of Sacramento River water at the City's intake will decline in all year types. In some years, this "lost water" will be made up primarily by San Joaquin River water. She give the example that in March of a normal water year, the fraction of Sacramento River water decreases from 60% to 40% when the Boundary 1 scenario is implemented (relative to EBC2 and NAA baselines), while the fraction of San Joaquin River water increases from 20% to 40% (Figure 7). [See Exhibit Antioch-202 errata, pp. 33 - 35.]

Dr. Paulsen's findings can be explained and in my opinion misrepresents the potential for water quality impacts anticipated from CWF near Antioch. Dr. Paulsen makes the point that CWF will take a large fraction of fresh water from Sacramento River Water. She believes that this would to reduce Sacramento River Contribution at Antioch and at the same time increase San Joaquin River contribution. [See Exhibit Antioch-202 errata, p. 33.] She also makes the point that Sacramento River water is typically of better quality than San Joaquin River, and therefore Dr. Paulsen claims that this leads to a degradation of water quality at Antioch. Dr. Paulsen gives an example of March of a Normal year, where the Sacramento River contribution drops from 60% to 40% and at the same time San Joaquin River contribution increases from 20% to 40%. [See Exhibit Antioch-202 errata, p. 33.] I agree with Dr. Paulsen, that Sacramento River water quality is typically good year round, and the San Joaquin River water quality can vary substantially depending on the time of year and hydrologic conditions. In general, the EC at Vernalis is higher during low flow periods (Vernalis flow less than 1000 cfs) and EC is typically low (at times similar to Sacramento River) at flows greater than 5000 cfs.

To demonstrate the relationship of the variation in flow, the San Joaquin River volumetric contribution, and EC at Antioch, I prepared Figures 7 and 8, shown below. My

Figure 7 shows monthly average flow at Vernalis versus San Joaquin River volumetric contribution at Antioch corresponding to the Boundary 1 operational scenario based on the DSM2 fingerprinting results. This Figure clearly shows that the San Joaquin River volumetric contribution at the City of Antioch can exceed 40% only when flow at Vernalis is greater than 7000 cfs. A flow of 7000 cfs is considered high flow at Vernalis and typically occurs during Winter and Spring of wet and above normal years when there is a lot of fresh water in the San Joaquin River tributaries.

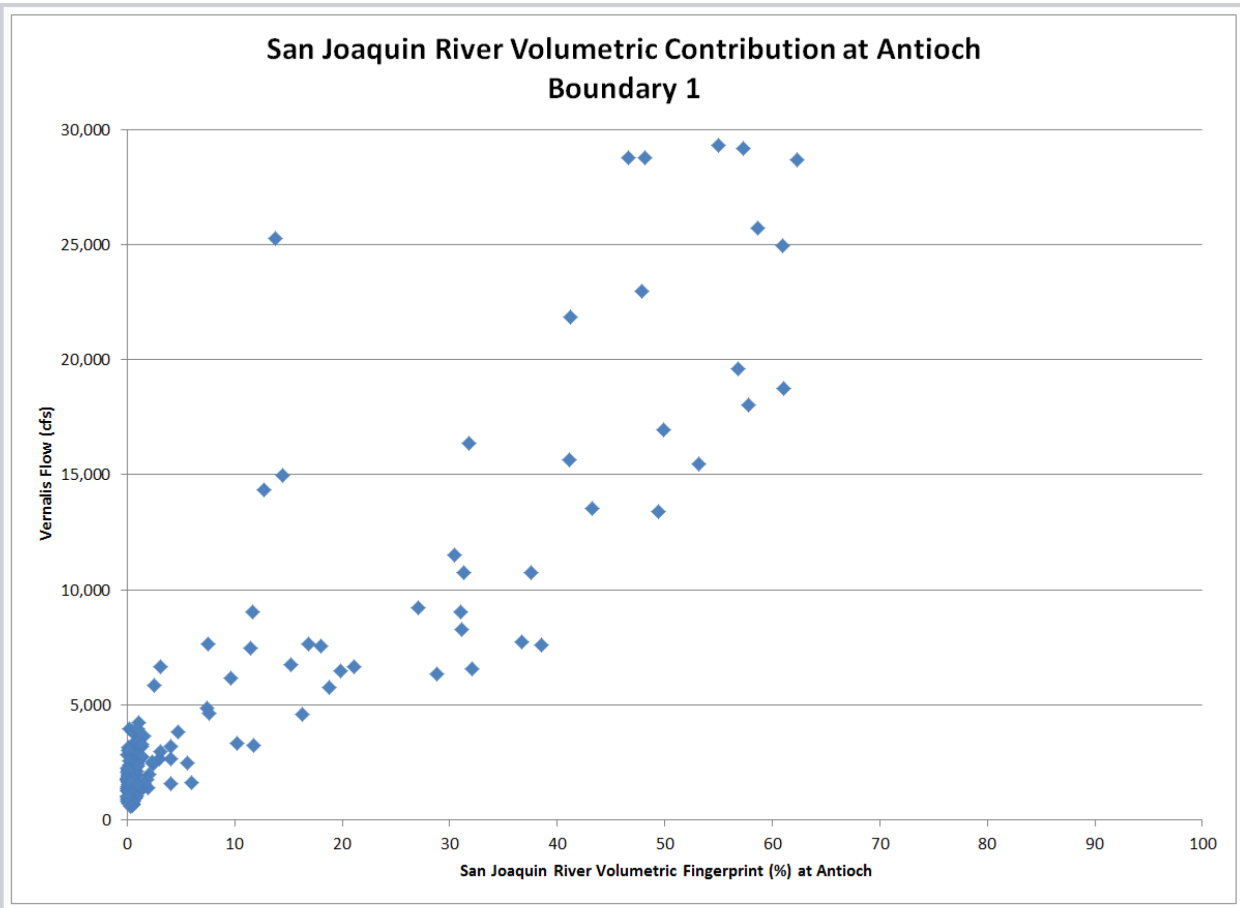

Figure 7. Vernalis Flow versus San Joaquin River Volumetric Contribution at Antioch (Boundary 1 operational scenario)

I also prepared Figure 8 that shows the monthly average EC at Vernalis versus the San Joaquin River volumetric contribution at the City of Antioch corresponding to the Boundary 1 operational scenario based on the DSM2 fingerprinting results. Figure 8 illustrates that when the San Joaquin River volumetric contribution exceeds 40%, Vernalis EC is at 300 uS/cm or lower. It also shows that at times when the Vernalis EC is above 700 uS/cm, the San Joaquin River volumetric contribution at Antioch is negligible (less than 5%).

Based on this information, it is my belief that there is no correlation between an increase in San Joaquin River volumetric contribution at Antioch and any significant increase in EC at Antioch.

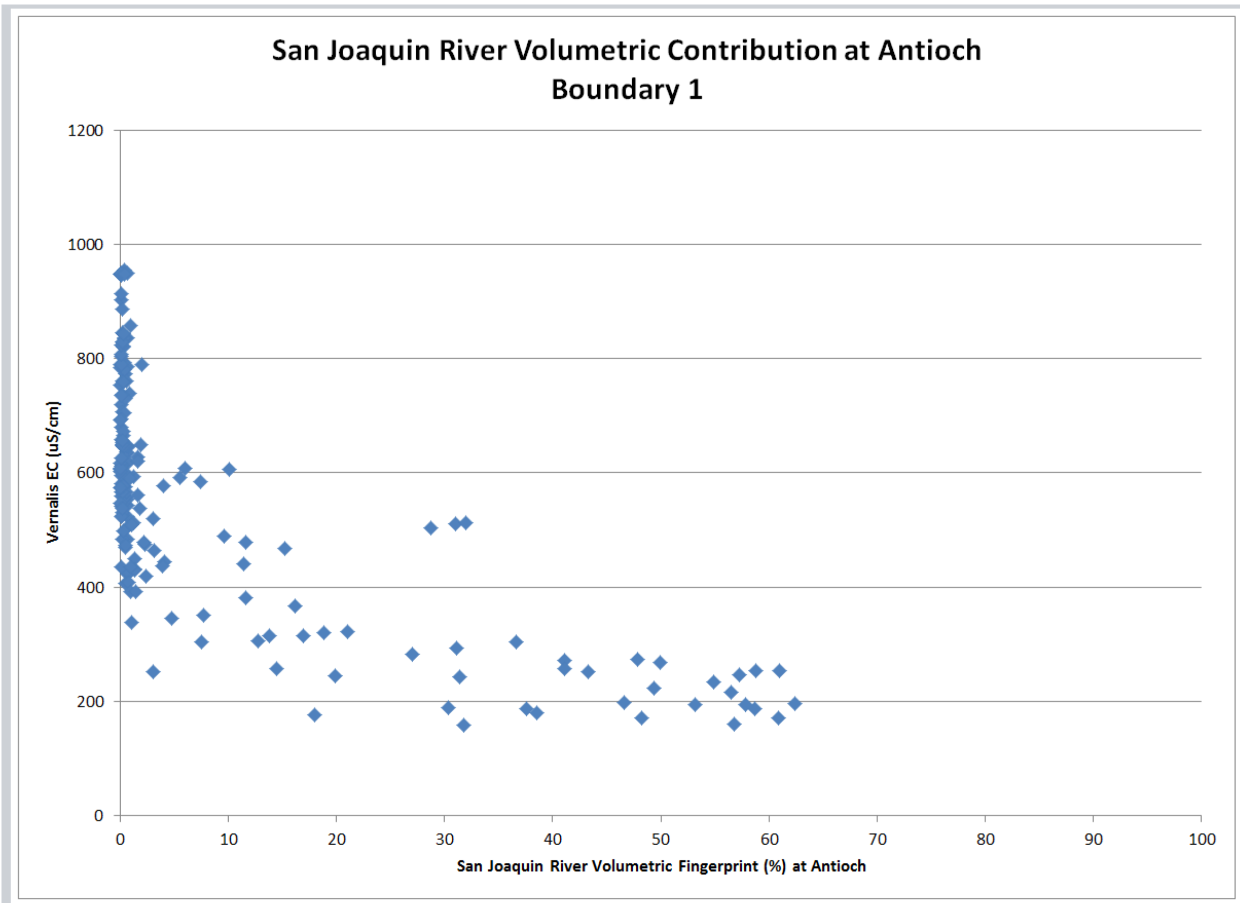

Figure 8. Vernalis EC VS San Joaquin River Volumetric Contribution at Antioch (Boundary 1 operational scenario)

Dr. Paulsen also provides simulation results that show that during all water year types the fraction of water from Martinez (the Bay) at Antioch's intake will increase significantly through summer and fall and into winter. [See Exhibit Antioch-202 errata, pp.

33 and 36.] The specific timing varies by water year type; e.g., during critical and dry years the percentage begins to increase in April and remains high (20% to 30%) through January, and during normal and wet water years salinity begins to increase during June and decreases during December, as shown on Figure 8 of her report. [See Exhibit Antioch-202 errata, p. 36.] Because water from Martinez is frequently much more saline that water from other sources, even a small increase in the fraction of water from Martinez can cause significant increases in the salinity of water at the City's intake. She gives an example of October in dry years, the fraction of Sacramento River water is simulated to decrease from approximately 85% to 62% when scenario B1 is implemented, while the fraction of Martinez inflow is simulated to increase from approximately 10% to 30%. [Exhibit Antioch-202, p. 33.]

Dr. Paulsen states that the CWF in general increases the volumetric contribution from seawater (Martinez) [see Exhibit Antioch-202, p. 36, Figure 8], and as a result increases the salinity at Antioch's intake. However, in doing so, Dr. Paulsen only shows the model results for the Boundary 1 operational scenario compared to NAA and EBC1. As explained earlier in my testimony, the Boundary 1 scenario does not include the USFWS BiOp Fall X2 criteria, while the NAA and EBC1 scenarios do include the Fall X2 criteria. To meet the Fall X2 requirement, in general, Delta outflow must be increased substantially in September-October of wet and above normal years which would in turn reduce salinity throughout the western Delta including at Antioch. I prepared Figure 9 below which shows the monthly averaged Martinez volumetric contribution at the City of Antioch for the years 1978-1981. Figure 9 shows higher Martinez volumetric contributions under the Boundary 1 operational scenario relative to the NAA for the years 1978 and 1980, both above normal years. This is in large part due to the Fall X2 action not being implemented in the Boundary 1 scenario. The Martinez volumetric contribution for Boundary 1 looks fairly similar to the NAA for the years 1979 (below normal) and 1981 (Dry year), clearly illustrating that the increase in salinity at Antioch corresponding to the Boundary 1 operational scenario can be primarily attributed to implementation of the Fall X2 action mostly in the months of

September through November of wet and above normal years.

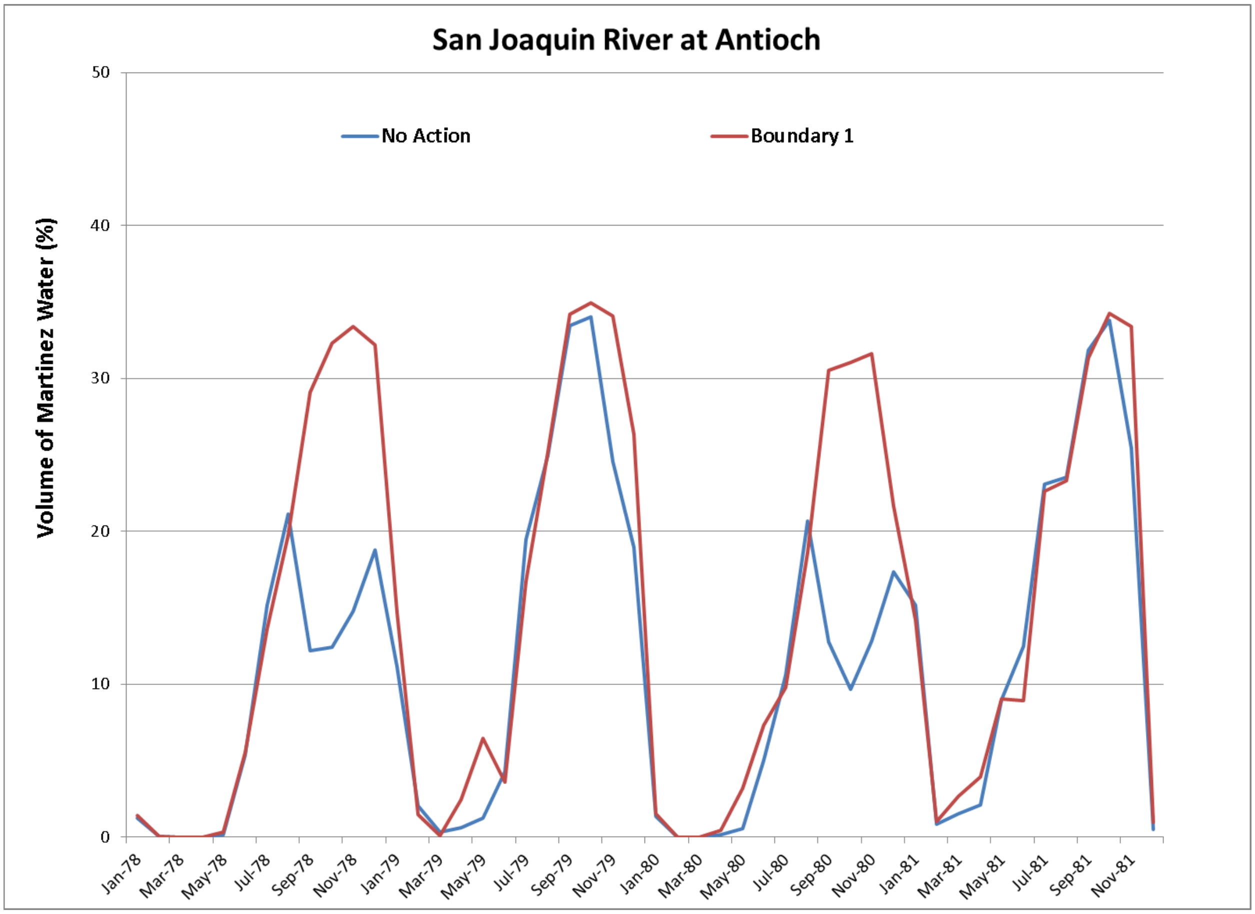

Figure 9. Martinez volumetric contribution at Antioch (1978-1981)

I also prepared Figure 10 below, which shows the monthly averaged Martinez volumetric contribution at Antioch for the same years (1978-1981) for Boundary 1, H3, and the NAA operational scenarios. Since H3 also includes the Fall X2 action, one can clearly see a much lower Martinez volumetric contribution during 1978 and 1980 relative to the Boundary 1. In fact, with a few exceptions, one can see a similar or reduced Martinez volumetric contribution for H3 compared to the NAA.

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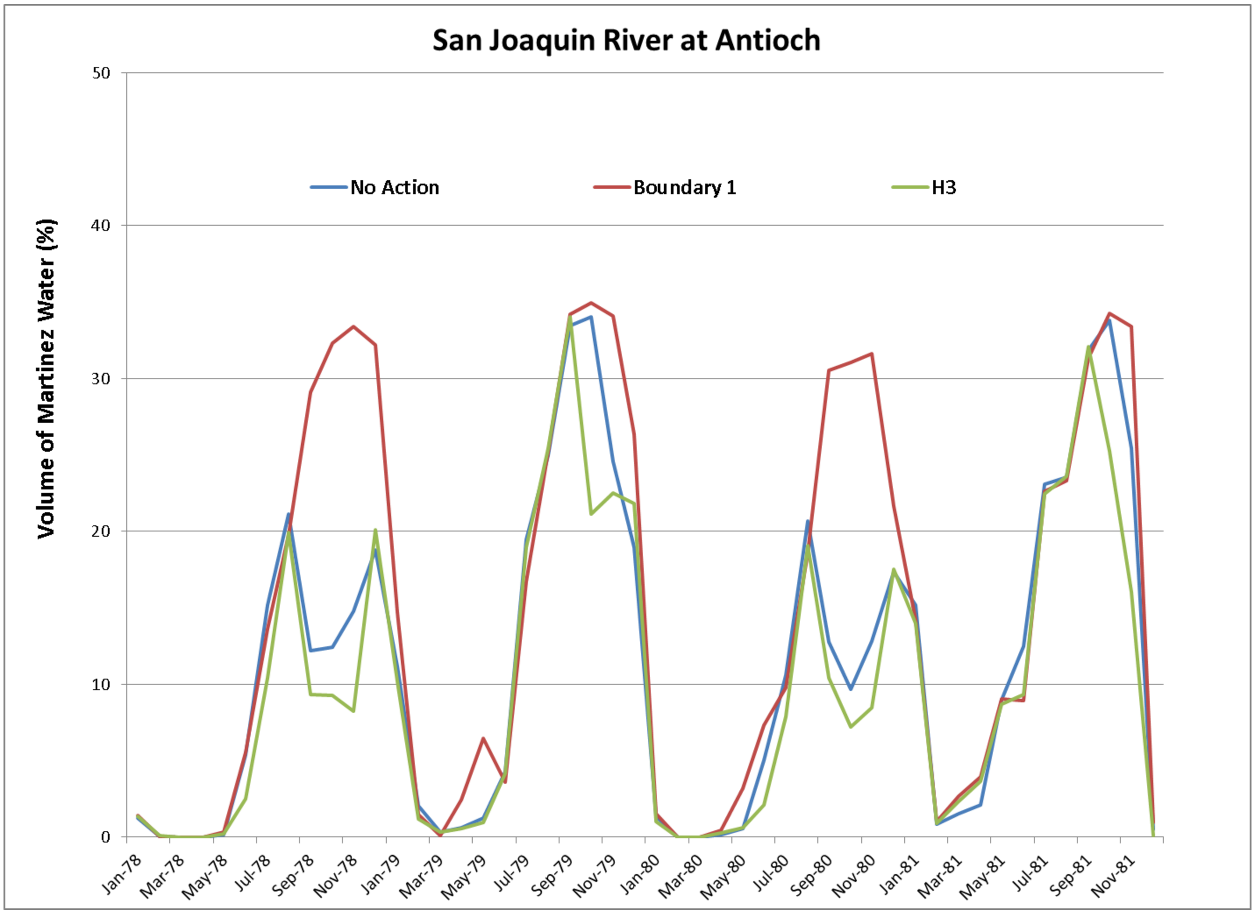

Figure 10. Martinez volumetric contribution at Antioch (1978-1981)

I reviewed the Martinez volumetric contribution for the H4 and the Boundary 2 operational scenarios, and I found similar or even lower values compared to the NAA.

B. Summary of Analysis of Water Quality at Antioch

Three primary conclusions can be drawn based on the information discussed above:

1. With the exception of Boundary 1, all CWF operational scenarios are generally expected to provide a similar or better water quality at Antioch as measured in EC, Chloride, or Bromide.
2. Boundary 1 shows a higher salinity at Antioch at times relative to the NAA mostly because it does not include the Fall X2 action.
3. At times when the EC values increased at Antioch in the Boundary 1 scenario, the main source of salinity is the ocean salt (Martinez) which is due to the absence of

the X2 flow requirement. The large increases from San Joaquin River volumetric contribution under CWF operational scenarios mainly occurs when San Joaquin River flows are higher and EC values are lower, and as a result are not expected to cause substantial increases in EC at Antioch.

VIII. PROPER USE OF CALSIM II AND DSM2 FOR CWF

A. Overview of Protestant's Inappropriate Use of Models

Many parties in the CWF hearing have relied upon CalSim II and DSM2 modeling provided by the Petitioners. Petitioners' provided large modeling results of data sets with significant spatial and temporal resolution. The modeling provides the ability to understand potential changes in physical conditions at many locations. Given the easy availability of large amounts of information, the modeling could be used to support an individual agency's arguments of possible effects of the CWF. However, given how some of the parties incorrectly applied the models in their testimony, see below for examples, and limitations associated with models and model inputs, one should use care in relying on these parties' results and conclusions.

The North Delta Water Agency submitted Table 1 in Exhibit NDWA-32_errata showing a change in Electrical Conductivity (EC) for each month of the DSM2 simulation under Alternative 4A Early Long Term (Alt 4A ELT) compared to the No Action Alternative (NAA) ELT. [Exhibit NDWA-32_errata, page 4.] Similarly in Figures 2, 4 and 6, and Tables 2 and 3[4], the EC result for one individual month under Alt 4A was compared to the EC result under the NAA for the same month (for example, EC in Oct 1976 under Alt 4A was compared to EC under NAA for Oct 1976.). Dr. Burke, in Exhibit SDWA-78-Errata p17: paragraph 3, and elsewhere, computed daily EC differences between CWF scenarios and NAA, and used those findings to draw conclusions. Dr. Burke also inappropriately compares DSM2 EC results for the NAA scenario in the CWF analysis to measured

[4] [Exhibit NDWA-32_errata, page 5, 7, 8, 9 and 10.]

historical EC values in Figure 4-7 of Exhibit SDWA-78-Errata, p. 27, and uses the comparison to draw conclusions to support his arguments. [Exhibit SDWA-78-Errata p26: ¶ 1.]. Mr. Burke also inappropriately computed the differences in 15 minute water level results under CWF scenarios and NAA as shown in Figures 4-8 through 4-11, and uses the findings to support his arguments. [Exhibit SDWA-78-Errata pp. 28 – 32.]

Dr. Burke also uses the same approach wherein he computes differences in daily simulated EC under CWF scenarios and NAA, as displayed in Exhibit SCDA-36, and used to support his arguments. [Exhibit SCDA-35 p. 4: last paragraph.]

Dr. Paulsen in her testimony for City of Brentwood and City of Antioch presented the modeling results appropriately for the most part. However, she presents daily time-series comparison of simulated EC in Figure 4 of Exhibit Antioch-202. She also presents similar information in Exhibit Brentwood-102, Figures 4 and 5.

Mr. Weaver analyzes Folsom reservoir operations in 1932-33 simulated under CWF and compares them to NAA for the same two years. (ARWA-100, p4: paragraph 14). Mr. Weaver's analysis is in contradiction with his own testimony on how not to use and interpret the CalSim II results. [Exhibit ARWA-100, p. 3, ¶ 10.]

These are examples of cases where the petitioners modeling results were presented/used inappropriately. I believe these are inappropriate use of model results because this is a comparative planning analysis and not predictive modeling, and there are several limitations associated with a planning analysis as described below.

B. Appropriate Use of CWF CalSim II and DSM2 Model Results

The modeling conducted to evaluate CWF scenarios is a planning analysis. A planning analysis is conducted to understand long-term changes in the Central Valley Project (CVP) and State Water Project (SWP) system due to a proposed change. The models developed and applied in planning analysis are generalized and simplified representations of a complex water resources system. Even so, the models used are informative and helpful in understanding the performance and potential effects (both positive and negative) of the operation of a project and its interaction with the water resources system under consideration.

Even though some of the models used in this planning analysis such as DSM2 are calibrated and validated to represent physical processes, given the nature of the boundary conditions used (derived from CalSim II, a generalized system model), DSM2 results would only tend to represent generalized long-term trends. Note that level of confidence, in the results of any well calibrated predictive model is only as good as the level of confidence in the input boundary conditions used.

Given the limitations of the planning analysis, a brief description of appropriate use of the model results to compare two scenarios or to compare against threshold values or standards is presented below. This information was also presented in the BDCP draft EIR/EIS (SWRCB-4) and the BDCP/CWF Final EIR/EIS.

1. Absolute Versus Relative Use of the Model Results

The CalSim II and DSM2 results in a planning analysis are appropriately used as "comparative tools" to assess relative changes due to the CWF scenarios compared to the NAA. In a planning analysis, models used are not predictive models and therefore the results cannot be considered as absolute with a quantifiable confidence interval. The model results are only useful in a comparative analysis and can only serve as an indicator of condition (e.g. compliance with a standard) and of trend or tendency (e.g. generalized impacts). Because CalSim II relies on generalized rules, a coarse representation of project operations, adjusted hydrologic conditions to reflect future demands and land use, and no specific operations in response to extreme events, results should not be expected to reflect what operators might do in real time operations on a specific day, month or year within the simulation period. In reality, the operators would be informed by numerous real-time considerations such as salinity monitoring.

2. Appropriate Reporting Time-Step

Due to the assumptions involved in the input data sets and model logic, care must be taken to select the most appropriate time-step for the reporting of model results. Sub-monthly (e.g. weekly or daily) reporting of model results are generally inappropriate for both models and the results should be presented on a monthly basis. There may be exceptions to this, and selected model results can be reported on a sub-monthly basis with adequate caution. An understanding of validity of the underlying operational conditions is critical in interpreting a sub-monthly result.

3. Appropriate Reporting Locations

Due to the assumptions involved in the input data sets and model logic, care must be taken to select the most appropriate reference locations (and/or boundaries) for the reporting of model results. Each model assumes a simplified spatial representation of the water resource system and sub-systems. Reporting of model results inconsistent with the spatial representation of the model is inappropriate. Care must be taken in selecting the locations desired for reporting model results and whether or not the models are adequate for that purpose.

4. Statistical Comparisons are Preferred

Absolute differences computed at a point in time between model results from an alternative and a baseline to evaluate impacts is an inappropriate use of model results (e.g. computing differences between the results from a baseline and an alternative for a particular day or month and year within the period of record of simulation). Likewise, computing absolute differences between an alternative (or a baseline) and a specific threshold value or standard is an inappropriate use of model results. Statistics based on the absolute differences at a point in time (e.g. maximum of monthly differences) are an inappropriate use of model results. By computing the absolute differences in this way, an analysis disregards the changes in antecedent conditions between individual scenarios and distorts the evaluation of impacts of a specific action (e.g. project).

Reporting seasonal patterns from long-term averages and water year type averages is appropriate. Statistics based on long-term and water year type averages are an appropriate use of model results. Computing differences between long-term or water year type averages of model results from two scenarios is appropriate. Care should be taken to use the appropriate water year type for presenting water year type average statistics of model results (e.g. D1641 Sacramento River 40-30-30 or San Joaquin River 60-20-20, and with or without climate modified conditions).

The most appropriate presentation of monthly and annual model results is in the form of probability distributions and comparisons of probability distributions (e.g. cumulative probabilities). If necessary, comparisons of model results against threshold or standard values should be limited to comparisons based on cumulative probability distributions. Information specific to a model calibration (should be considered in using these types of comparisons.

5. Suggested Formats for Presentation of Model Results

In my opinion the most appropriate format to present model results is:

- Long term average summary and year type based summary tables and graphics showing monthly and/or annual statistics derived from the model results
- Cumulative exceedance probability monthly and/or annual model results shown only by rank/order or only by probability statistic

Comparative statistics based on these two types of presentations are generally acceptable.

C. Model Specific Considerations

As stated earlier, the models developed and applied in planning analysis are generalized and simplified representations of a complex water resources system, which means they are limited in some way. The following is a description of considerations specific to each model.

1. CalSim II

CalSim II is a monthly time-step model. It represents projected conditions under current or future regulatory and operational regimes. The operational decisions in CalSim II (e.g. determining the flow needed to meet a salinity standard in the Delta) are on a monthly time-step which does not consider operational responses to changes that are on a sub-monthly timescale. Results for an individual parameter are either a monthly average or an end-of-month condition.

A few specific concerns regarding CalSim II model results include the following:

- Storage results from CalSim II reflect end-of-month conditions and not monthly-average conditions. Therefore, any attributes derived from storage results such as littoral area or water surface elevation in the reservoir reflect end-of-month values.
- CalSim II operates to a monthly approximation of compliance to selected Delta standards. CalSim II monthly average salinity and X2 location outputs are ANN-based. (note that ANN outputs are lagged by one month). Following are some more details on CalSim II D1641 compliance limitations:
    - o Even though additional standards are identified in SWRCB D-1641, CalSim II only recognizes five stations for compliance with a salinity standard:
        - Sacramento River at Emmaton
        - San Joaquin River at Jersey Point
        - Old River at Rock Slough
        - Sacramento River at Collinsville
        - Sacramento River at Chipps Island
    - o Some standards in SWRCB D-1641 require compliance for a specified number of days in a year (e.g. CCWD 150mg/L Chloride Standard). In such cases, CalSim II does not have any discretion on which days the standards are met, but rather depends on a predetermined schedule, which cannot be altered dynamically.
    - o Some of the standards modeled in CalSim II may not match exactly with the values specified in the SWRCB D-1641. Modeled standards may be more constrained ("ramped") to make operations more responsive to comply with a standard over the season.

- Under extreme operational conditions, CalSim II may fail to comply with D1641 and other standards. This situation occurs rarely and is needed to maintain feasibility of the model solution.

- San Luis Storage operations in CalSim II are simplified compared to real time operations. The results are uncertain and prone to reflect how CalSim II represents CVP and SWP operations. This is due to the relatively coarse SWP/CVP allocation decisions (e.g. no updates after May) used in the model and uncertainty in the model's capability to forecast export capabilities.

2. DSM2

In a planning analysis, the flow boundary conditions that drive DSM2 are obtained from the monthly CalSim II model. The agricultural diversions, return flows and associated salinities used in DSM2 are on a monthly time step. The implementation of Delta Cross Channel gate operations in DSM2 assumes that the gates are open from the beginning of a given month, irrespective of the water quality needs in the South Delta.

A few specific concerns regarding DSM2 model results include the following:

- Even though CalSim II releases sufficient flow to meet the standards on a monthly average basis, the resulting EC from DSM2 may exceed the standard for part of a month while complying with the standard for the remainder of the month, depending on the spring/neap tide and other factors (e.g. simplification of operations). It is appropriate to present the results on a monthly basis. Frequency of compliance with a criterion should be computed based on monthly average results. Averaging on a sub-monthly (14-day or more) scale may be appropriate as long as the limitations with respect to the compliance of the baseline model are described in detail and the alternative results are presented as an incremental change from the baseline model.

- In general, it is appropriate to present DSM2 QUAL results including EC, DOC, volumetric fingerprinting and constituent fingerprinting on a monthly time step. When comparing results from two scenarios, computing differences based on these mean monthly statistics would be appropriate.

D. Extreme Operational Conditions under Regulatory Uncertainty

Continuing uncertainty in the regulatory environment makes the long-term planning of CVP and SWP operations challenging. The No Action Alternative CalSim II model used to establish the modeling of the CWF scenarios assumes the full implementation of the operational actions of the 2008 USFWS and 2009 NMFS BiOp. However, under full implementation of the BiOps, not all conditions of the BiOps can be met. This is due to competing hydrologic, operational and regulatory requirements. As a result the simulation results in what is referred to as “extreme operational conditions”. Frequency of such conditions can increase in the future with climate change, if the hydrology is drier or occurrence of sea level rise, without changes in the existing obligations of CVP-SWP.

Extreme operational conditions are defined as simulated occurrences of storage conditions at CVP and SWP reservoirs in which storage is at “dead pool” levels. Reservoir storage at or below the elevation of the lowest outlet is considered to be at dead pool level.

Under extreme operational conditions, CalSim II will utilize a series of rules within the specified priority to reach a numerically feasible solution to allow for the continuation of the simulation. The outcome of these types of solutions in CalSim II may vary greatly depending upon the antecedent conditions from the previous time-step result. The model may reach a numerical solution, but the results of the simulation may not reflect a reasonably expected outcome (i.e. an outcome which would require negotiation). In such cases, flows may fall short of minimum flow criteria, salinities may exceed standards, diversions may fall short of allocated volumes and operating agreements may not be met, indicating a stressed water supply condition.

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VIII. D-1641 EXCEEDANCES SHOWN BY THE MODEL ARE GENERALLY NOT REAL

A. Modeled D-1641 Salinity Exceedances

The modeling results presented in the Part 1 of the hearing indicated that the D-1641 salinity requirements could be exceeded under a few conditions under both the NAA as well as the CWF scenarios. However, the frequency of days CWF scenarios exceeded D-1641 salinity requirements are mostly similar or lower compared to the NAA.[5] As discussed by the direct testimony of Armin Munevar and Parviz Nader-Tehrani and in their responses during cross-examination, the modeled exceedances of all the scenarios presented for the hearing, including the NAA, are a result of: (1) limitations of the modeling process used in analyzing the CWF scenarios, or (2) a stressed CVP-SWP system under extreme operational conditions. [Exhibits DWR-66 and DWR-71.]

Several parties suggested that these modeled exceedances are likely real. For example, the North Delta Water Agency through Dr. Parvathinathan during his cross-examination suggested that some of the exceedances shown in the petitioners' are likely real. [October 28, 2016, Transcript Vol 25, p. 138: 5-25.] Similarly, Dr. Paulsen, during her cross-examination suggests the exceedance of 250 mg/L M&I standards are likely real. [December 14, 2016, Transcript Vol 35, pp. 36:23-37:4.]
Additional explanations are provided below to counter the protestant's testimony.

1. Limitations of the Delta Salinity Modeling Approach

Delta salinity changes were analyzed based on the modeling results from CalSim II and DSM2 simulations of the CWF scenarios and the NAA. DSM2 salinity results indicated exceedances of a few salinity requirements. This section provides background on the models and examines three types of modeling limitations that could have resulted in exceedances.

CalSim II is a water operations model that simulates Delta flows for regulatory and operational criteria assumed under the NAA and the CWF scenarios on a monthly time

[5] Exhibit DWR-513, Figures C1 through C6.

step. The model simulates compliance with salinity standards in the Delta. CalSim II relies on an Artificial Neural Network (ANN) for monthly averaged flow verses salinity relationships in the Delta. ANN emulates flow-salinity relationships derived from DSM2 for a given Delta channel configuration and sea level rise condition.

DSM2 application for analyzing CWF scenarios uses the monthly CalSim II Delta inflows and diversions/exports results, and simulates Delta hydrodynamics and salinity from the water year 1976 to water year 1991, on a 15-minute time step. Flow inputs assumed in DSM2 modeling of CWF scenarios are based on monthly CalSim II outputs downscaled to a daily time step using WY 1976 – 1991 (16 years) historical flow patterns as shown below in my Figure 11 “Sacramento River Inflows to the Delta”. The daily patterns assumed are based on observed historical Delta flows, and do not represent any sub-monthly operational adjustments that could occur to address any potential issues with salinity control in the Delta under the CWF scenarios. Both the ANN and DSM2 accounts for the effects of the projected sea level rise of 15 cm at about year 2030.

Daily averaged salinity outputs from DSM2 simulations were used to evaluate compliance with D-1641 salinity requirements. DSM2 salinity results indicated exceedances of a few salinity requirements. The modeling limitations that could have resulted in exceedances are listed below:

a. CalSim II is a monthly model – some salinity standards are partial month
b. DSM2 daily flow boundary conditions
c. CalSim II flow-salinity ANN

a. CalSim II is a Monthly Model – Some Salinity Standards Are Partial Month

Armin Munevar in his direct testimony noted:

> *While there are certain components in the model that are downscaled to a daily time step (simulated or approximated hydrology), the results of those daily conditions are always averaged to a monthly time step. As an example, a certain number of days with and without the action is calculated and the monthly result is calculated using a*

day-weighted average based on the total number of days in that month. However, ultimately model operational decisions based on those components are made on a monthly basis. Therefore, the use of sub-monthly results of CalSim II should be used with caution.

[Exhibit DWR-71, p. 12:19-26.]

Since CalSim II is a model with a monthly time-step and a number of daily D-1641 salinity standards are active during only portions of a month (ex: April 1 – June 20 and June 20 to August 15), D-1641 standards are calculated as a monthly weighted average in the model. The model attempts to meet these objectives on a monthly average basis, even though the objectives themselves are often transitioning within a month from one value to the other, and may start or end in the middle of a month. When the monthly weighted average standards calculated for CalSim II are less stringent than the daily D-1641 EC standards, CalSim II adjusts SWP and CVP operations to release less flow to meet monthly weighted average EC standards instead of the flow needed to meet higher daily D-1641 EC standards. My Figure 12 "Sacramento River at Emmaton" below shows the difference between daily D-1641 EC standards and the monthly weighted average EC standards modeled in CalSim II. Therefore, within the months where the salinity standard is transitioning, there may be days where DSM2 inflows are less than the required flow to comply with the salinity standard, and more flow on other days. This results in a few days within such months where the modeled salinity exceeds the compliance standard. Importantly however, in reality the CVP and SWP operations will be adjusted on day-to-day basis to meet the Delta standards.

b. DSM2 Daily Flow Boundary Conditions

Flow inputs assumed in DSM2 modeling of CWF scenarios are based on monthly CalSim II outputs downscaled to a daily time step using WY 1976 – 1991 (16 years) historical flow patterns as shown below in Figure 11. In an effort to better represent the sub-monthly flow variability, particularly in early winter, a monthly-to-daily flow patterning technique is applied to inflows in DSM2. The technique applies historical daily patterns, based on the hydrology of the year, to transform the monthly volumes into daily flows. In all cases, the monthly volumes are preserved between the daily and monthly flows. It is important to note that this daily patterning approach does not in any way represent the flows resulting from operational responses on a daily time step. The historical daily patterns were only applied to Delta inflows, while the daily exports were mostly set equal to the monthly CalSim II results without any daily patterning. This mismatch in the daily patterning of the inflows and exports, in some cases resulted in unintended salinity intrusion into the Delta. In such situations, there may be days where the DSM2 results indicate exceedance of a water quality standard. Detailed description of the daily mapping of the DSM2 boundary conditions is included in the Appendix 5A of the BDCP/CWF Draft EIR/EIS. [SWRCB-4, Appendix 5A, Section D.9.]

c. CalSim II Flow-Salinity ANN

In CalSim II, the reservoirs and facilities of the SWP and CVP are operated to assure the flow and water quality requirements for these systems are met. Meeting regulatory requirements, including Delta water quality objectives, is the highest operational priority in CalSim II. CalSim II uses the ANN to configure system operations to meet salinity objectives. Because meeting the objectives is the highest priority in CalSim II, the model attempts to meet the applicable water quality objectives on a monthly average basis according to the ANN, unless there is no feasible way to meet the objective (i.e., upstream reservoirs at dead pool conditions). In some cases, even though the ANN predicts that the objective would be met on a monthly average basis, it can be an imperfect predictor of compliance on the time-step (e.g daily standard) and averaging basis (e.g. 14-day running average) that these objectives need to be met. Thus when using the CalSim II results in such cases, the DSM2 results may indicate an exceedance of a salinity standard, when CalSim II does not.

2. Stressed CVP-SWP System Under Extreme Operational Conditions

Existing obligations on the CVP-SWP system (water demands, biological opinions and other regulatory requirements) in combination with climate change and sea level rise could result in extreme operational conditions. Under such extreme operational conditions, flows may fall short of minimum flow criteria, salinities may exceed standards, diversions may fall short of allocated volumes and operating agreements may not be met. In some months, unavailability of the flow to meet the salinity standards in the Delta when upstream storage is at deadpool conditions was a factor for the modeled exceedances of the standards. In such cases any salinity standard exceedances are reflections of the system operations for a given scenario simulated in the CalSim II model. For the CWF scenarios, it has been demonstrated that the upstream storage conditions simulated are similar to the No Action Alternative.

C. Summary of Modeling Exceedances

In summary, both the NAA and the CWF scenarios indicate a few modeled exceedances of the D1641 salinity standards. The frequency of exceedances under the CWF scenarios is similar or less than the NAA in most cases. The exceedances are mostly a result of limitations in the modeling process with a few resulting due to the extreme operational conditions. In reality, staff from DWR and Reclamation constantly monitor Delta water quality conditions and adjust operations of the SWP and CVP in real time as necessary to meet water quality objectives. These decisions take into account real-time conditions and are able to account for many factors that the best available models cannot simulate. At times, under extreme conditions, negotiations with the State Water Resources Control Board occur in order to effectively maximize and balance protection of beneficial uses and water rights, which cannot be modeled.

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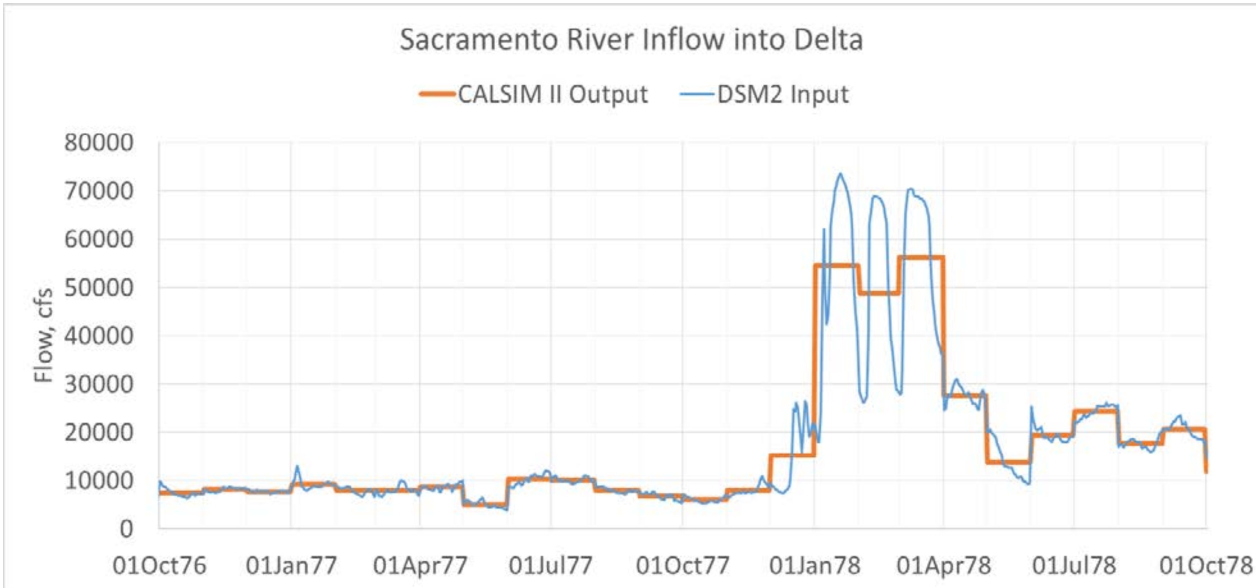

Figure 11. Example Plot Comparing Monthly Sacramento River Inflow to the Delta Resulting from CalSim II Model, and assumed Daily Patterned Sacramento River Inflow in the DSM2 Model in the BDCP/CWF DEIRS (SWRCB-3, Appendix A – Revisions to the Draft EIR/EIS Appendix 8H – Electrical Conductivity – Attachment 1).

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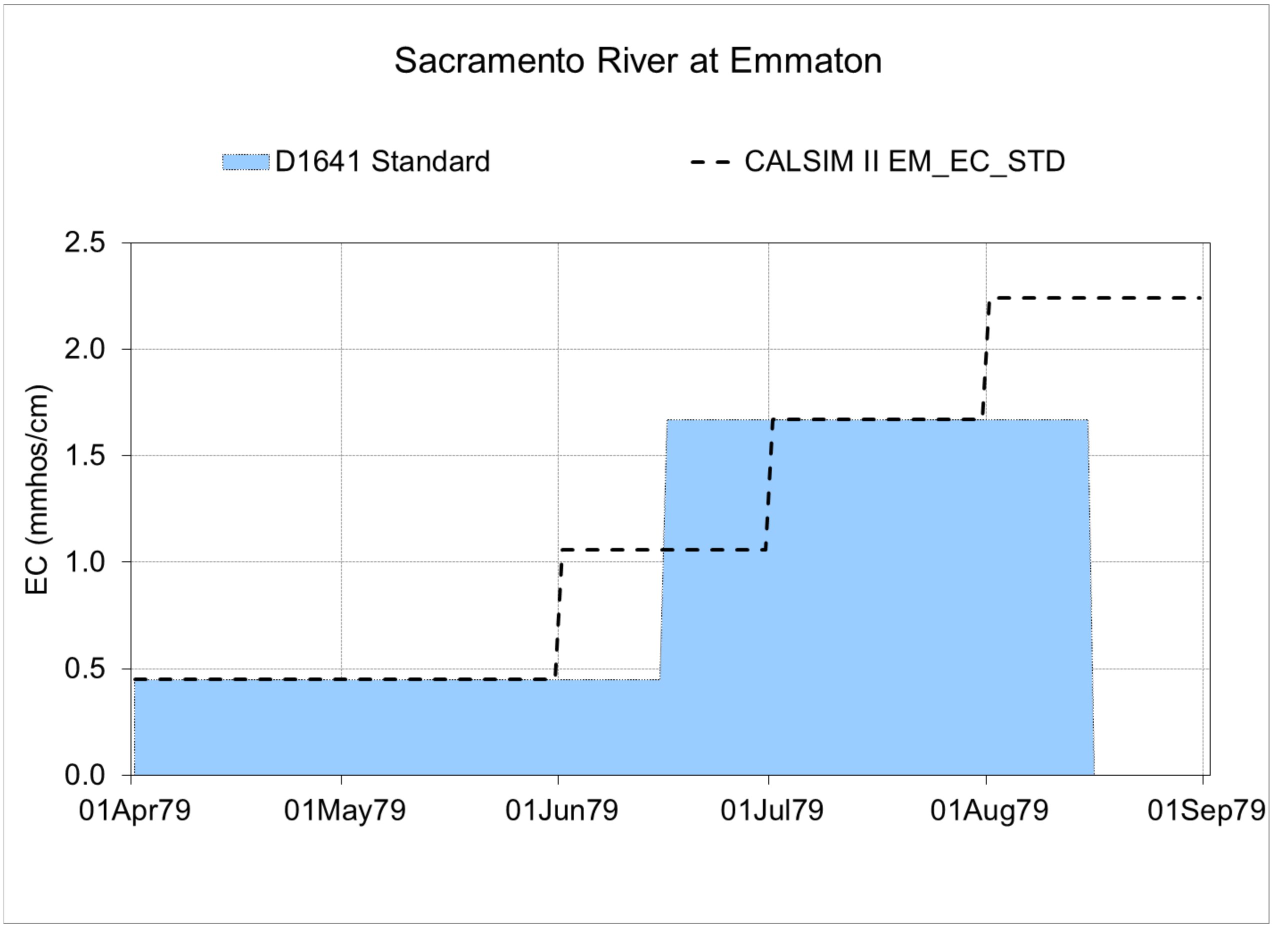

Figure 12. D-1641 Salinity Control Requirement at Emmaton as Simulated in CalSim II

IX. <u>CALIBRATION AND VALIDATION OF DSM2</u>

A. Parties Incorrectly Contend DSM2 Is Not Calibrated.

Protestant Deirdre Des Jardins inferred that DSM2 was not calibrated and validated for use in the CWF hearings. [December 13, 2016 Transcript, Vol. 34, p. 151:18 - 25.] She also contended that the calibration information was not provided for this proceeding, and she incorrectly stated that Mr. Munevar said that a numerical calibration was not yet done. [December 13, 2016 Transcript, Vol. 34, p. 147:3 – 148:8; p. 148:9 – 19; p. 151:7 – 25.] Mr. Burke in Exhibit SDWA-78-Errata (p.10: ¶ 3) and Mr. Ringelberg made similar statements during cross examination. [November 4, 2016 Vol 27, p. 194:16 – p. 195:15.]

Ms. Des Jardins and others were incorrect in all of their contentions regarding DSM2 calibration and validation, as well as regarding the availability of detailed information describing the calibration findings. DSM2 has in fact been numerically calibrated several times since its initial development. All the calibration efforts have been well-documented and readily available for anyone interested by going to DWR's website: (http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm). More importantly, the relevant calibration effort to support the use of the DSM2 model for CWF analyses was described in detail in the 2013 BDCP DEIR/EIS [Exhibit SWRCB-4, Appendix 5A, Section D], as well as in the 2016 CWF Biological Assessment [SWRCB-104, Appendix 5.B].

B. DSM2 Calibration For BDCP/CWF

DSM2 is an important tool to model and study Delta hydrodynamics. Given DSM2's importance of the tool, significant effort has been made to ensure suitability of the DSM2 for use in the BDCP/CWF analyses. For example, in 2009 DSM2 hydrodynamics and salinity results were calibrated based on the observed conditions in the Delta. As noted in my direct testimony, this effort has been described in extensive detail in a report available for public access on DWR's DSM2 Users Group website since 2009. For more information see the DSM2 calibration and validation report was also attached to the 2013 BDCP DEIR/EIS (SWRCB-4, Appendix 5A Section D Attachment 1).

Ms. Des Jardins repeatedly cites the recommendations from the 2012 Scientific Panel on Analytical Tools for Evaluating Water Supply, Hydrodynamic and Hydropower Effects in the Bay Delta Plan for the best calibration for Delta hydrodynamics models. [See DDJ-108-Errata, pp. 6:12-7:3, pp. 15:18-16:11.] Even though the 2009 calibration effort was prior to these recommendations, all the key aspects included in the panel recommendation were considered in 2009 calibration effort, as shown in the documentation of this effort.

In my opinion, DSM2 is the best available tool to study potential impacts from WaterFix.

XI. CONCLUSION

In conclusion, based on the information and analysis provided above, in my opinion, CWF will not have water quality or water level effects as presented by many of the parties for the reasons summarized below:

- The Boundary 2 operational scenario includes a more aggressive Head of Old River Gate operation, requiring a complete closure during the months of March through May. My testimony offered an explanation that the increases in EC in South Delta under Boundary 2 are mostly due to a difference in the operation of Head of Old River Gate and are not directly related the proposed North Delta diversions.
- The Fall X2 implementation has a major effect on water quality and water levels at specific locations in the Delta. Most of the negative effects on water quality and water levels corresponding to Boundary 1 are directly related to the lack of inclusion of Fall X2 in the assumed operations. Furthermore, I believe these impacts are not real since Fall X2 requirement has never been fully implemented.
- WaterFix will not cause an increased frequency of SRFEs affecting EBMUD operations at their Freeport facility. I believe Dr. Bray's analysis is fundamentally flawed. Dr. Bray's CalSim II analysis ties Sacramento River flows less than 8000 cfs to equate to occurrence of a SRFE. EBMUD's own testimony shows that there were 4 SRFE from April 2014 through December 2015. Due to extreme drought, there were 371 days where flow at Freeport was less than 8000 cfs based on CDEC data, I also believe that Dr. Bray's analysis based on the DSM2 analysis is also flawed because his methodology to correct the DSM2 velocity bias significantly overstates the expected increase in occurrence of SRFE.
- Through the use of DSM2 model results for 1976-77 period, I showed that the reduction in water levels are expected to be much smaller during low flow periods, since the bypass flow rules would limit the use of the proposed North Delta diversions to a minimum health and safety requirements. During extreme low flows, I

expect a maximum reduction in water level of less than 2 inches downstream of the proposed intakes, with even smaller reductions at places that are farther away.

- In general the water quality will continue to remain fresh at most places in the North Delta under WaterFix operations (at places upstream of Rio Vista), including areas around Ryer Island. The NDWA expert testimony showed only a very small increase in the expected number of days where the EC values would exceed the thresholds set forth in the NDWA Contract at Three Mile Slough and Rio Vista.
- With the exception of Boundary 1, the water quality at Antioch would be similar or better under WaterFix. The EC increase at Antioch under Boundary 1 can be mostly attributed to lack of inclusion of Fall X2.

In addition, in regard to the proper use of models, it is my belief that several parties used the modeling results in an inappropriate manner. Specifically, I believe the presentation of DSM2 model results (when used in conjunction with CalSim II) based on 15 min, daily, or even single monthly comparisons are not appropriate, may distort results, and therefore should not be relied upon. Any presentation of the results should mainly be based on either long term averages (or possibly long term water year type comparison), or in the form of a cumulative exceedance probability.

I would like to reiterate that the modeled exceedances in D-1641 agricultural, municipal, and industrial water quality objectives are not real, and occur mainly due to a difference in the assumptions in DSM2 and CalSim II, including a difference in the size of the time-step in the two models.

Finally, it is my opinion that DSM2 has been properly calibrated and validated, and I believe it represents the best available tool to evaluate the changes in water quality and water levels in the Delta that may occur under WaterFix.

Executed on this 23 day of March, 2017 in Sacramento, California.

(Parviz Nader-Tehrani)