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CALIFORNIA DEPARTMENT OF WATER RESOURCES

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 CHANDRA SEKHAR (CHANDRA) CHILMAKURI

I, Chandra Chilmakuri, do hereby declare:

I. OVERVIEW

I am currently employed by the Metropolitan Water District of Southern California as a Principal Engineer working on modeling of the Sacramento San Joaquin Bay Delta (“Bay Delta”) and SWP-CVP operations. In my previous position at CH2M, I preformed similar tasks and worked as a sub consultant to ICF on California WaterFix (“CWF”). My specific expertise includes estuarine hydrodynamics and water quality modeling, specifically related to the Bay-Delta, including using CalSim II and DSM2 models. I have over 12 years of experience in development and application of an integrated suite of reservoir operations, hydrodynamics, water quality, temperature, aquatics, and power models for several projects in the California Central Valley. A summary of my expertise is previously included in Exhibit DWR-31 and a true and correct copy of my statement of qualifications is submitted as Exhibit DWR-1202.

This rebuttal testimony provides a response to issues raised by Protestants relating to the CWF modeling assumptions and results. I reviewed the written and oral testimonies of witnesses who either discussed modeling presented by petitioners or performed their own analyses related to CWF and rebut portions of these testimonies.

To summarize, my opinions are:

1. Delta Cross Channel (DCC) gate operations with CWF are expected to remain consistent with current operations, and therefore, proposed permit condition in EBMUD-155 is not necessary.
2. Exports at the south Delta SWP and CVP pumping facilities under CWF H3+ are not expected to be greater than the No Action Alternative.
3. CWF is not expected to impact CVP north-of-Delta carryover storage conditions, and therefore proposed permit conditions in ARWA-502, CSPA-202-errata, PCFFA-87 for carryover storage requirements are not necessary.
4. CWF is not expected to impact Lake Oroville carryover storage conditions, and therefore proposed permit condition for Oroville carryover storage in CSPA-202-errata is not necessary.
5. Applicable salinity requirements for City of Antioch's M&I use will continue to be met.
6. CWF is not expected to impact Sacramento Regional County Sanitation District (SRCSD) and the Sacramento Regional Wastewater Treatment Plant (SRWTP) operations.
7. Salt budget analysis presented in SDWA-291 is incomplete, imprecise and unreliable, and any opinions about CWF effects on south Delta salinity based on this analysis are incorrect.

II. Opinion 1: Delta Cross Channel (DCC) gate operations with CWF are expected to remain consistent with the current operations, and therefore, proposed permit condition in EBMUD-155 is not necessary.

EBMUD witness Mr. Setka opined that CWF would result in more frequent and longer opening of DCC gates relative to the No Action Alternative in the fall months, and therefore, the Board should add a condition to the CWF permit which requires mandatory closing of the DCC gates for 15 days in October and November. (EBMUD-155 p. 17.)

In my opinion the existing regulations adequately address the DCC gate closure needs, and DCC operations under CWF are expected to be consistent with NAA. Therefore, the proposed CWF permit condition is not warranted. In my opinion, DCC gate operations under CWF are expected to be consistent with the No Action Alternative based on two factors:

1) CWF H3+ does not include any changes to the DCC gate operations criteria compared to the NAA. (DWR-1143.) All the criteria and the real time decision making processes that govern DCC operations under the NAA, included in D1641 and 2009 NMFS BiOp, are proposed to continue with CWF; and

2) The NMFS BiOp for CWF states that the DCC closure during high Sacramento River flows (>25,000 cfs) should be triggered based on the flows measured at Freeport gage, which is upstream of the proposed intakes. (SWRCB-106 p. 1036.)

Mr. Setka based his opinions on the DCC modeling results included in the CWF BA for October and November. (SWRCB-104.) As shown in Table 1, DCC operations in fall months would vary depending on the real time conditions. Table 2 shows the months where the DCC gates are open for greater number of days as modeled under CWF H3+ compared to the No Action Alternative. The numbers included in the second column indicate the total number of years CWF H3+ modeling has longer modeled DCC openings than NAA for each month. For example, for October CWF H3+ has greater number of days with DCC opened in 31 years than NAA. As shown in Table 2, modeling indicates that DCC was open longer under CWF H3+ than NAA only in September through December and June months. Even though the modeling results indicate longer opening of the DCC gates under the CWF H3+ compared to the NAA, the gate operations under future real time operations are not expected to be different with or without CWF for the reasons I describe below.

Table 1. Delta Cross Channel operations criteria and CalSim II assumptions (Legend: cells filled with pattern indicate operations vary in real-time from year to year, cells with tan fill indicate fixed operations from year to year)

<table>
<tr><th rowspan="2">Month</th><th colspan="2">D1641</th><th colspan="2">2009 NMFS BiOp</th><th rowspan="2">High Sac River Flow</th></tr>
<tr><th>Requirement</th><th>CALSIM II Input</th><th>Requirement</th><th>CALSIM II Input</th></tr>
<tr><td>OCT</td><td>Open</td><td>Open</td><td rowspan="4">Based on fish catch and temperature at Knights Landing, Mill Creek, Deer Creek and Wilkins Slough flows, and Delta water quality compliance</td><td rowspan="2">Varies based on Wilkins Sl flow, and Rock Sl salinity</td><td rowspan="12">Closed when SacR flow above DCC > 25000 cfs Applied in all months in CalSim II</td></tr>
<tr><td>NOV</td><td rowspan="3">Closed for 45 days out of 92 days – coordinated with potential closures for experiments/ studies</td><td>Open for 20 days</td></tr>
<tr><td>DEC</td><td>Open for 16 days</td><td rowspan="2">Closed from Dec 15 – Jan 31</td></tr>
<tr><td>JAN</td><td>Open for 11 days</td></tr>
<tr><td>FEB</td><td>Closed</td><td>Closed</td><td>Same as D1641</td><td>Closed</td></tr>
<tr><td>MAR</td><td>Closed</td><td>Closed</td><td>Same as D1641</td><td>Closed</td></tr>
<tr><td>APR</td><td>Closed</td><td>Closed</td><td>Same as D1641</td><td>Closed</td></tr>
<tr><td>MAY 1st – MAY 20th</td><td>Closed</td><td>Closed</td><td>Same as D1641</td><td>Closed</td></tr>
<tr><td>MAY 21st – JUN 30th</td><td>Closed for 14 days during May 21st - June 15th</td><td>Open for 26 days in June, rest closed</td><td>Same as D1641</td><td>Open for 26 days in June, rest closed</td></tr>
<tr><td>JUL</td><td>Open</td><td>Open</td><td>Same as D1641</td><td>Open</td></tr>
<tr><td>AUG</td><td>Open</td><td>Open</td><td>Same as D1641</td><td>Open</td></tr>
<tr><td>SEP</td><td>Open</td><td>Open</td><td>Same as D1641</td><td>Open</td></tr>
</table>

There are two reasons for the differences between the modeling and water is expected in real time:

1) CalSim II representation of 2009 NMFS BiOp Action IV.1.2 real-time DCC gate operations triggers is simplified: Table 1 compares the DCC operations criteria and the CalSim II assumptions for each month. As shown in Table 1, 2009 NMFS BiOp requires DCC to be closed during October through January months based on the Knights Landing fish catch and Delta water quality compliance. Under current real time operations, in consultation with the Water Operations Management Team as described in the 2009 BiOp, DCC closure decisions are based on Wilkins Slough flow, Mill Creek and Deer Creek flow, Knights Landing temperature and the Knights Landing catch index (KLCI). However, in the CalSim II model, the number of days DCC gates would be closed is dependent only on Wilkins Slough flow. Therefore, even a slight reduction in the Wilkins Slough flow under CWF H3+ compared to the NAA would result in longer opening of DCC gates. As shown in the third column of Table 2, differences in Wilkins Slough flows are the reason for modeled greater openings in October, November and December months under CWF H3+. Unlike the modeling, DCC closure decisions in real time operations under CWF will be based on the current real time procedures.

2) CalSim II uses Sacramento River flow downstream of the proposed intakes to trigger closure of the DCC gates under high flow conditions: Under current operations, DCC gates are closed during high Sacramento River flows, typically when it is around 20,000 cfs to 25,000 cfs. In the CalSim II model, the DCC gate closure due to high flows is triggered based on the Sacramento River flow downstream of the proposed intakes. As shown in the fourth column of Table 1, the years in which CWF H3+ has greater openings than NAA in June and September months is because of the differences in the Sacramento River flow downstream of the proposed intakes. NMFS BiOp for CWF states that DCC closures during high flows should be based on the flows at the Freeport gage, which is upstream of the proposed intakes. As shown in the Figures 1 and 2, the frequency of time Sacramento River flows at Freeport at or above 25000 cfs for CWF H3+ and NAA would be similar (about 8% in June, and about 19% and 27% in September). By relying on the flow upstream of the proposed intakes DCC closures during high flow is not expected to differ in the future with or without CWF.

Table 2. Number of Years with Longer DCC Gate Opening Modeled under CWF H3+ compared to NAA

Month	Number of years with longer DCC opening in CWF H3+ compared to NAA	Factors affecting the longer DCC opening		
		Wilkins Slough Trigger	SacR 25000cfs Trigger	Water Quality Trigger
OCT	31	31	0	0
NOV	31	31	0	0
DEC	11	11	0	0
JUN	5	N/A	5	N/A
SEP	22	N/A	22	N/A

Therefore, in my opinion, DCC gate operations under CWF are expected to be consistent with current operations in the real-time. In my opinion the existing regulations adequately address the DCC gate closure needs, and there is no need for the proposed CWF permit condition under EBMUD-155.

III. <u>Opinion 2: Exports at the south Delta SWP and CVP pumping facilities under CWF H3+ are not expected to be greater than the No Action Alternative.</u>

EBMUD witnesses Ms. Workman and Dr. Bray testified that south Delta exports in April and May would increase under CWF compared to the No Action Alternative (EBMUD-156 and EBMUD-157). The two EBMUD witnesses relied upon comparison of B1, H3, H4 and B2 modeling results to the NAA. As indicated by the petitioners, CWF H3+ represents the adopted operational scenario . CWF H3+ modeling indicates that south Delta exports would not increase in April and May relative to the No Action Alternative as shown in the Figures 3 and 4, in contrast to the EBMUD witnesses' opinions.

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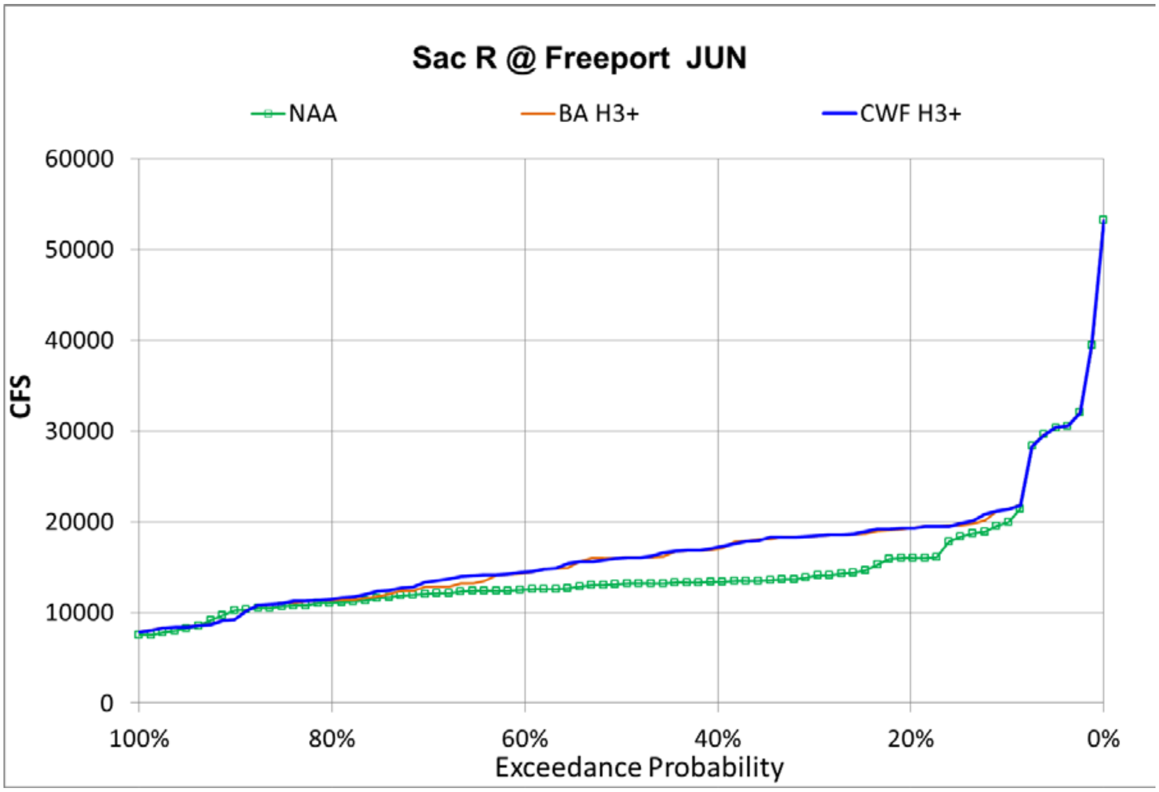

Figure 1. Probability of exceedance of Sacramento River flow at Freeport for June modeled under NAA, BA H3+ and CWF H3+ scenarios

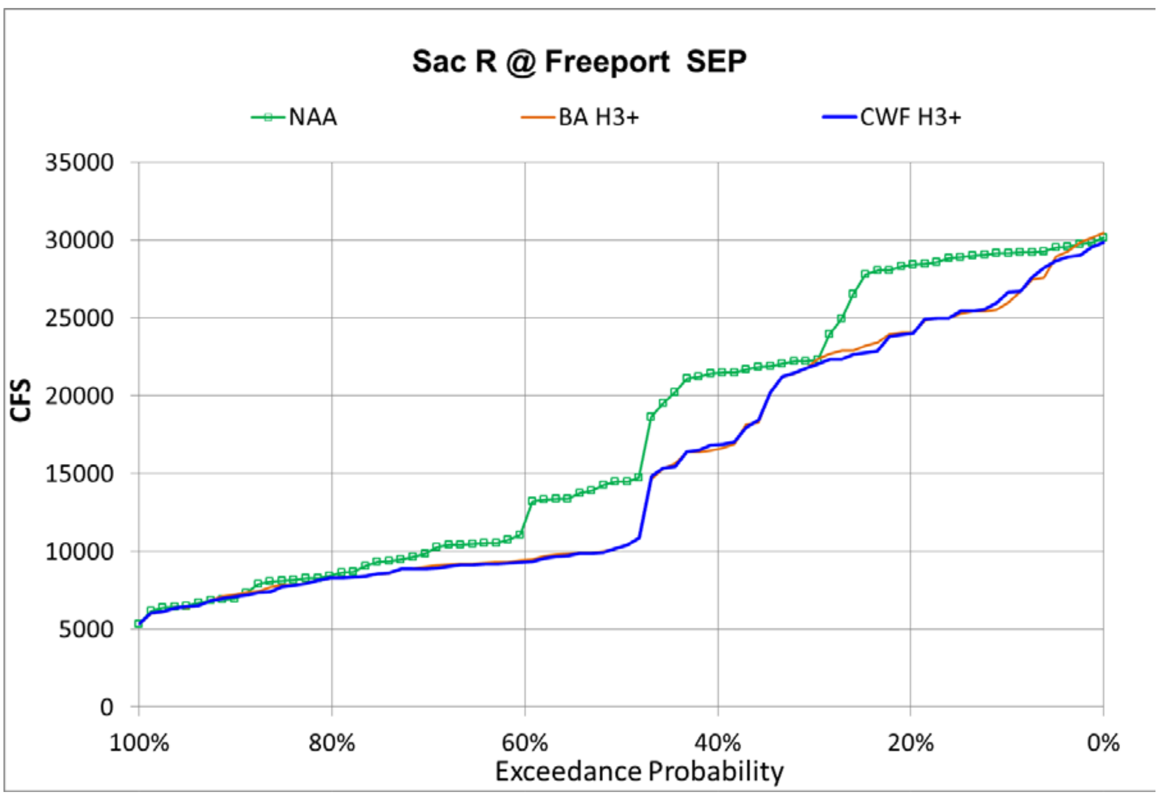

Figure 2. Probability of exceedance of Sacramento River flow at Freeport for September modeled under NAA, BA H3+ and CWF H3+ scenarios

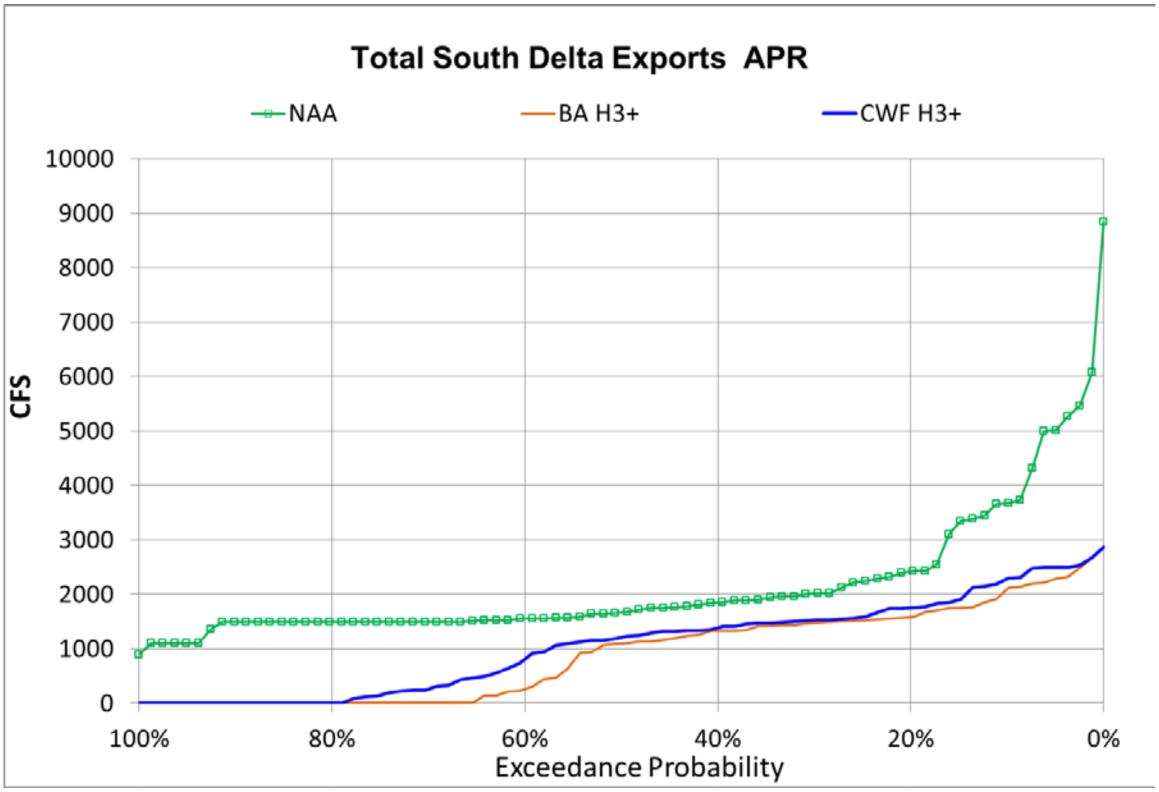

Figure 3. Probability of exceedance of south Delta SWP and CVP exports for April modeled under NAA, BA H3+ and CWF H3+ scenarios

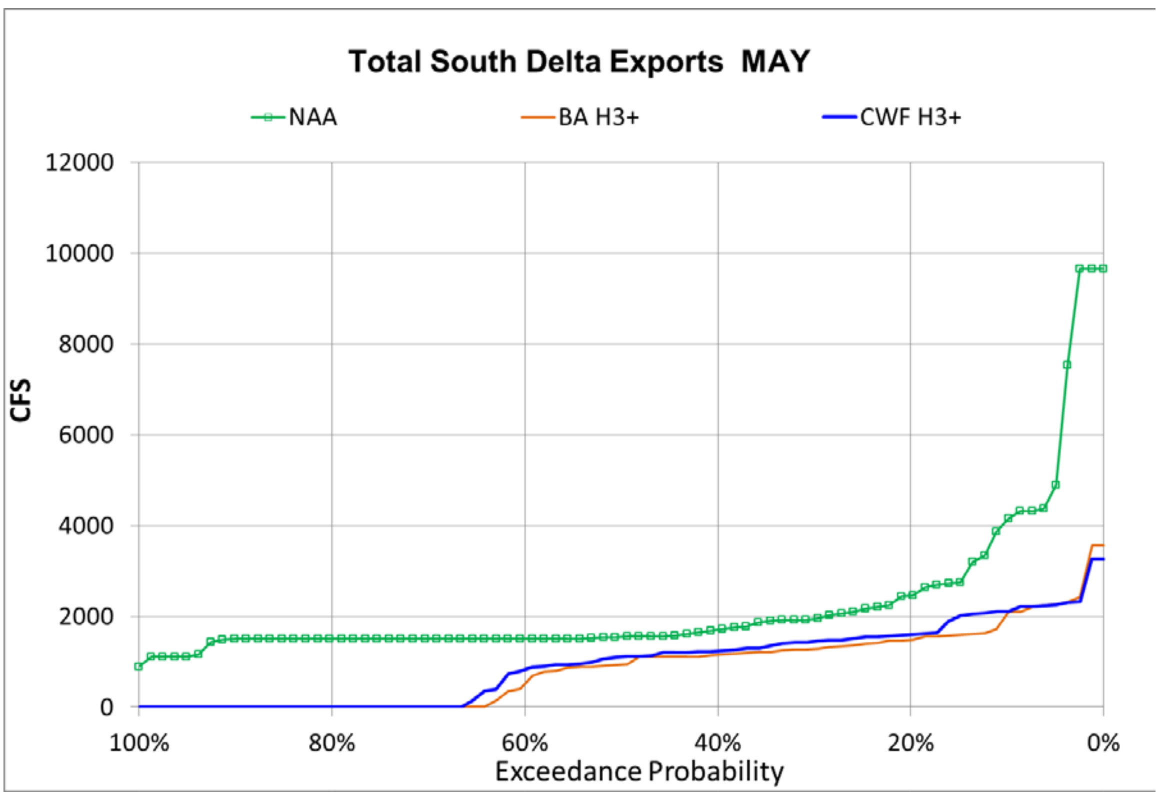

Figure 4. Probability of exceedance of south Delta SWP and CVP exports for May modeled under NAA, BA H3+ and CWF H3+ scenarios

IV. Opinion 3: CWF is not expected to impact CVP north-of-Delta carryover storage conditions, and therefore, proposed permit conditions in ARWA-502, CSPA-202-errata, and PCFFA-87 for carryover storage requirements are not necessary.

ARWA witnesses, Mr. Gohring and Mr. Bratovich testified that CWF would exacerbate Folsom end-of-month storage conditions in June and July relative to the No Action Alternative, and thereby propose a need for their "Modified Flow Management Standard". Specifically, they point to the potential for lower end-of-month storage in June and July under CWF (BA H3+) relative to the No Action Alternative, as well as potential increased frequency of dead pool conditions with CWF. (ARWA-500 p. 2 opinion 6.)

CSPA witness Mr. Shutes proposes that the Board should include carryover storage requirements for north-of-Delta CVP reservoirs (Trinity Lake, Shasta Lake, and Folsom Lake) as part of the CWF permit. (CSPA-202-errata, pp. 13-16.)

PCFFA witness Thomas Stokely proposes that the Board require a carryover storage level for Trinity Lake as part of the CWF permit. (PCFFA-87, pp. 13-14.)

Contrary to ARWA's claims, as shown in Table 3, the number of months and years when the modeled Folsom end-of-month storage is near dead pool conditions[1] under CWF H3+, is similar to the NAA.

Table 3. Number of Months and Years with Folsom Lake Storage less than 100 TAF under CWF H3+ and NAA, modeled under projected Q5 climate change sea level rise conditions at 2030

Month	NAA	CWF H3+
Number of months out of 984 months with modeled Folsom Lake storage is less than 100 TAF	19	18
Number of years out of 82 water years with at least one month modeled Folsom Lake storage is less than 100 TAF	5	5

As shown in the Table 4, CalSim II modeling results for Folsom storage under CWF H3+ would remain similar to the NAA. (DWR-1312, Table 4 and Figure 1.) The largest reduction in

[1] Modeled dead pool conditions are only indicators of stressed water supply conditions, as the modeling does not reflect actions that may be taken in real time.

June and July Folsom storage is 10% under CWF H3+ compared to No Action Alternative, which is considered to be similar storage conditions[2] under both scenarios. More importantly, the greatest reductions are when storage levels in Folsom Lake are well above the dead pool conditions. These apparent differences in modeled Folsom storage conditions are a result of CalSim II's attempt to balance the Trinity, Shasta and Folsom storage conditions in any given month, which may result in a slightly different end-of-month storage conditions in a CWF scenario compared to the NAA. It is not a result of any specific action under CWF. End-of-month carryover storage results for Trinity Lake and Shasta Lake are presented in Tables 5 and 6, which show that the CWF H3+ and NAA are similar. (DWR-1312, Tables 5 and 6 and Figures 2 and 3.)

A good indicator of effects to CVP north-of-Delta storage is the change in combined Trinity, Shasta and Folsom storage conditions with CWF. As shown in the Table 7, modeled CVP north-of-Delta storage under CWF H3+ is similar compared to the NAA, with differences ranging from -2% to +7%. (DWR-1312, Table 7 and Figure 4.)

CWF is not proposing any changes to the upstream operations criteria, and as indicated by the modeling results, Folsom Lake storage conditions under CWF H3+ would be similar to the NAA. Therefore, in my opinion CWF is not expected to exacerbate low storage conditions in Folsom Lake, and the ARWA's proposed permit conditions are not necessary. Similarly, CWF is not expected to impact the carryover storage conditions in the other CVP north-of-Delta storage reservoirs as indicated by the modeling results, and therefore, carryover storage requirements beyond existing regulations, such as the ones proposed by CSPA and PCFFA are not necessary in the CWF permit. Any such requirements would potentially limit operational flexibility in the system, and worsen the conflicts between storage and instream /Delta flow needs.

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[2] Considering 10% change or lower as "similar" is the standard practice employed by the experts in the industry, including ARWA witnesses Mr. Bratowich and Mr. Weaver, when the environmental analysis is based on CalSim II results.

V. Opinion 4: CWF is not expected to impact Lake Oroville carryover storage conditions, and therefore, the proposed permit condition for Oroville carryover storage in CSPA-202-errata is not necessary.

CSPA witness Mr. Shutes testified that DWR's Oroville carryover storage policy is substantively inadequate, and CSPA requests the SWRCB to impose carryover storage targets. However, Mr. Shutes fails to demonstrate that CWF would impact Oroville carryover storage conditions. As shown in Table 8, Oroville end-of-month storage conditions under CWF H3+ are expected to remain similar to the NAA as indicated by the differences ranging from -6% to +15%. (DWR-1312, Table 8 and Figure 5.) Given that CWF is not expected to impact Oroville carryover storage conditions while complying with all the existing policies and regulatory requirements, there is no need for any additional carryover storage requirements as part of the CWF permit.

VI. Opinion 5: Applicable salinity requirements for City of Antioch's M&I use will continue to be met.

CWF H3+ operational scenario results in largely similar salinity conditions at Antioch Intake location compared to the NAA, as shown in Figure 5. More importantly, as testified by Ms. Smith, CWF H3+ and NAA modeling results indicate similar probability of exceedance of the applicable D-1641 salinity requirements for Antioch at Rock Slough Pumping Plant (DWR-1015 Figure C13 and C14).

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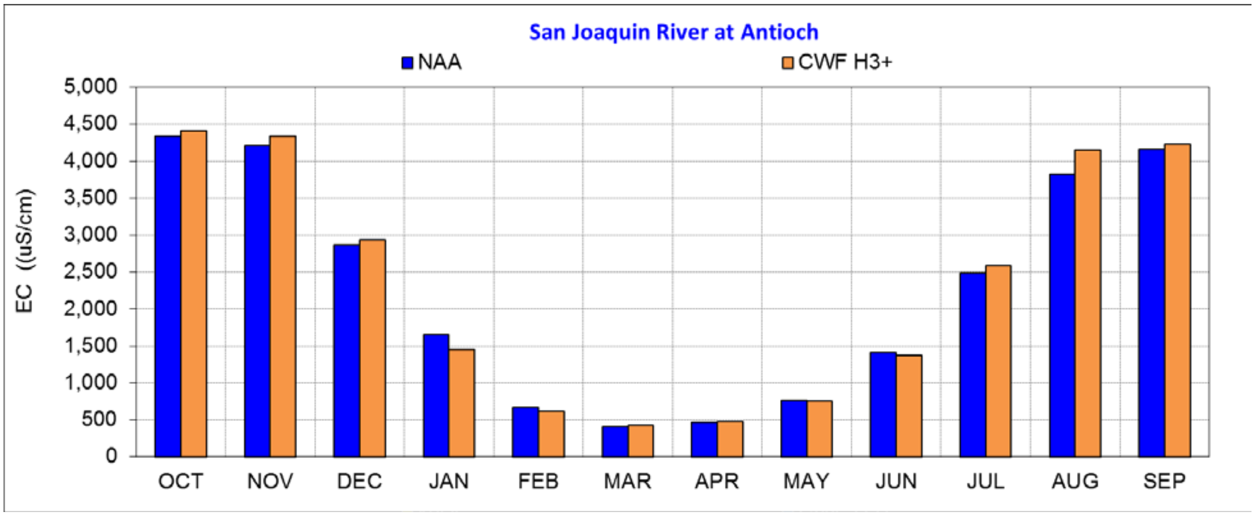

Figure 5: Modeled average monthly EC for San Joaquin River at Antioch under NAA and CWF H3+ scenarios

Dr. Paulsen presented water quality results for the City of Antioch in Tables 1, 2 and 3 of Antioch-500 errata. Excerpted copies of Tables 1 and 2 from Antioch-500 Errata pages12 and 14 are provided below. As shown in these excerpted tables, CWF scenarios H3, H4 and B2 all indicate similar or better salinity conditions relative to NAA. It is clear that, with the exception of Boundary 1 (B1) scenario, all other scenarios presented are expected to provide similar or higher number of compliance days compared to NAA, in which chloride levels are below 250 mg/l at Antioch in all water year categories from the driest 10% to the wettest 10%. Even the B1 scenario results from Dr. Paulsen's analysis indicate that 250 mg/L threshold is not met only 54 days compared to the NAA (397 days compared to 343 days under NAA) resulting in an increase of only 1% relative to NAA over the 16-year DSM2 simulation period. (Antioch-500 errata Table 3.) Furthermore, this relatively small increase in B1 scenario is a result of different assumptions in fall Delta outflow requirements relative to NAA, as acknowledged by Dr. Paulsen in her testimony. (Antioch-500 Errata p. 17 15:20.)

Dr. Paulsen's alleged impacts to City of Antioch salinity conditions are based on incorrect comparisons of CWF scenarios to the EBC2 scenario and pre-1918 historic conditions. Note that the veracity of the salinity data used by Dr. Paulsen for pre-1918 historic conditions could not be verified by the Petitioners, as detailed information on how the data was obtained and what adjustments, as she claimed, were performed, were not provided. During cross-examination Dr.

Paulsen acknowledged that the data was based on several sources listed in Antioch-216. (Transcript Volume 21 p. 127 21:25.) One specific source she mentioned was C&H Sugar's barge travel data. As cautioned by Dr. Hutton (DWR-1224), the data presented in Exhibit Antioch-216 is not appropriate to consider because it appears to be shifted forward in time by half a month, resulting in biased reporting related to timing of initial and peak seawater intrusion.

The most appropriate comparison to assess the potential CWF effects is to compare the modeling outputs for the CWF H3+ scenario to the NAA, with consistent assumptions for climate change/sea level rise, level of development, and regulations. Dr. Paulsen's analyses and her conclusions are all based on either comparison between CWF modeling outputs (B1, B2, H3 and H4), which include climate change and sea level rise, to the EBC2 scenario, which does not include either of those factors, or a comparison between CalSim II modeling outputs for CWF scenarios to historic observations. As noted above, and indicated by Dr. Paulsen's own analysis (Antioch-500 Errata), when the CWF scenarios are compared to the appropriate baseline (NAA), CWF is not expected to impact salinity conditions for City of Antioch's Delta water supply. Dr. Paulsen acknowledged this during cross-examination. (Transcript Volume 21 p. 141 4:11, p. 142: 5:12, and p. 143: 20:25.)

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Excerpted from Antioch-500 Errata:

Table 1. Number of days per year chloride is below 250 mg/L at Antioch during low-tide for different hydrologic conditions and different exceedance levels (calculated from DSM2 model results for 1976-1991).

	EBC2 (days)	NAA (days)	B1 (days)	H3 (days)	H4 (days)	B2 (days)	Historical [pre-1918] Condition[a]
Driest 10 %	61	64	59	62	62	124	275
Driest 25 %	117	119	116	138	139	161	320
Median	164	164	159	172	171	260	365
Wettest 25 %	291	270	209	317	319	361	365
Wettest 10 %	325	328	281	334	338	365	365

[a] Historical information indicates that during the driest 25 percent of historical (pre-1918) water years, chloride remained below 250 mg/L year-round (see Figure 1). Exceedance estimates for historical conditions (pre-1918) were adjusted for the 1976-1991 period because critical years occurred 31 percent of the time in 1976-1991 but less frequently in the historical record (e.g., only 14 percent of the time from 1906 to 2016).

Testimony of Susan Paulsen – Antioch 500 Errata

Table 2. Number of days per year chloride is below 250 mg/L at Antioch 2 hours after higher-high tide for different hydrologic conditions for different exceedance levels (calculated from DSM2 model results for 1976-1991)

	EBC2 (days)	NAA (days)	B1 (days)	H3 (days)	H4 (days)	B2 (days)
Driest 10 %	0	0	0	0	0	0
Driest 25 %	10	13	0	14	13	60
Median	108	104	87	103	104	116
Wettest 25 %	183	174	140	182	186	206
Wettest 10 %	278	252	207	259	261	282

Lastly, fall X2 is a fish-related adaptive management action that is required as part of the existing 2008 USFWS Delta smelt BiOp. Independent of CWF, this action could potentially be changed based on the latest understanding of the Delta smelt science. Petitioners will continue to adhere to the prevailing requirement once CWF becomes operational, which may be the existing requirement as stated in 2008 USFWS BiOp or a modified requirement. Therefore, based on the fact that fall X2 is a Delta smelt action and subject to adaptive management, and given that the CWF scenarios which include fall X2 requirement indicate no impacts to City of Antioch's salinity conditions, Petitioners believe that the decision about including the fall X2 requirement should be independent of the CWF change petition proceeding, and should be informed by best available science.

VII. Opinion 6: CWF is not expected to impact Sacramento Regional County Sanitation District (SRCSD) and its Sacramento Regional Wastewater Treatment Plant (SRWTP) operations.

A. Salinity

Dr. Paulsen offers an opinion that "WaterFix will cause an increase in salinity in the Delta". (See SRCSD-29, p. 5.) However, she fails to explain how, even if true, this would affect SRCSD. Dr. Paulsen's opinion is based on an incomplete characterization of expected salinity conditions under CWF. The conclusion was based solely on an analysis of expected changes at Antioch under Boundary 1 scenario. (SRCSD-29, p. 5:21-27.) As an example, Dr. Paulsen claims that chloride concentration at City of Antioch will increase under CWF (SRCSD-29, p. 5:20-23,Table 2.) Dr. Paulsen's analysis did not present any other scenarios including H3, H4 and Boundary 2 for her salinity testimony in SRCSD-29, even though results for these scenarios were included in numerous other analyses she presented to the Board. (e.g. Antioch-500-errata.) She fails to acknowledge her own analysis in Antioch-500-errata that shows CWF H3, H4 and Boundary 2 scenarios would improve salinity conditions compared to NAA at City of Antioch, as described in my Opinion 5 above. Dr. Paulsen also fails to recognize that salinity conditions in the Sacramento River in the vicinity of SRCSD outfall and downstream up to Cache Slough confluence (about 30 river miles downstream) remain similar to NAA under all the CWF operational scenarios presented by the petitioners, including Boundary 1, as shown in Figure 6. Therefore, in my opinion SRCSD would not be impacted by the projected Delta salinity changes under CWF.

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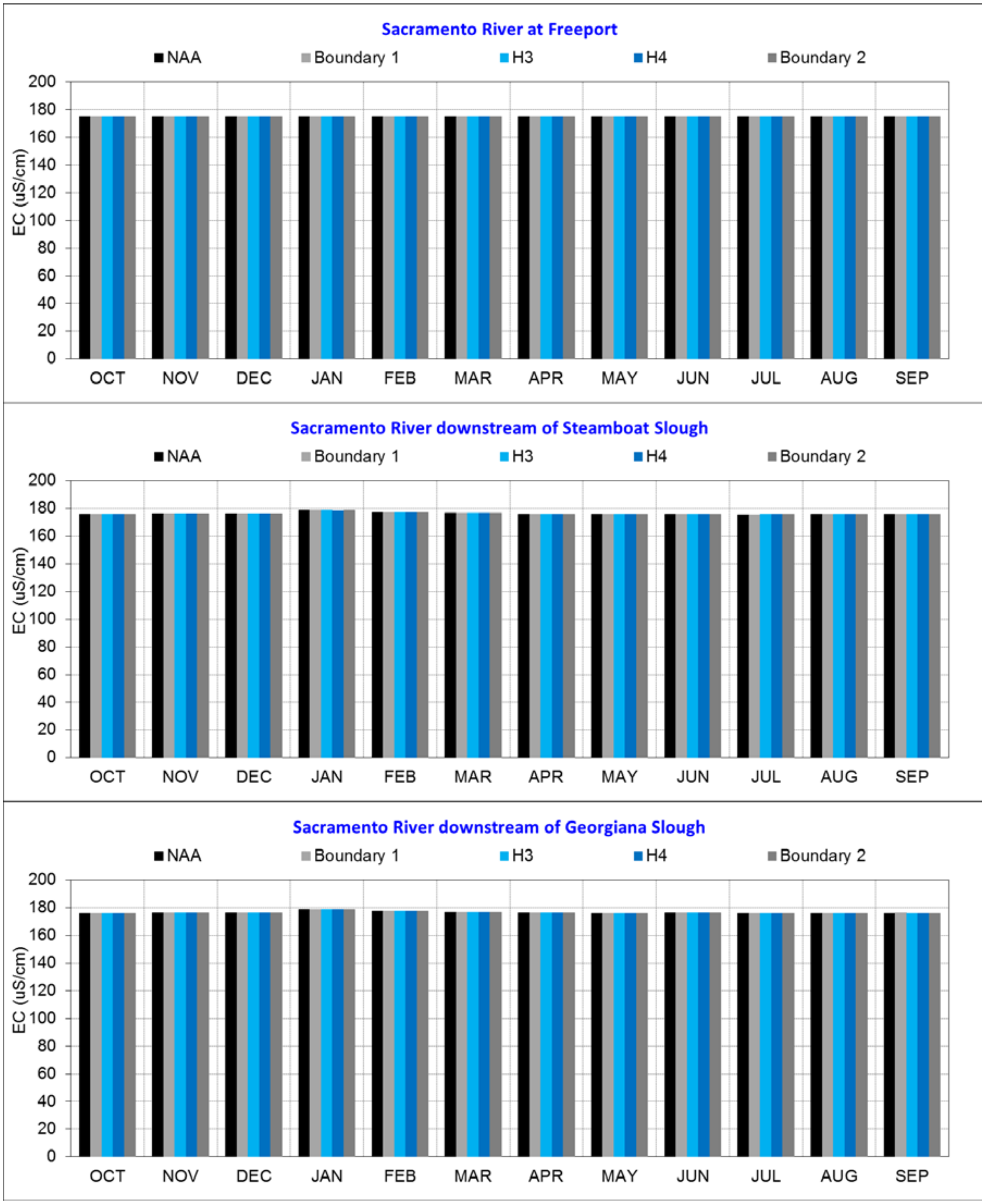

Figure 6. Average monthly EC modeled under NAA, Boundary 1, H3, H4, and Boundary 2 scenarios at various locations on Sacramento River upstream of Cache Slough confluence

B. Residence Time

Dr. Paulsen's Opinion 2 in SRCSD-29, "WaterFix will increase residence time in the Delta" is a general conclusion, which is based on an analysis that is oversimplified for a complex estuary such as the Bay Delta and it is inappropriate to support her conclusions. The supporting analysis presented in SRCSD-31 page 10 and STKN-026 page 39 assumes that the Delta is a large tank with constant volume of 1.2 million acre-feet. (STKN-026 p. 11 of 42.) This constant volume is then divided by the sum of monthly average inflows to compute monthly residence time for each of the CWF scenarios. This analysis ignores any effect of the factors such as the numerous in-Delta diversions, exports, tides and the heterogeneity of the hydrodynamic characteristics of different areas in the Delta, on residence times. For example, her analysis would provide the same residence time values for two scenarios if their inflows are identical and with differing south Delta exports. Similarly, it does not distinguish the residence times in the Sacramento River downstream of the proposed intakes where conditions are typically more riverine from the residence times in the south Delta, where conditions are typically more tidal. Therefore, in my opinion, Dr. Paulsen's results for one dry year (SRCSD-31 Table 1) using this overly simplistic approach, and her conclusion on residence time in the Delta are incomplete at best, and do not provide a full and fair characterization of potential CWF effects.

Furthermore, Dr. Paulsen relies on this inappropriate residence time analysis to hypothesize potential increase in microcystis growth rate and water quality degradation. (SRCSD-031, pp. 11-12.) However, she does not show how her findings would impact SRCSD. In claiming the CWF impacts on microcystis growth, Dr. Paulsen points to the effects of changes in residence times on flushing and lower mixing. However, her residence time analysis completely ignores the heterogeneity of Delta waterbodies, and is not a good indicator of how localized properties such as flushing and mixing in a complex estuary would change. Dr. Paulsen also makes a generic claim that CWF would increase Delta water temperature (SRCSD-31 page 12) without any evidence. She did not perform any analysis or cite to any evidence to show potential effects from CWF on Delta water temperatures. Furthermore, she incorrectly characterizes DWR's temperature analysis presented in DWR-653 as flawed because DWR did not present daily or monthly location-specific temperature results. However, DWR presented detailed monthly temperature results over 82-year simulation period at nine (9) representative locations throughout the Delta. (DWR-653, Appendix A, p. 50.) Based on this detailed analysis, DWR expert witnesses concluded that CWF has negligible effects on Delta water temperatures and would not substantially increase frequency or magnitude of cyanobacteria blooms within Delta. (DWR-653 p. 34.)

Finally, based on a comprehensive look at all the potential factors that could affect the cyanobacteria blooms, DWR expert witnesses concluded that the CWF does not change the frequency or magnitude of cyanobacteria blooms relative to the NAA. (DWR-81.)

C. SRWTP Operations

Dr. Paulsen's Opinion 4 claims that CWF will affect Sacramento Regional Wastewater Treatment Plant (SRWTP) operations by increasing the frequency and duration of diversion events relative to baseline conditions based on an analysis described in Exhibit SRCSD-31, page 21. I have reviewed the analysis presented in SRCSD-31 and Appendix A, which describes the assumptions used in the Flow Science analysis of SRWTP Emergency Storage Basin (ESB), and presents results which in my opinion significantly overestimate the effects of CWF on SRWTP operations.

As pointed out during DWR's cross-examination, SRCSD did not submit the underlying SRWTP operations model that was used to generate the results that form basis of Dr. Paulsen's opinion. At request of DWR, SRCSD agreed to provide the SRTWP operations model along with detailed inputs, outputs and assumptions and any evidence of independent review of this model during the cross-examination. (Transcript Volume 20, page 59.) However to date, SRCSD has failed to provide this information. Without access to the model that Dr. Paulsen relied upon, my opinions are only based on the review of exhibit SRCSD-31 and its Appendix A, and my own analysis based on the assumptions presented in SRCSD-31 Appendix A.

The crux of Dr. Paulsen's opinion 4 is that SRWTP would have to stop releasing effluent and divert it to the onsite ESBs more frequently and for longer periods with CWF (under B1, B2, H3 and H4 scenarios compared to NAA) as Sacramento River flow at SRWTP outfall under CWF scenarios would not allow them to meet the 14:1 NPDES permitted dilution requirement consistent with the NAA. In coming to this conclusion, the SRCSD's analysis assumed that the

SRWTP would be operated to discharge the NPDES permitted maximum allowable effluent flow everyday over the 16-year simulation period. The SRCSD-31 Appendix A explains that SRWTP's NPDES permit allows the plant to discharge a maximum average dry weather flow (ADWF) of 181 mgd. However, as shown in SRCSD-31 Appendix A Table 1 (excerpted below), the SRWTP influent flows in recent years have been well below this permit limit of 181 mgd ADWF. Table 1 (Appendix A, page 4) lists the 2015 measured monthly inflows versus the maximum NPDES permitted effluent discharge used in the analysis. As such, the analysis relied on effluent rates that are not based on current conditions and are approximately 50% larger than historical measurements of influent flow[3]. In my opinion, using this assumption leads to a drastic overestimation of the number of ESB diversion events under all the CWF operational scenarios including the NAA.

Excerpted from SRCSD-31 Appendix A:

Table 1 — Monthly SRWTP Influent Flows versus Modeled Monthly Flows Scaled to 181 mgd ADWF

Month	Influent Flow	Scaled to 181 mgd ADWF
	mgd	mgd
1	134	202
2	146	220
3	133	200
4	132	199
5	124	186
6	123	185
7	121	182
8	120	181
9	120	180
10	122	183
11	123	184
12	128	192

The effluent discharge values used as the input to Flow Science's SRWTP operations model were not presented in Dr. Paulsen's testimony. Figure 7 is an estimation of the daily

[3] Also noted in SRCSD-28 page 3 lines 25-26: on average over the past decade SRWTP discharge was 133 MGD compared to maximum permitted ADWF discharge of 181 MGD.

maximum and minimum effluent discharge timeseries for a typical year, based on the hourly diurnal effluent rates computed using information provided in SRCSD-31 Appendix A Tables 1 and 2. Figure 7 also shows the flow timeseries to meet the 14:1 dilution requirement, corresponding to the estimated daily maximum and minimum effluent discharge rates. As shown in the figure, maximum daily effluent discharge in a typical year is 395 cfs and minimum daily effluent discharge would be 203 cfs. The discharge would vary throughout the day with hourly values ranging from 203 cfs to 395 cfs. These discharges would require Sacramento River flows near the outfall to be between 5,528 cfs and 2,838 cfs to meet the 14:1 dilution requirement. 5,528 cfs corresponds to the daily maximum effluent discharge value of 395 cfs, and 2,838 cfs corresponds to the daily minimum effluent discharge value of 203 cfs. It is important to remember that these flow values correspond to maximum permitted ADWF discharge of 181 MGD.

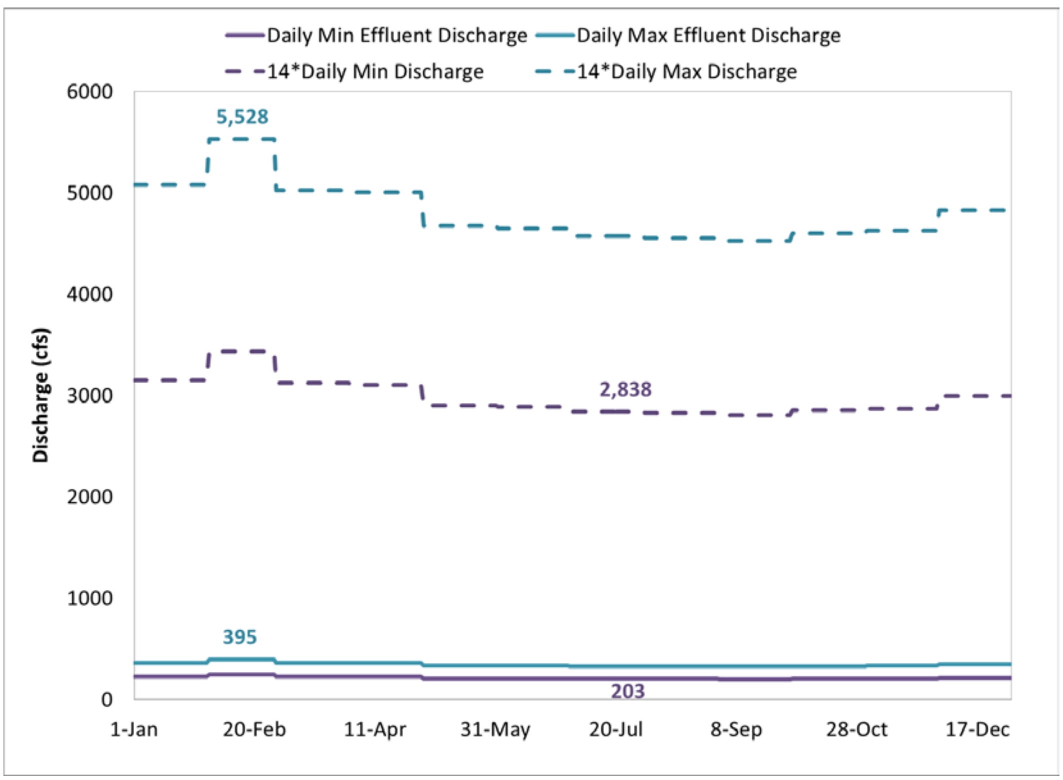

Figure 7: Daily maximum and minimum SRWTP effluent discharges using the hourly estimates based on Tables 1 and 2 in SRCSD-31 Appendix A, and corresponding flows to meet the 14:1 dilution requirement in a typical year

Monthly duration when the Sacramento River flow near the SRCSD outfall is less than 5,528 cfs and 2,838 cfs flow levels needed to meet the 14:1 dilution requirement for maximum permitted SRWTP discharge was computed for NAA and CWF H3+. Using the hourly flow output from DSM2 at the downstream end of DSM2 channel 412 for the NAA and CWF H3+ scenarios, the times when hourly Sacramento River flows were less than 5,528 cfs and 2,838 cfs were flagged (this would also flag hours when Sacramento River flow would reverse). The flagged hours were accumulated over each month for NAA and CWF H3+ to compute the monthly duration. Figures 8 and 9 compare the long-term average monthly duration when simulated Sacramento River flow is less than the maximum (5,528 cfs) and minimum (2,838 cfs) flow levels, respectively, for both NAA and CWF H3+ scenarios over the 82 year period. The figures also include the total number of hours in a given month for reference. Tables 9 and 10 show the same results and also present the differences between CWF H3+ and NAA, expressed as hours and percent of time in a month.

This analysis demonstrates that the Sacramento River flows under both NAA and CWF H3+ are greater than the 5,528 cfs and 2,838 cfs flow levels, a majority of the time in all months. October shows the greatest amount of time when the flows are below the thresholds (for 5,528 cfs threshold: 13% for NAA and 14% for CWF H3+; for 2,838 cfs threshold: 7% for NAA and 8% for CWF H3+), on average. The largest increase for CWF H3+ relative to NAA is in September 4% for the 5,528 cfs flow level (increasing from 8% to 12%) and 2.6% for the 2,838 cfs flow level (increasing from 4.7% to 7.3%). These changes are minor.

Figure 10 shows cumulative probability of exceedance plot of the monthly duration when hourly Sacramento River flow at SRCSD outfall is less than 5,528 cfs and 2,838 cfs for NAA and CWF H3+ scenarios over the 82-year simulation period. The results show that the exceedance probability of duration when flows are less than 2,838 cfs is similar under both CWF H3+ and NAA. The exceedance probability of duration when flows are less than 5,528 cfs is slightly higher under CWF H3+ compared to NAA. However, this result is conservative as it assumes that 5,528 cfs, which corresponds to a maximum effluent discharge value of 395 cfs, is needed all the time over the 82 year period. Given that the discharge would vary hourly and most likely would be less than 395 cfs, the expected increase in monthly duration where 14:1 dilution requirement is not met under CWF H3+ would be minimal compared to the NAA, and the differences in monthly duration when diversions are required to ESBs would be minimal.

This conclusion is also corroborated by the results Dr. Paulsen presented in SRCSD-31 Table 6 and SRCSD-31 Appendix A, which show that the percent of time diversion required to ESBs is about 9% or less under all scenarios over the 16-year simulation period, and it is only increasing by a maximum of 1% of time under the CWF B1 (8.3%), B2 (8.3%), H3 (8.6%) and H4 (9%) scenarios compared to the NAA (8.0%). Similarly, the percent of time effluent stored in ESBs is about 18% or less under all scenarios over the 16-year simulation period, and it is only increasing by a maximum of 2% of time under the CWF B1 (17.1%), B2 (17.0%), H3 (17.6%) and H4 (18.4%) scenarios compared to the NAA (16.4%). Dr. Paulsen's statement about the CWF scenarios increasing these parameters between 4% and 17% (SRCSD-31 p. 21) relative to NAA is misleading. 4% and 17% are relative changes in percent of time, which do not help understand the actual increase in percent of time the diversions required or effluent stored in ESBs. As discussed above the actual increase in percent of time under CWF scenarios is either 1% or 2% depending on the parameter compared to the NAA based on the SRCSD's ESB analysis.

Based on the preponderance of evidence presented in here, any impacts to the SRWTP operations under CWF would be minimal compared to the NAA. Notwithstanding this finding, the FEIR/S (SWRCB-105) included a mitigation measure to work with SRCSD on an operations protocol to minimize any impacts to the SRWTP operations.

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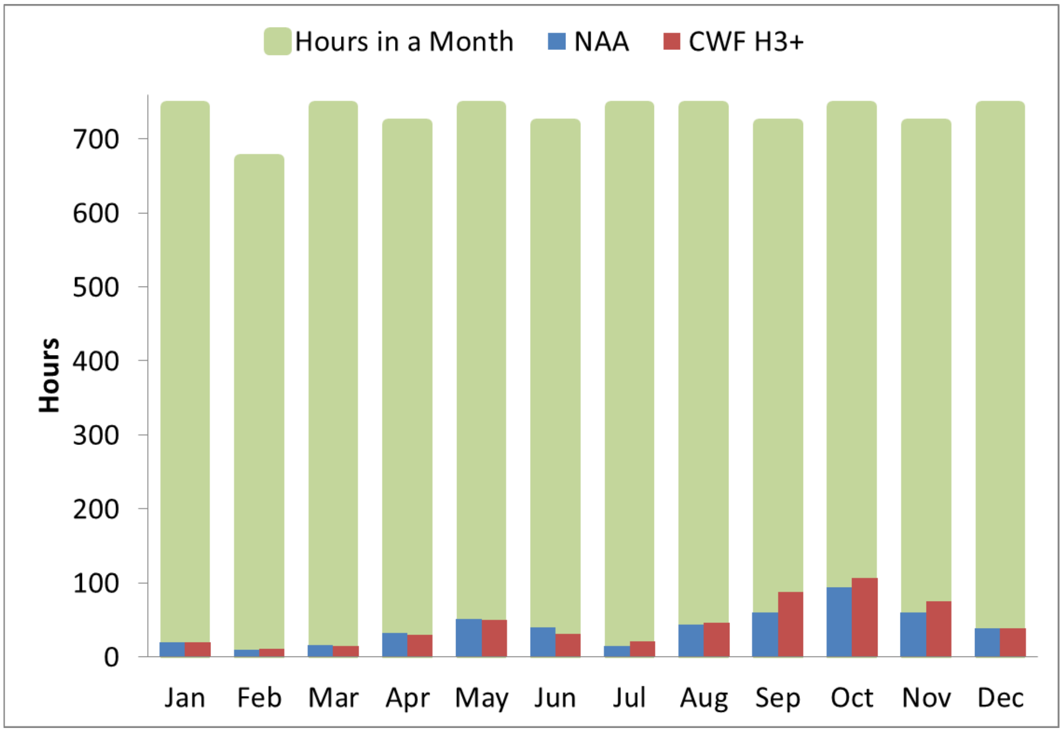

Figure 8: Amount of time in a month modeled Sacramento River hourly flow at SRWTP outfall less than 5,528 cfs under NAA and CWF H3+ scenarios, on average over the 82-year simulation period

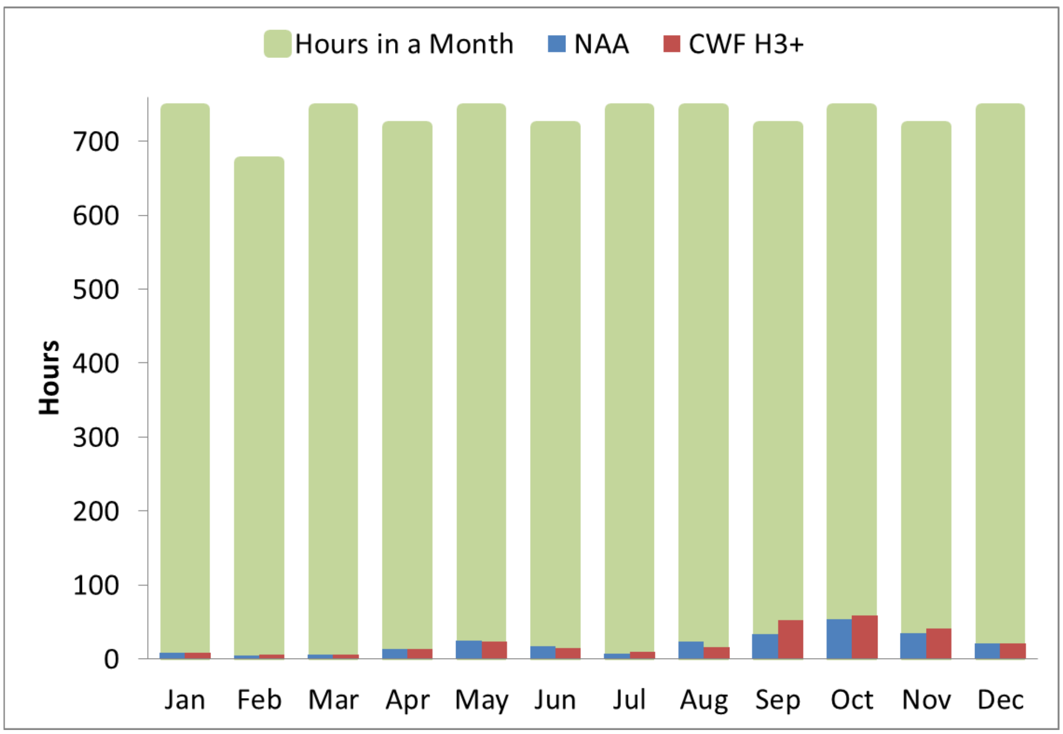

Figure 9: Amount of time in a month modeled Sacramento River hourly flow at SRWTP outfall less than 2,838 cfs under NAA and CWF H3+ scenarios, on average over the 82-year simulation period

Table 9: Amount of time in a month modeled Sacramento River hourly flow at SRWTP outfall less than 5,528 cfs under NAA and CWF H3+ scenarios, on average over the 82-year simulation period

				Hours expressed as percent of time in a month		
Month	NAA (hr)	CWF H3+ (hr)	CWF H3+ - NAA (hr)	NAA (%)	CWF H3+ (%)	CWF H3+ - NAA (%)
Jan	19.7	19.8	0.1	3%	3%	0%
Feb	10.0	11.4	1.3	1%	2%	0%
Mar	15.6	14.7	-0.9	2%	2%	0%
Apr	32.0	30.4	-1.7	4%	4%	0%
May	50.8	49.7	-1.1	7%	7%	0%
Jun	39.4	30.9	-8.5	5%	4%	-1%
Jul	14.7	20.7	6.1	2%	3%	1%
Aug	44.2	46.1	1.9	6%	6%	0%
Sep	59.9	88.0	28.1	8%	12%	4%
Oct	93.5	106.9	13.4	13%	14%	2%
Nov	59.8	75.1	15.3	8%	10%	2%
Dec	39.1	39.0	-0.1	5%	5%	0%

Table 10: Amount of time in a month modeled Sacramento River hourly flow at SRWTP outfall less than 2,838 cfs under NAA and CWF H3+ scenarios, on average over the 82-year simulation period

				Hours expressed as percent of time in a month		
Month	NAA (hr)	CWF H3+ (hr)	CWF H3+ - NAA (hr)	NAA (%)	CWF H3+ (%)	CWF H3+ - NAA (%)
Jan	8.4	8.2	-0.3	1%	1%	0%
Feb	5.0	5.8	0.9	1%	1%	0%
Mar	6.4	5.8	-0.6	1%	1%	0%
Apr	13.7	12.9	-0.9	2%	2%	0%
May	24.5	23.6	-0.9	3%	3%	0%
Jun	17.3	14.6	-2.7	2%	2%	0%
Jul	6.5	9.4	2.9	1%	1%	0%
Aug	22.9	16.3	-6.6	3%	2%	-1%
Sep	33.7	52.8	19.0	5%	7%	3%
Oct	54.1	58.7	4.6	7%	8%	1%
Nov	34.7	40.6	5.9	5%	6%	1%
Dec	21.3	20.5	-0.8	3%	3%	0%

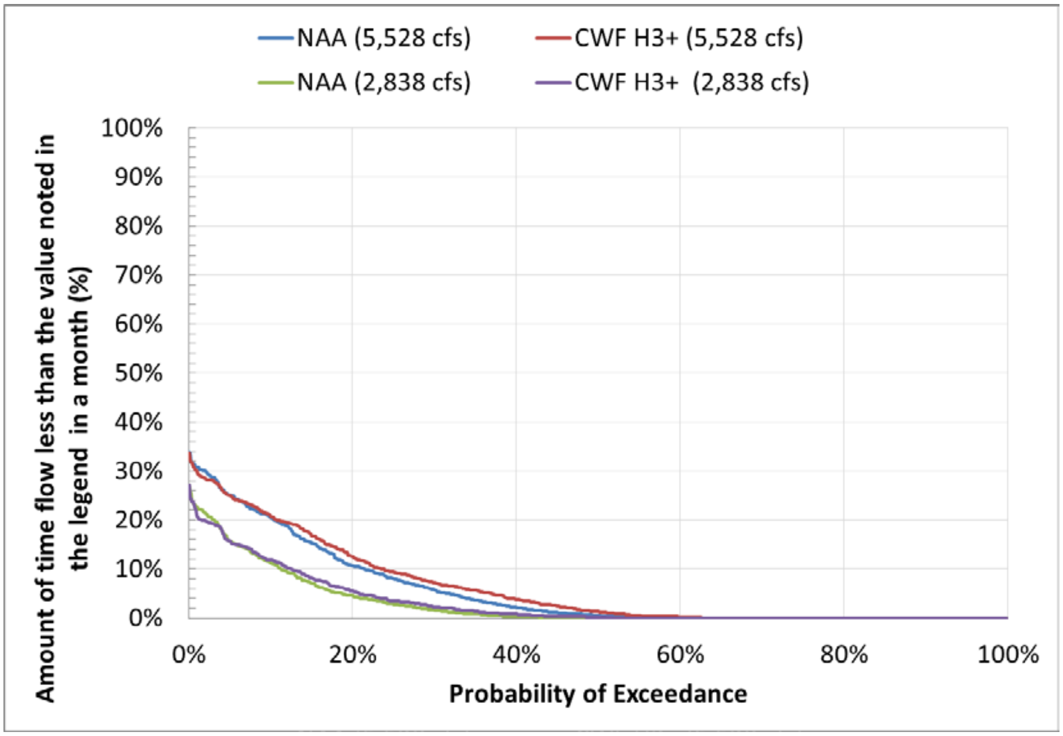

Figure 10: Probability of exceedance of the amount of time in a month hourly Sacramento River flow at SRCSD outfall is less than 5,528 cfs (corresponds to maximum hourly SRWTP discharge of 395 cfs) and 2,838 cfs (corresponds to minimum hourly SRWTP discharge of 203 cfs). The plot was based on hourly flow outputs from DSM2 modeling over the 82-year period for both NAA and CWF H3+ scenarios.

VIII. <u>Opinion 7: Salt budget analysis presented in SDWA-291 is incomplete, imprecise and unreliable, and any opinions about the effects of CWF on south Delta salinity based on this analysis are incorrect.</u>

Mr. Burke attempted a salt budget analysis for a subarea (SDWA-291 Figure 1) in the south Delta using the DSM2 results for NAA and BA H3+ scenarios. Mr. Burke's Opinion 1 presented in SDWA-291 is not appropriate based the analysis he presented. Mr. Burke incorrectly claims that BA H3+ scenario increases the salt brought into the south Delta by about 30,000 metric tons (mt) per year. As explained below, analysis presented in SDWA-291 does not support this claim. Mr. Burke's Opinion 2 and Opinion 3 were based on his Opinion 1, and therefore are invalid. Furthermore, Mr. Burke is mistaken in stating that petitioners have not examined the effects of Delta salinity changes on the biological resources (Opinion 3). As documented in the CWF BA, CWF ITP Application, CWF FEIR/EIS and as presented in petitioners' Part 2 direct testimonies, the effects of potential changes in Delta salinity were analyzed extensively by the Petitioners.

A. Potential problems with the approach

Mr. Burke's salt budget analysis for south Delta is incomplete, as he accounts for the salt sources and sinks that are external to the study area, and ignores the sources (e.g. agricultural drainage) and sinks (e.g. agricultural diversions) within the study area. Thus the objective of Mr. Burke's analysis, which is to evaluate potential salt loading to the south Delta from the CWF (SDWA-291 p. 5 11:12), is not achieved.

In performing his analysis, Mr. Burke utilized one set of EC-Chloride conversions for each salt influx/outflow location he considered for the entire 82-year period, which fails to recognize any variation in the source of salt. Field data shows a substantial difference in EC-Chloride relationship depending on whether the major source of salinity is land salt or ocean salt (DWR-932 pp. 8-9). For the same EC value, the Chloride concentration is lower if the major source of salinity is land salt (which happens mostly during higher flows). During low flow periods, often the major source of salinity is ocean salt. Using a single EC-Chloride relationship for the full simulation period, ignores these large fluctuations in the Chloride contribution, and adds uncertainty to the Chloride predictions.

For example, Dr. Nader-Tehrani illustrated in DWR-932, p. 11, Figure 3 that under H3, H4, and Boundary 2, the sea water component (Martinez contribution) is reduced substantially at City of Stockton's Intake relative to NAA, which indicates that the EC-Chloride relationship has the potential of changing under CWF (lower Chloride for the same EC value) at this location. Therefore, one set of EC-Chloride conversions may not be valid under all flow conditions or for both NAA and CWF. Rather than relying on single conversion for each source or sink, Dr. Burke should have utilized DSM2 finger-printing analysis, which would have isolated the sea-water components.

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Excerpted from DWR-932 p. 11:

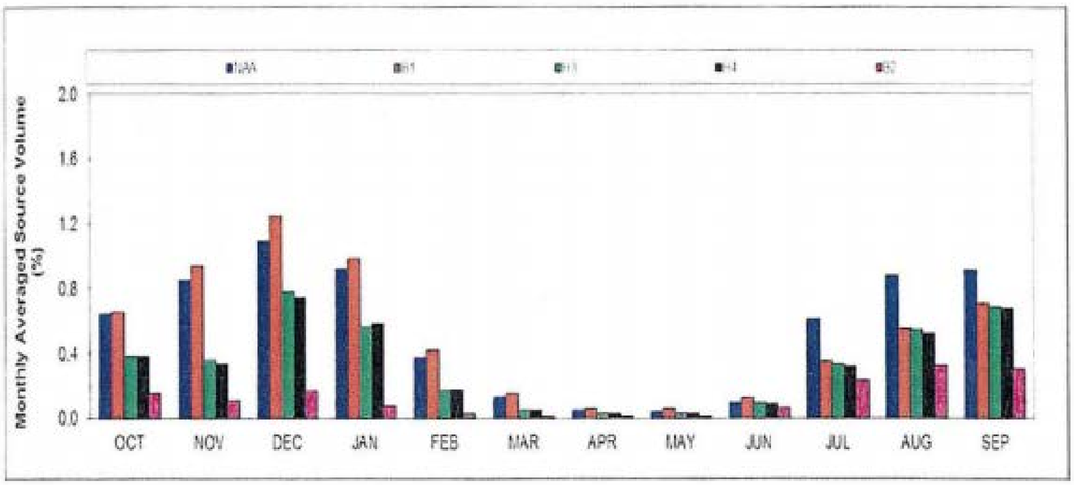

Figure 3- Source Water Finger-Print from Martinez Long Term Monthly Average (1976-1991) at City of Stockton's Intake Location

Mr. Burke's analysis focuses on the arithmetic sum of salt mass from a number of very large quantities of salt sources, each of which is subject to substantial inaccuracies for the reasons noted above. Even a small error of 5-10% in any of these large quantities, has the potential in making large changes in the net salt balance in the area. An accurate salt flux analysis for south Delta requires much more precision than what was utilized by Mr. Burke.

B. <u>Problems with the interpretation of the results</u>

As Mr. Burke noted in SDWA-291 Table 2, a negative net value represents a net outflow of salt from the south Delta and a positive net value represents a net influx of salt into the south Delta. The annual net chloride value that Mr. Burke estimated for NAA is negative 48,693 mt (Table 3), and for BA H3+ it is negative 18,370 mt (Table 4). Given that the net Chloride values for both NAA and BA H3+ are negative, per Mr. Burke's definition of signs, there should be a net outflow of salt from the south Delta under both scenarios. Mr. Burke stated that if more salt flows into the area than flows out there will be an accumulation of salt, which can result in salinity increase (SDWA-291 p. 5 17:18). If the opposite is true, which is the case for both NAA and BA H3+ south Delta salinity should reduce over time.

Mr. Burke computed the difference between net salt residuals under BA H3+ and NAA to be about 30,000 mt. I disagree with Mr. Burke's interpretation of what the value 30,000 mt means. It does not mean that 30,000 mt of more salt is brought in BA H3+ compared to NAA, as Mr. Burke concluded in Opinion 1 of his testimony. Clearly, his results indicate that the salt influx is significantly lower under BA H3+ compared to NAA. It also does not mean that 30,000 mt of more salt is remaining or accumulating in south Delta under BA H3+ compared to NAA as Mr. Burke testified during cross examination (Transcript Volume 15 p. 139-140 and p. 145-146). If either of Mr. Burke's interpretations were to be correct, there should be a steady increase in south Delta salinity under BA H3+ compared to NAA.

In summary, the results from Dr. Burke's analysis clearly demonstrate that his estimates for the net salt flux for the south Delta region cannot be relied upon to formulate any opinions on the changes in water quality in south Delta under CWF. Rather than relying on this imprecise analysis to study the effects of CWF on south Delta salinity, the better option would be to rely on DSM2 EC results in the south Delta channels. Figure 11 compares the modeled average monthly EC values at several locations in the south Delta for NAA and CWF H3+ scenarios. The results clearly indicate that the salinity conditions under CWF H3+ would be similar to NAA in the south Delta channels.

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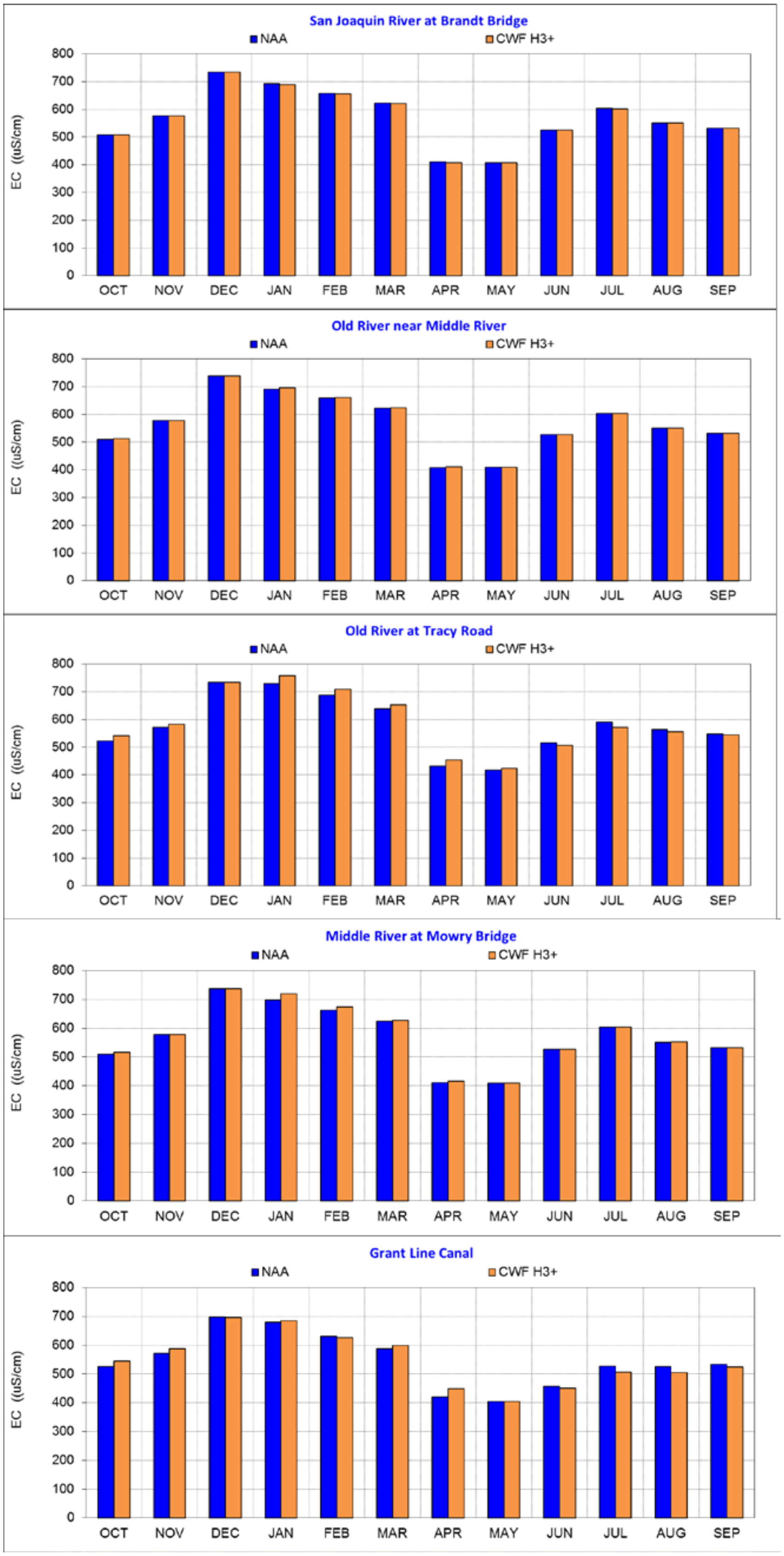

Figure 11: Modeled average monthly EC values at several locations in the south Delta for NAA and CWF H3+ scenarios

IX. CONCLUSION

On the basis of the rebuttal testimony that I have provided, I reiterate my opinions:

1. DCC gate operations with CWF are expected to remain consistent with current operations, and therefore, proposed permit condition in EBMUD-155 is not necessary.
2. Exports at the south Delta SWP and CVP pumping facilities under CWF H3+ are not expected to be greater than the No Action Alternative.
3. CWF is not expected to impact CVP north-of-Delta carryover storage conditions, and therefore proposed permit conditions in ARWA-502, CSPA-202-errata, PCFFA-87 for carryover storage requirements are not necessary.
4. CWF is not expected to impact Lake Oroville carryover storage conditions, and therefore proposed permit condition for Oroville carryover storage in CSPA-202-errata is not necessary.
5. Applicable salinity requirements for City of Antioch's M&I use will continue to be met.
6. CWF is not expected to impact SRCSD and the SRWTP operations.
7. Salt budget analysis presented in SDWA-291 is incomplete, imprecise and unreliable, and any opinions about CWF effects on south Delta salinity based on this analysis are incorrect.

Executed on this 10th day of July, 2018 in Sacramento, California.

Chandra Chilmakuri