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On behalf of South Delta Water Agency,
Central Delta Water Agency, Lafayette Ranch,
Heritage Lands, Mark Bachetti Farms
and Rudy Mussi Investments L.P.

STATE OF CALIFORNIA

STATE WATER RESOURCES CONTROL BOARD

Hearing in the Matter of California Department of Water Resources and United States Department of the Interior, Bureau of Reclamation Request for a Change in Point of Diversion for California Water Fix	**SUR-REBUTTAL TESTIMONY OF THOMAS K. BURKE, PART 2**

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I, Thomas Burke, submit this written testimony at the request of Protestants South Delta Agency, Central Delta Water Agency, Lafayette Ranch, Heritage Land Company, Mark Bachetti Farms and Rudy Mussi Investments L.P., the ("South Delta Parties/Protestants"). This Sur-rebuttal testimony has been prepared to rebut testimony by Dr. Chilmakuri in his rebuttal testimony (DWR-1217).

I. Background and Qualifications

I am a hydrologist and water resources engineer with over 35 years of experience in surface water and groundwater hydrologic modeling. Prior to starting Hydrologic Systems, I held the position of Senior Associate with PWA, Western Regional Director of Water Resources for EA Engineering Science and Technology, and Hydraulic Engineer with the US Army Corps of Engineers. My experience ranges from development of two and three-dimensional river and reservoir flow and circulation models to local and regional groundwater and transport models for basin-wide hydrologic analyses. My experience also includes the analysis of one and two-dimensional flow in river and wetland systems.

I hold a Master of Science in Civil Engineering from Colorado State University, Fort Collins (1992) and hold a Bachelor of Science in Civil Engineering from The University of Florida, Gainesville (1980). My Statement of Qualifications is marked as SDWA-47.

II. Overview of Testimony

In rebuttal testimony presented in Part 2 of the California WaterFix hearing, the Petitioners presented criticism of the salt budget that I developed in my Part 2 Case In Chief. In Particular, Dr. Chilmakuri provided the following opinion:

The 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.

The only plausible explanation for such testimony is that it is based on his misunderstanding of the salt budget presented in my testimony (SDWA – 291.) In particular, I would like to address seven points which Dr. Chilmakuri used as a basis of his opinion.

1. Page 26, Line 2 through 6.

   "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."

This statement by Dr. Chilmakuri is incorrect. The DSM2 model, which I used for my salt budget, and was used by the Petitioners for the CWF BA, CWF ITP Application, and CWF FEIR/EIS, accounts for, and contains components to track and model both the external salt source and sinks as well as the internal salt source and sinks to the study area. If the DSM2 model did not contain those salt sources and sinks, all of the salinity analyses developed for the BDCP and the WaterFix project would be incorrect.

The sources and sinks within the study area consist of irrigation diversions (sink), irrigation return flows (source) and seepage (sink). The irrigation diversions remove salt from the system, the irrigation return flows return salt to the system, and the seepage removes salt from the study area. The flow values assigned to each of these three components is identical for every time step in both the NAA and the CWF H3+ scenarios over the 82-year simulation period. Since there is no change in flow for any of these sources within the study area, they generally cancel each other out when comparing the NAA and CWF H3+ scenarios.

The salt budget is developed by multiplying the flow rate for each flow component by the salt concentration for that component. The salinity values assigned to the irrigation return flows are specified in the model and are the same for both the NAA and the CWF H3+

scenarios. The salinity values assigned to the two sinks, irrigation diversions and seepage, are the computed model values at the point of diversion for each scenario. The difference in the salt loss for these two sinks is relatively minor given the identical flows, and therefore will not affect the results from the salt budget.

2. Page 26, lines 7 through 9.

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.

Dr. Chilmakuri is incorrect. I used individual EC-Chloride relationships that were developed for each of the inflow and outflow locations in the study area. These relationships were developed from actual water samples that were collected at these locations over many years. This collected data reflects actual changes in the mix of flow sources, concentrations, and flow rates that were observed at these locations over several decades. This is not a theoretical assumption of source tracking from a model as these measured samples reflect the actual result of flow from different sources, mixing in the Delta, and, ultimately, flowing to these locations. Source tracking can be helpful if you don't have real data, but the data collected at the actual site location provides the best representation of the variability of the EC-Chloride relationship from the different sources. As indicated in the plots of EC-Chloride provided in SDWA-291, there is variability in the relationship between EC and Chloride, but the relationship is consistently providing a Coefficient of Determination (R^2) between .94 and .99. The Coefficient of Determinization is a measurement of what statisticians refer to as the "goodness of fit" between a fitted regression line and the measured data. The value can range from 0 to 1.0.

In addition to the relatively good fit for something that is as variable as salinity in the Delta, the developed EC-Chloride relationships for each source were applied identically to both the NAA scenario and the CWF H3+ scenario, thus removing any bias in the conversion of EC to Chloride in comparing the two scenarios.

Dr. Chilmakuri refers to Dr. Tehrani's Figure 3 from DWR-932. That figure shows the percent change of the Martinez flow component at the City of Stockton's intake location for each month. As can be seen in the figure, the largest percent change ranges from 0.1% to 0.2%. During one-third of the year, the change is less than 0.1%. This small of a change can affect the salinity concentration but changing 0.1% of the data is not going to have a significant effect on the development of the EC-Salinity relationship, especially considering that 99.8 to 99.9% of the flow will have the same EC-Chloride relationship as in the NAA. Resorting to a theoretical fingerprint analysis would be interesting, but it would add a level of abstraction to the data that is not necessary, and would not be as accurate nor as truly representative as actual data collected at the site.

3. Page 27, Line 12-16

"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."

As described in the sections above, there are not any substantial inaccuracies in the salt budget analysis. The data that was used was taken from DWR's DSM2 models for the NAA and CWF H+ scenarios. Any inherent inaccuracy of the data would be directly attributable to inaccuracies in the DSM2 model itself. No model is perfect, but at the present, the Petitioners have selected DSM2 to be the model to use for flow and salinity analysis. Dr. Chilmakuri states that even a small 5 to 10% change in any of the large quantities has the potential to change the budget. A 5-10% change to any of the large budget components would *not* be a small change. A reduction in flow or salinity concentration of 10% to the San Joaquin River or South Delta Exports would be a huge change, which is exactly what is seen in DWR's model results. The reduction in south Delta exports has resulted in what was 485,000 metric tons per year of Chloride being removed from the Delta in the NAA to only 259,000 metric tons of Chloride being removed from the South Delta under the CWF H3+. That is a 46% reduction in the amount of Chloride being removed from the South Delta.

4. Page 27, Line 23-26.

   "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."

Dr. Chilmakuri is mixing apples and oranges by combining the testimony presented on page 5 of SDWA-291 with, what I assume, is his misinterpretation of the salt budget residual that he is referring to in the last sentence of his statement. As a general statement, if more salt flows into an area than flows out then there will be an increase in salinity. That statement is both factually and logically true. However, Dr. Chilmakuri is comparing that statement to his misinterpretation of the residual of the salt budget. The residual of the salt budget is shown in Table 3 for the NAA and Table 4 for the CWF H3+ scenario. The data in these two tables represent the net salt loading from the external flow components. These specific flow components are being modified by the CWF H3+, which is why they are a focus of my analysis. The residual for each scenario is equal to the net consumptive use (Irrigation Diversion - Return Flow), seepage, and change in salt within the channels. Therefore, the sign of the residual has little meaning without looking at the residual values from each of those components. The differences between the residual for the CWF H3+ and the NAA is critically important. The difference shows the net *change* in salt loading to the South Delta. The net consumptive use and seepage changes will be minor compared to the change in salt loading from the rivers and exports. Therefore, if the net consumptive use and seepage differences are minor, the difference between the salt residual for the NAA and the CWF is essentially equal to the net change in salt in the South Delta Channels. The residual for the NAA and H3+ is -48,693 and -18,370 metric tons (mt) respectively. As shown above, these values do not represent the amount of salt that is leaving the system under each scenario. The residuals do represent the components in the 2 equations shown below.

$$Residual_{\text{NAA}} = (Consumptive\ Use) + Seepage - Channel\ Salt\ Mass\ NAA = -48{,}693\ mt$$

$$Residual_{\text{CFW H3+}} = (Consumptive\ Use) + Seepage - Channel\ Salt\ Mass\ NAA = -18{,}370\ m$$

Given that the change in consumptive use and seepage due to the CWF H3+ will be relatively minor compared to the flow changes in the South Delta, the difference between the CWF H3+ residual and the NAA residual will be the change in salt mass within the South Delta channels.

$$Salt\ Mass\ Change = (Res\ H3+) - (Res\ NAA) = -18{,}370\ mt - (-48693\ mt)$$
$$Salt\ Mass\ Change = +30{,}323\ m$$

5. Page 27, line 27 through Page 28, Line 2

   "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."

Dr. Chilmakuri's testimony is incorrect. As illustrated in the preceding paragraphs, the 30,000 mt is the increase in the mean annual salt mass being brought in to the South Delta as a result of the CWF H3+. Dr. Chilmakuri mistakenly attempts to represent the salt budget residual as the amount of salt leaving the South Delta under each scenario. As explained above, the residual represents several things, including the amount of salt in the channel. The correct way to evaluate the change in salt loading is to compare the change in the residual between the two scenarios.

6. Page 28, Line 8-11.

   "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."

Again, Dr. Chilmakuri's testimony is simply mistaken. The salt budget results are as precise and accurate as the DSM2 model results can provide. The DSM2 modeled salinity results that were used in this budget analysis were the same exact model results that were used by the Petitioners for the CWF BA, CWF ITP Application, and CWF FEIR/EIS. Dr. Chilmakuri's opinion may have been influenced by his misunderstanding of what the salt budget residual represents.

7. Page 28, line 10 through 15

   "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."

Dr. Chilmakuri is wrong. Looking at EC values in the Delta Channels is not a better way to evaluate changes in salinity. A salt budget provides a way to evaluate not only salinity from the same EC results that Dr. Chilmakuri is referring to, but also accounts for the flow rates that are moving that salt into and out of the Delta channels. By looking only at EC's, you ignore the importance of volume weighting the salinity concentrations as they enter and leave the delta. An EC of 0.5 has a completely different effect on salt loading when the associated flow is 100 cfs compared to that 0.5 EC when it is associated with a flow rate of 1,000 cfs. The critical factor of volume weighting is ignored by considering only EC values.

Nevertheless, for the sake of completeness, as part of SDWA – 323 I analyzed salt concentrations as well as the salt mass. As part of SDWA – 323, developed an EC analysis which shows the elevated increases in EC that will result from the project. Figure 1, below, is from SDWA-323 and shows the increase in salinity that is apparent if the data is not averaged over multiple years. It was also clearly shown in SDWA-78 in Part 1 of this hearing, where showed that salinity values for the H3 scenario during the summer period would be higher than the NAA 90% of the time.

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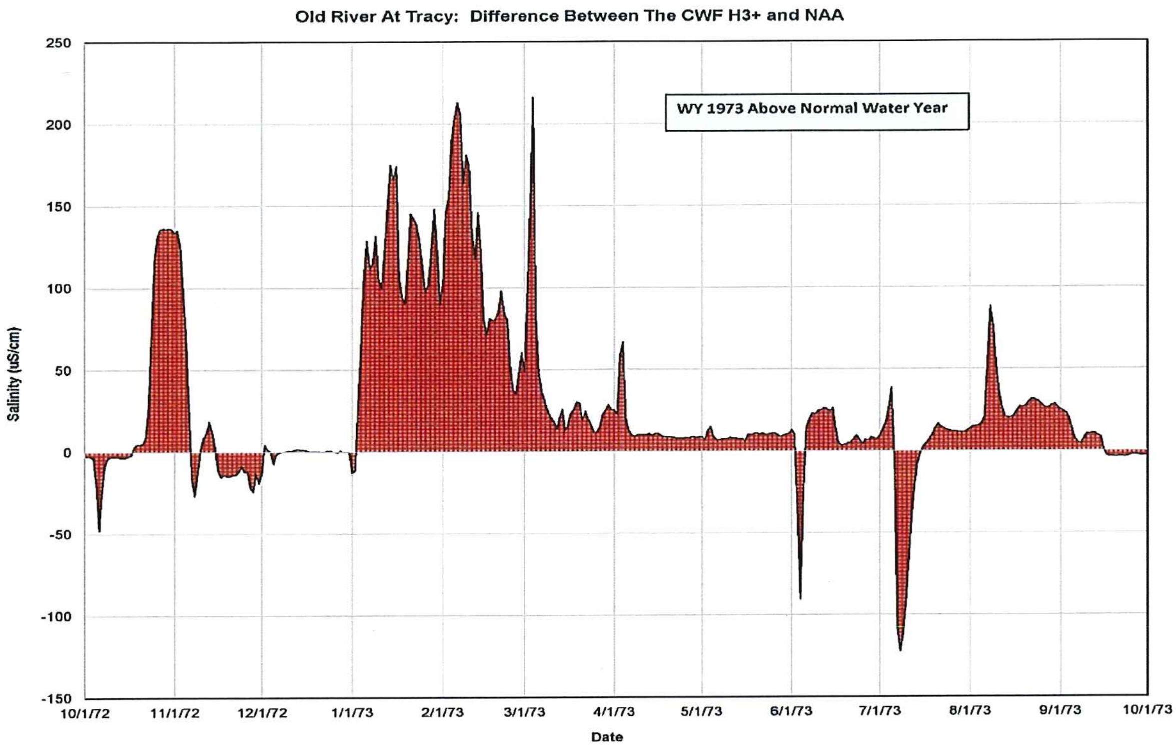

Figure 1 Salinity Difference; WY 1973, "Above Normal Water Year" (Figure 6 from SDWA 323) Dr. Chilmakuri presents Figure 11 in his Part 2 Rebuttal testimony as an example of how to properly evaluate the salinity data produced by the DSM2 model. This figure shows the average mean monthly salinity values for the NAA and CWF H3+ scenarios at several locations in the South Delta. In my professional opinion Dr. Chilmakuri is mistakenly interpreting the EC data in the figure. This is a classic example of the improper use of statistics. These plots could be the poster child for how to wash all your impacts away with multiple iterations of averaging. The 15-minute data from the DSM2 model has been averaged into months and then that monthly data has been averaged over multiple years. After all of that averaging it is surprising that any differences are shown. If I performed the same type of gross averaging analysis on streamflow data in California it would indicate that California's history has been devoid of floods or droughts.

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In fairness to Dr. Chlmkauri, this type of long-term gross averaging may be effective tool for long-term water supply forecasting but must shorter time durations must be analyzed to meaningfully evaluate impacts. In my professional opinion, Petitioners presentation of only long-term gross averages results in an erroneous assessment of the effects on the south and central Delta from the project.

Executed on the 20th day of September 2018, at Placerville, California.

Thomas K. Burke

THOMAS K. BURKE, P.E.