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BEFORE THE 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. SUSAN PAULSEN IN SUPPORT OF THE CITY OF ANTIOCH'S SUR REBUTTAL TO THE REBUTTAL TESTIMONY OF DWR and FEDERAL PETITIONERS.** **(Exhibit: Antioch-400)**

Qualifications

My name is Susan Paulsen and I am a Registered Professional Civil Engineer in the State of California (License # 66554). My educational background includes a Bachelor of Science in Civil Engineering with Honors from Stanford University (1991), a Master of Science in Civil Engineering from the California Institute of Technology ("Caltech") (1993), and a Doctor of Philosophy (Ph.D.) in Environmental Engineering Science, also from Caltech (1997). My education included coursework at both undergraduate and graduate levels on fluid mechanics, aquatic chemistry, surface and groundwater flows, and hydrology, and I served as a teaching assistant for courses in fluid mechanics and hydrologic transport processes.

I currently am a Principal and Director of the Environmental and Earth Sciences practice of Exponent, Inc. ("Exponent"). Prior to that, I was employed by Flow Science Incorporated, in Pasadena, California, where I worked for 20 years, first as a consultant (1994-1997), and then as an employee in various positions, including President (1997-2014). I have 25 years of experience with projects involving hydrology, hydrogeology, hydrodynamics, aquatic chemistry, and the environmental fate of a range of constituents. My Ph.D. thesis was entitled, "A Study of the Mixing of Natural Flows Using ICP-MS and the Elemental Composition of Waters," and the major part of my Ph.D. research involved a study of the mixing of waters in the Sacramento-San Joaquin Bay-Delta (the Delta) using source water fingerprints. I also directed model studies to use chemical source fingerprinting to validate volumetric fingerprinting simulations using Delta models (including the Fischer Delta Model (FDM) and the Delta Simulation Model (DSM)). I have designed and directed numerous field studies within the Delta using both elemental and dye tracers, and I have designed and directed numerous surface water modeling studies within the Delta.

As before, I incorporate my prior Report and exhibits I submitted in support of Antioch's case in chief and Antioch's rebuttal to DWR's case in chief into as part of my testimony.

A copy of my curriculum *vitae* is included as Exhibit Antioch-201.

<u>Summary of Testimony</u>

I was retained by the City of Antioch to assist the City in its evaluation of the California WaterFix Project (WaterFix). I provided testimony to the State Board during Phase 1 of the WaterFix hearings as detailed in Exhibits Antioch-200 through Antioch-202, including Antioch-202 Errata, with supporting testimony included as Exhibits Antioch-203 through Antioch-234. I also provided testimony at the State Board proceedings on December 14, 2016. I provided rebuttal testimony to the State Board during Phase 1 rebuttal of the WaterFix hearings as detailed in Exhibits Antioch-300 through Antioch-302, and provided rebuttal testimony at the State Board proceedings on

May 23, 2017. The testimony presented here is not intended to be duplicative of information previously provided to the State Board, but is intended to address two Rebuttal Opinions. My two rebuttal opinions are that Dr. Nader-Tehrani's analysis of San Joaquin River inflows and EC with regard to Antioch's intake reaches inaccurate conclusions, and that Dr. Nader-Tehrani's rebuttal testimony regarding compliance with D-1641 water quality objectives is misleading.

Testimony

Sur-Rebuttal Opinion 1: Dr. Nader-Tehrani's rebuttal analysis of San Joaquin River inflows and EC and the effects on water quality at Antioch reaches inaccurate conclusions.

Dr. Nader-Tehrani prepared a critique of my analysis in Antioch-202 where I reached the conclusion that WaterFix will increase the fraction of San Joaquin River water at Antioch's intake, which will in turn result in water quality degradation. He stated that "Dr. Paulsen's findings can be explained and in my opinion misrepresents the potential for water quality impacts anticipated from CWF near Antioch." (DWR-79, 22:12-13) Specifically, Dr. Nader-Tehrani presented his own analysis and arrived at the conclusion that "there is no correlation between an increase in San Joaquin River volumetric contribution at Antioch and any significant increase in EC at Antioch." (DWR-79, 24:5-7). I believe my initial findings are accurate, and that my evaluation, which is based on DWR's modeling, clearly shows both an increase in salinity and an increase in the percent contribution of water from the San Joaquin River for certain WaterFix scenarios. Further, I note that my conclusions about both the source of water and the quality of water at Antioch's intake are based directly upon DWR's DSM2 model files and model results. Contrary to Dr. Nader-Tehrani's assertions, I have considered the relationship between the EC of San Joaquin River water and flow of the San Joaquin River, as that relationship is embedded within the DSM2 model files provided by DWR and thus is considered in my conclusions, which are based upon that modeling.

More specifically, Dr. Nader-Tehrani's analysis in DWR-79 can be summarized as follows:

- Dr. Nader-Tehrani asserted that the volumetric percentage of San Joaquin River water at Antioch's intake increases as a result of increasing San Joaquin River inflow at Vernalis (DWR-79 Figure 7). Dr. Nader-Tehrani stated 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." (DWR-79 23:3-5)
- Dr. Nader-Tehrani also prepared a figure that shows the simulated EC levels at Antioch as a function of the San Joaquin River Volumetric Fingerprint (%) at Antioch (DWR-79, Figure 8). Dr. Nader Tehrani stated that "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%)." (DWR-79 from 23:28-24:4)
- Ultimately, Dr. Nader-Tehrani concluded that "The large increases from San Joaquin River volumetric contribution under CWF operational scenarios mainly occurs [sic] 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." (DWR-79, p. 28:1-4)

Although it is not clear just what is depicted in Figures 8 and 9 of DWR-79, Dr. Nader-Tehrani's analysis appears to assume that the EC observed in the San Joaquin River water at Vernalis in a given month can be compared directly to the monthly average volumetric source fraction at Antioch for the same month. However, Dr. Nader-Tehrani has acknowledged that it takes a significant amount of time (perhaps a month or more) for water that enters the Delta via the San Joaquin River at Vernalis to travel to the location of Antioch's intake.[1] Thus, I conclude that the information depicted in Figures 7 and 8 of DWR-79 is misleading in that it does not appear to incorporate the time required for water to travel from Vernalis to Antioch. However, even if corrected for this apparent oversight, the information in Figures 7 and 8 is not relevant to our assessment of source contribution or water quality at Antioch.

Exponent has previously conducted analyses of the fate of the San Joaquin River water in the Delta for historical conditions in critical, dry, and below normal water years. These prior analyses determined that only a small fraction of San Joaquin River water entering the Delta at Vernalis reaches the western Delta in the months following its entrance—typically less than one percent (see, for example, SJTA-205 Attachment 6, beginning on p.735). To evaluate if this conclusion held for WaterFix project scenarios, DSM2 fingerprinting was conducted for the Alternative 4A scenario. Specifically, San Joaquin River inflow at Vernalis between February 1 and June 30, 1987 (a dry water year) was tagged to track its movement through the Delta (note that San Joaquin River flows before and after this time period were modeled but not tagged). Volumetric fingerprinting results were used to track the volume and fraction of tagged San Joaquin River inflow that was exported at Tracy Pumping Station (CVP), Clifton Court (SWP), Rock Slough (CCWD), and at Antioch; because San Joaquin River water would not be present or exported from the North Delta Diversion (NDD) locations, which are located on the Sacramento River at the upstream end of the Delta, the fate of San Joaquin River water was not evaluated at this location (see also Antioch-202 at p. 23). The fate of the San Joaquin River water that entered the Delta at Vernalis between February 1 and June 30, 1987, is shown in Figure 1 and tabulated in Table 1; note that water that remained in the Delta at the end of the water year or that was diverted as DICU in the interior Delta is

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[1] When asked about residence time of San Joaquin River flows, Dr. Nader-Tehrani stated that water at Antioch's intake during a given month might have "actually entered the Delta in the prior month or the month before that. That's just how the Delta works." Transcript 41, p.41:5-6.

not shown. Figure 1 and Table 1 indicate that the majority of the San Joaquin River water that enters the Delta during this time period exits the Delta through the State Water Project (SWP) and Central Valley Project (CVP) pumps. Only 1.8% of the total inflow at Vernalis in this time period exited the Delta as Delta outflow by the end of the water year. These results are consistent with DSM2 model runs for historical conditions and demonstrate that only a small fraction (a few per cent) of the San Joaquin River water that enters the Delta will flow past Antioch as Delta outflow, whether WaterFix is implemented or not. Thus, I conclude that only a small fraction of the San Joaquin River water that enters the Delta will reach Antioch's intake.

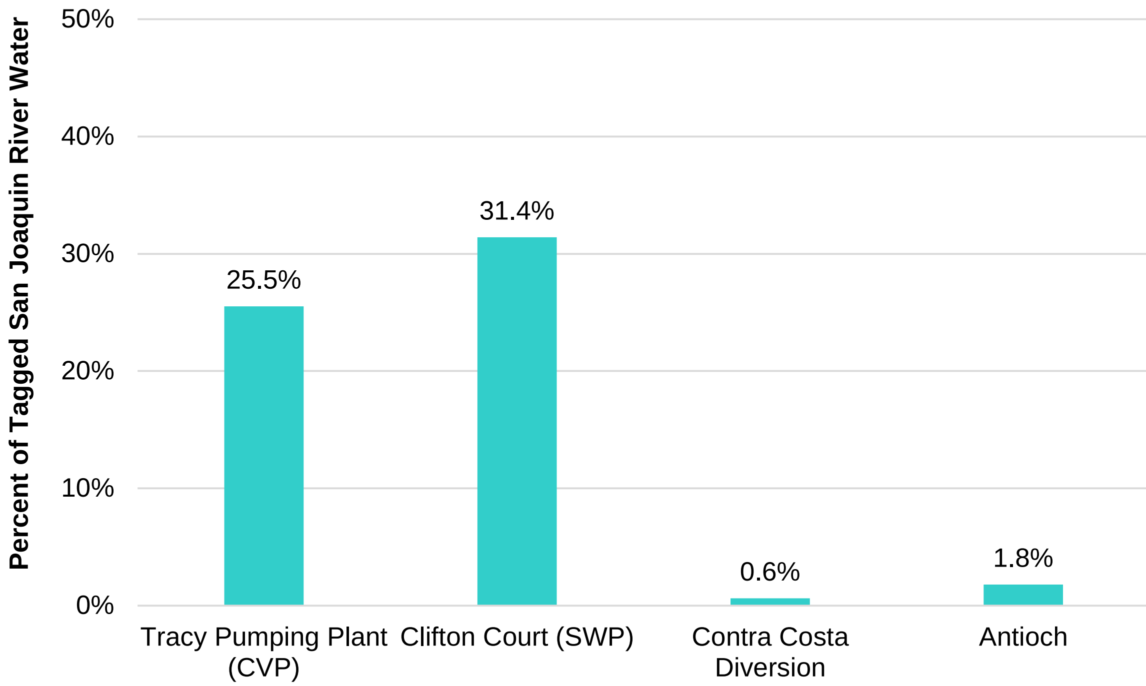

Figure 1 Fate of San Joaquin River water that flows into the Delta between February 1 and June 30, 1987 (a dry water year). Not shown is water that remains in the Delta or is diverted from the Delta as part of DICU.

Table 1 Fate of San Joaquin River water entering the Delta between February 1 and June 30, 1987 (a dry year) for WaterFix Scenario 4A, on a mass basis.

Fate of San Joaquin River Inflow between Feb.1 and Jun.30 1987 by mass (TAF)					
Total Inflow	Central Valley Project	State Water Project	Contra Costa Canal	Delta Outflow	Total Export
612	156	192	4	11	363

Dr. Nader-Tehrani concluded that "there is no correlation between an increase in San Joaquin River volumetric contribution at Antioch and any significant increase in EC at Antioch" (DWR-79, 22:12-13), but this is neither directly responsive to our rebuttal testimony nor relevant to our conclusions.

With the WaterFix project, new points of diversion would be added on the Sacramento River, and diversions of water from the NDD would remove Sacramento River water that otherwise would flow into the Delta. Antioch-202 Section 7.2 shows clearly, based on DWR's modeling, that the percent of Sacramento River water decreases at Antioch's intake during certain times of year, depending on water year type, for the Boundary 1 scenario (Figure 2) relative to the NAA and EBC2 (existing condition) model scenarios. Reductions in the fraction of Sacramento River water at Antioch are "made up" by San Joaquin River water and inflow from the Bay (see Figure 3 and Figure 4, reproduced from Antioch-202 Figures 7 and 8). As described in detail in Antioch-202 (Section 3.2) and as confirmed in Dr. Nader-Tehrani's rebuttal testimony[2], San Joaquin River water is typically higher in EC than the Sacramento River, and water from the Bay typically has a higher salinity than all other sources of water to the Delta. Dr. Nader-Tehrani's rebuttal testimony has not changed my conclusion that as these other, lower-

2 "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." DWR-79, p.22:22-26.

"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." DWR-79, p.25:5-7.

quality water sources replace Sacramento River water at Antioch's intake, water quality will be degraded.

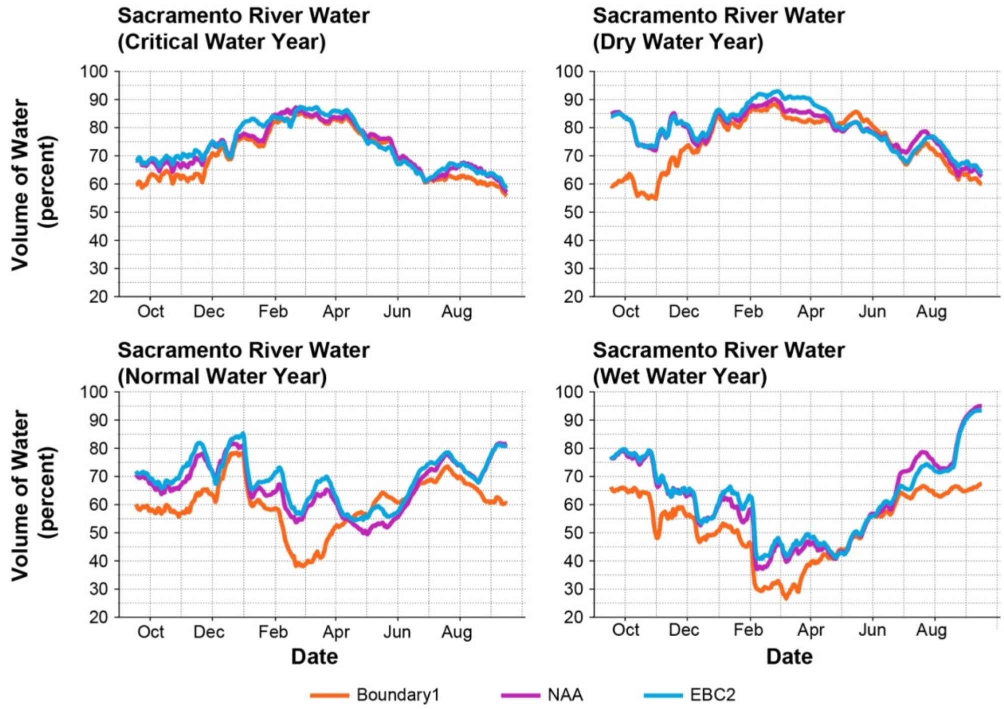

Figure 2 Source fractions of Sacramento River water at Antioch's intake as modeled by DSM2, averaged by water year type (Figure 6 of Antioch-202).

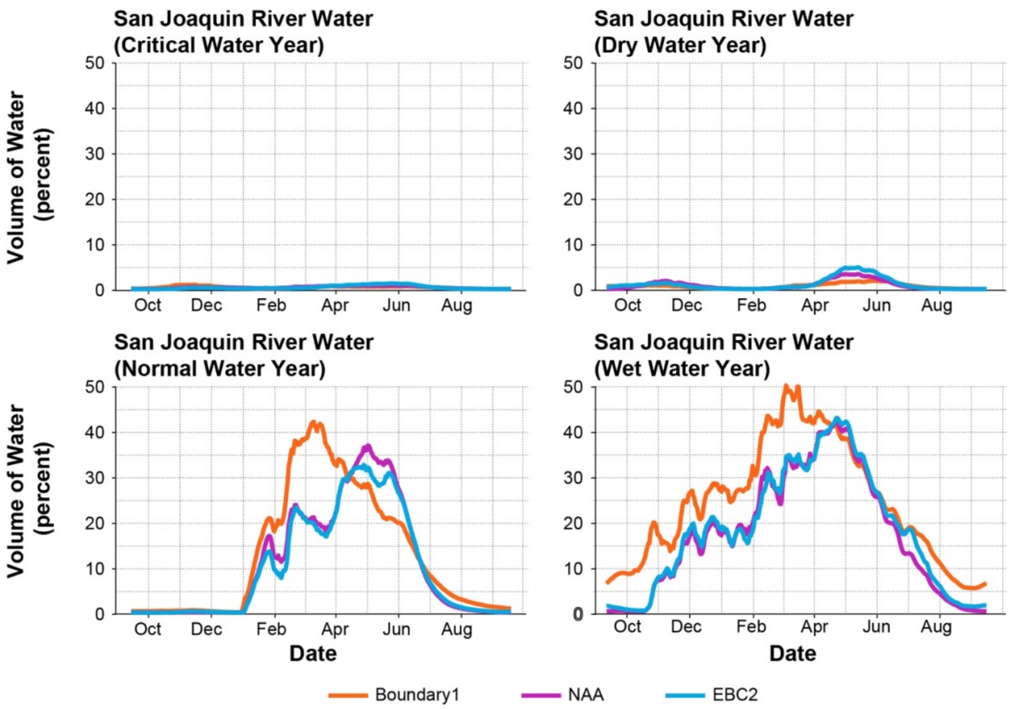

Figure 3 Source fractions of Sacramento River water at Antioch's intake as modeled by DSM2, averaged by water year type (Figure 7 of Antioch-202).

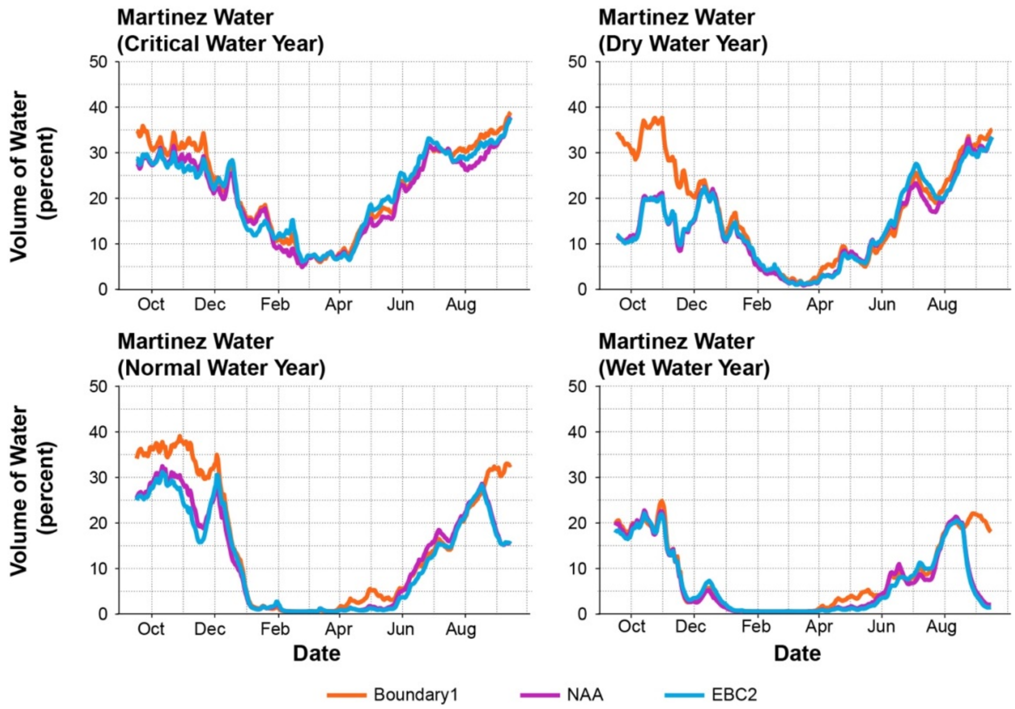

Figure 4 Source fractions of Sacramento River water at Antioch's intake as modeled by DSM2, averaged by water year type (Figure 8 of Antioch-202).

In addition, the relationship between EC and flow is incorporated into the DSM2 model. See, for example, Figure 5 below, which shows flow rates of the San Joaquin River at Vernalis and EC in those inflows to the Delta. The top images show the EC and flow at Vernalis for the entire simulation period, and the bottom images show water years 1981 (dry) and 1982 (wet), which were chosen because they show low and high flow periods. Because my analysis is based upon DWR's model results, and because DWR's modeling incorporates the relationship between flow and EC at Vernalis directly, in my opinion it is misleading and erroneous for DWR to imply that the relationship between flow and EC in San Joaquin River inflows to the Delta somehow negates or misrepresents the salinity increases indicated by DWR's modeling and illustrated in Antioch-202.

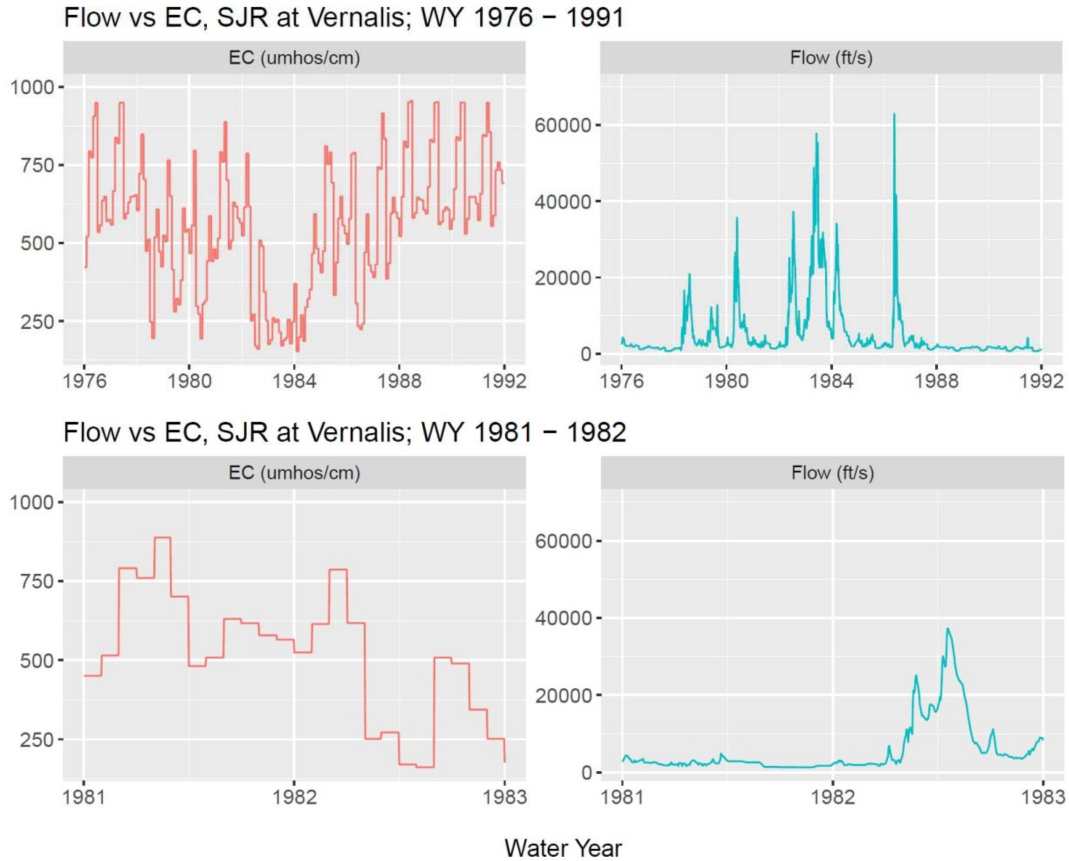

Figure 5 DSM2 model results showing the relationship between EC and flow of the San Joaquin River at Vernalis. The top images show the EC and flow for the entire 16-year record, and the bottom image shows water years 1981 and 1982.

Rebuttal Opinion 2: Dr. Nader-Tehrani's rebuttal testimony regarding compliance with D-1641 water quality objectives is misleading.

Dr. Nader-Tehrani testified that "the frequency of days CWF scenarios exceeded D-1641 salinity requirements are mostly similar or lower compared to the NAA." (DWR-79, p.36:5-6). As shown in Antioch-202 Table 8 and Table 9, the Boundary 1 scenario exceeds the 250 mg/L chloride water quality objective much more frequently in dry and normal years than the NAA. For example, in 1979 (below normal water year) the 250 mg/L chloride water quality objective was exceeded 64 days under the Boundary 1 scenario and 17 days for the NAA scenario, an increase of 47 additional days.

Analysis of the exceedance of the 150 mg/L water quality objective does show that in fact, the WaterFix scenarios are generally no worse than the NAA.[3] However, my analysis demonstrates that water quality will be degraded at Antioch regardless of whether strict compliance with the D-1641 150 mg/L objective is achieved. That is, DWR's DSM2 model runs indicate that chloride concentrations are expected to increase substantially in some year types, particularly for the Boundary 1 scenario. As shown in Antioch-202 Table 12, there are many years of the modeled record (1976 to 1991) where there is a substantial loss in the number of days where chloride remains below 150 mg/L even though the water quality objective is met. Over the 16-year period (by water year), DWR's model results show that chloride concentrations in the Boundary 1 scenario would exceed 150 mg/L a total of 1,976 days, whereas chloride concentrations in the NAA would exceed 150 mg/L a total of 1,628 days (i.e., the Boundary 1 scenario would exceed a chloride concentration of 150 mg/L for an additional 348 days compared to the NAA).

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[3] During my cross examination by Mr. Berliner on May 23, 2017, I was asked about my understanding of DWR-513 Figure C6, which presents DWR's analysis of compliance with the 150 mg/L water quality objective. I stated that "we tried to reproduce this chart, and were not able to do." This was a misstatement. While my colleagues and I were initially unable to reproduce the information in this chart, in later analyses we were able to verify DWR's analysis using calendar days, as would be expected since we have used the same model runs.

Executed on June 8, 2017 in Pasadena, CA.

Susan C. Paulsen