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BEFORE THE STATE WATER RESOURCES CONTROL BOARD

PHASE 2 - 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	**REBUTTAL TESTIMONY OF SUSAN PAULSEN IN SUPPORT OF PROTEST OF THE CITY OF ANTIOCH, PHASE 2.** **(Exhibit: Antioch – 600)**

I, Susan C. Paulsen, declare as follows:

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 (1997-2014) in various positions, including President. 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 that used chemical source fingerprinting to validate volumetric fingerprinting simulations using Delta models (including the Fischer Delta Model (FDM) and the Delta Simulation Model II (DSM2)). 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.

A copy of my *curriculum vitae* can be found in Exhibit Antioch-201.

As before, I incorporate as part of my testimony my prior Reports and exhibits submitted in support of Antioch's Part 1 case in chief, rebuttal, and sur-rebuttal and Part 2 case in chief.

SUMMARY OF TESTIMONY

The Petitioners' Part 2 case in chief proposed a new operations scenario, CWF H3+, as the preferred alternative for the California WaterFix (WaterFix) (DWR-1010 p.2:5-7), and Petitioners released Delta Simulation Model (DSM2) modeling files for the CWF H3+ scenario concurrently with their Part 2 case in chief testimony. Because Protestants did not have access to the CWF H3+ modeling files prior to the Part 2 proceedings, I was asked by the City of Antioch (City) to evaluate the CWF H3+ scenario and determine impacts to water quality at the City's intake. My rebuttal testimony is focused on water quality impacts to the City resulting from CWF H3+ operations.

My analysis of CWF H3+ does not change the four opinions that comprised my

Part 2 case in chief testimony (Antioch-500 Errata):

- Opinion 1. Prior to about 1917, water within the Delta and at Antioch's intake location was historically fresh.
- Opinion 2. The Boundary 2 scenario is closest to "natural" flow conditions.
- Opinion 3. Fall X2 is an important component to establishing flow criteria that will not impair beneficial uses of water in the western Delta
- Opinion 4. At a minimum, flow criteria protective of beneficial uses and public trust values at Antioch should include requiring D-1641 municipal and industrial water quality objectives be maintained at Antioch, as the 1968 Agreement is not protective of such beneficial uses at Antioch.

I have formed additional opinions following a review of DSM2 output data for CWF H3+, which are numbered sequentially and are as follows:

- Opinion 5. CWF H3+ results in periods of higher salinity in the western Delta than other WaterFix scenarios; fewer days of useable water at Antioch's intake compared to scenarios H3, H4, BA H3+, and Boundary 2; and fewer days of compliance with the D-1641 chloride criterion of 250 mg/L at Contra Costa Canal than scenarios H3, H4, BA H3+, and Boundary 2.
- Opinion 6. Total exports from the NDD and south Delta are greater during some months for CWF H3+ than all other scenarios, including the Boundary scenarios.
- Opinion 7. Water quality at Antioch's intake and in the western Delta will be worse than modeled for Scenario CWF H3+ if, through adaptive management, the Project is operated to Boundary 1.

TESTIMONY

Opinion 5: CWF H3+ results in periods of higher salinity in the western Delta than other WaterFix scenarios; fewer days of useable water at Antioch's intake compared to scenarios H3, H4, BA H3+, and Boundary 2; and fewer days of compliance with the D-1641 chloride criterion of 250 mg/L at Contra Costa Canal than scenarios H3, H4, BA H3+, and Boundary 2.

Model scenarios H3, H4, BA H3+ and CWF H3+ use many common operations assumptions in CalSim II. For example, the North Delta Diversion (NDD) intake operations, NDD bypass flows, minimum flows near Rio Vista, south Delta exports, and Head of Old River barrier operations are defined by Scenario H3 operations (DWR-1069). There are differences, however, in Delta outflow criteria and Old and Middle River flow criteria that make Scenarios H3, H4, BA H3+, and CWF H3+ unique.

DWR-1015 describes the differences between CWF H3+ and Scenarios H3, H4, and BA H3+, and some of the water quality changes that result from these differences. From my review of DWR-1015 and DWR-1069, three components that differentiate CWF H3+ include:

1) The requirements for combined flow in Old and Middle River (OMR) during October and November for CWF H3+ are defined by the No Action Alternative (NAA), while for all other months, the requirements for OMR are defined by Scenario H3 (DWR-1069).[1]

2) South Delta export restrictions were removed for the months of October and November for Scenario CWF H3+, resulting in lower net Delta outflow (NDO) and higher salinity in the fall and winter months (DWR-1015, p.4:11-12).

3) The spring Delta outflow requirements for CWF H3+ are higher than for other

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[1] The information provided in DWR-1069 at Table 1 indicates that the CWF H3+ scenario was modeled using the OMR requirements for the NAA scenario for October and November, and the OMR requirements for the H3 scenario in all other months. However, Table 3 of DWR-1069 appears to imply that the OMR criteria were consistent for scenarios H3, H4, and H3+; we believe that the "H3+" scenario referenced in DWR-1069 Table 3 is actually Scenario "BA H3+."

scenarios, resulting in less south Delta exports. “With less exports, fresher Sacramento River water is not moved through sections of the interior Delta, resulting in higher salinity in those sections of the Delta.” (DWR-1015 p.4:5-7)

DWR did not present figures of modeled salinity at Antioch’s intake location as part of their Part 2 case in chief, but DWR did present modeled salinity at Contra Costa Canal. Contra Costa Canal is located in the western Delta and is one source of supplemental water purchased by Antioch from CCWD. Thus, model results describing salinity at Contra Costa Canal are indicative of salinity in the western Delta generally, and of salinity in one of the main sources of Antioch’s supplemental water supply. I examined salinity impacts both at Contra Costa Canal (using DWR’s figures and DWR’s model results) and at Antioch’s intake (using DWR’s model results), as discussed below.

Sixteen-year monthly average simulated chloride concentrations at Contra Costa Canal for the NAA and for WaterFix scenarios H3, H4, BA H3+, and CWF H3+ were depicted by DWR in DWR-1015 Figure CL1 (reproduced below). As shown in DWR-1015 Figure CL1, sixteen-year monthly average[2] chloride concentrations at Contra Costa Canal are simulated to be higher for scenario CWF H3+ than for the other scenarios shown in DWR-1015 Figure CL1 (NAA, H3, BA H3+, H4) during the months of October, November, February, March, and April. During December and January, sixteen-year monthly average chloride concentrations for CWF H3+ are higher than for the project scenarios (H3, H4, BA H3+) but lower than the NAA scenario. Thus, sixteen-year monthly average chloride concentrations are higher at Contra Costa Canal than all

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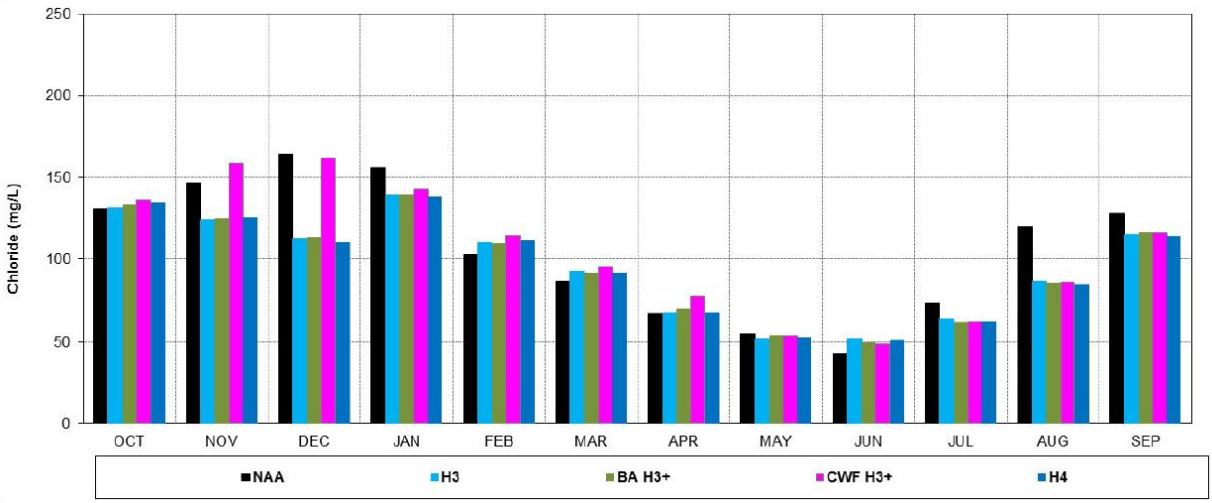
[2] Monthly average salinity presented by DWR is calculated as the average of each salinity data point during each month for all 16 years. For example, the monthly average salinity during January is the average salinity during each day of January, during every January of the 16-year DSM2 simulation. When sixteen-year monthly averages are calculated from DSM2 data on 15-minute intervals, the monthly average salinity during January would be the average of 47,616 data points (4 [15-minute periods]/hour*24 hours/day*31 days/month*16 years). As discussed in prior testimony, long-term average data are not appropriate to evaluate project impacts and are not useful for planning purposes for water purveyors such as the City. However, increases in long-term average salinity values are useful in comparing overall salinity trends between model scenarios.

the project scenarios presented in DWR's Part 2 case in chief testimony in 7 of 12 months (58% of months), and higher than the salinity simulated in the NAA scenario in 5 of 12 months (42% of months).



DWR-1015 Figure CL1. Monthly average chloride concentration at Contra Costa Canal.

Because the water quality impacts of the proposed WaterFix project are difficult to discern from long-term average data (such as the results shown in DWR-1015 Figure CL1; see also prior testimony), I evaluated daily average chloride concentrations at Antioch's intake location for Scenarios CWF H3+ and BA H3+ using DWR's DSM2 output files. Specifically, I used model results for scenarios CWF H3+ and BA H3+ to update the analysis of chloride concentrations at Antioch's intake on each day at slack current after higher high tide (i.e., at the time of day when water is determined to be "useable" per the 1968 Agreement) (Antioch-500 Errata pp. 12-14). Figure 1 was created from DSM2 results to show, using colored bars, time periods when water is simulated to be "useable" at the City's intake. During the 10% wettest conditions in the sixteen-year simulation period, CWF H3+ results in fewer days of "useable" water than all scenarios except Boundary 1. Results are also tabulated for each year in the 16-year simulation period in Table 1. Figure 1 and Table 2 show that CWF H3+ results in 365 more days of useable water per year than Boundary 1 and 327 fewer days of useable

water than Boundary 2. The CWF H3+ Scenario results in 1 and 39 fewer days of useable water than Scenarios H3 and H4, respectively. Relative to existing conditions (EBC2), Scenario CWF H3+ results in 65 fewer days of useable water in the sixteen-year model period.

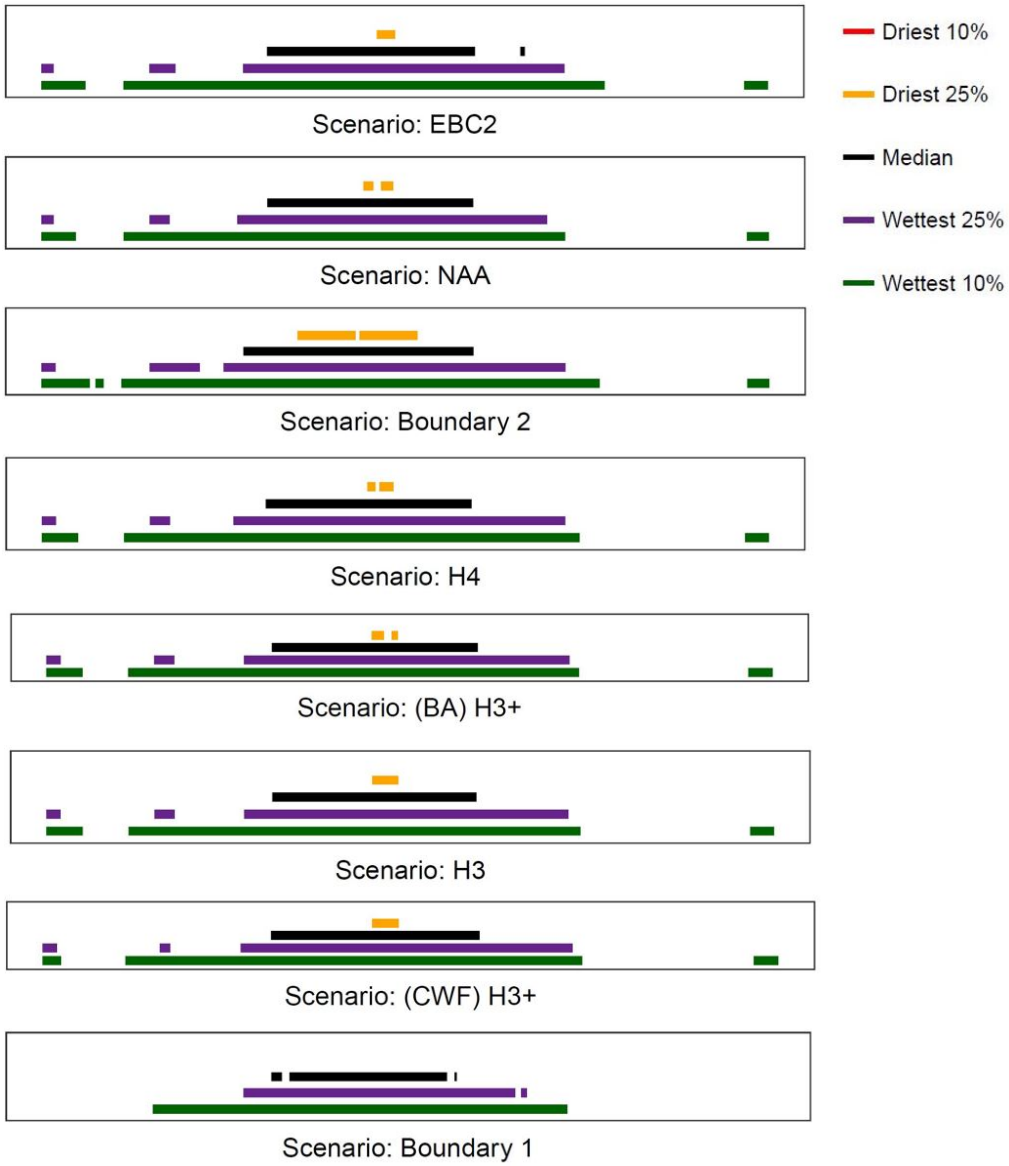


Figure 1. The presence of "useable water" at Antioch's intake as determined using modeled salinity at two hours after higher high tide for the simulation period 1976-1991. Colored bars indicate simulated chloride concentrations below 250 mg/L under different hydrologic conditions as indicated in the plot.

Table 1. Number of days of useable water per year (chloride concentration below 250 mg/L at Antioch 2 hours after higher-high tide) for different hydrologic conditions (calculated from DSM2 model results for 1976-1991)

	EBC2 (days)	NAA (days)	B1 (days)	CWF H3+ (days)	H3 (days)	BA H3+ (days)	H4 (days)	B2 (days)
Driest 10 %	0	0	0	0	0	0	0	0
Driest 25 %	10	13	0	14	14	11	13	60
Median	108	104	87	104	103	104	104	116
Wettest 25 %	183	174	140	179	182	183	186	206
Wettest 10 %	278	252	207	250	259	259	261	282

Table 2. Number of "useable" water days per year as defined by the 1968 Agreement.[3]

WY Type	WY	EBC2	NAA	Boundary 1	CWF H3+	H3	BA H3+	H4	Boundary 2
Critical	1976	26	34	5	44	43	44	43	99
Critical	1977	0	0	0	0	0	0	0	0
Normal	1978	165	161	159	163	163	163	165	168
Normal	1979	145	145	104	146	146	146	146	149
Normal	1980	174	160	140	175	171	172	179	183
Dry	1981	97	85	74	85	76	81	79	100
Wet	1982	247	225	203	232	235	236	242	244
Wet	1983	365	320	300	300	319	318	312	331
Wet	1984	252	235	186	233	233	232	258	245
Dry	1985	85	95	39	113	112	124	109	178
Wet	1986	163	156	126	164	161	163	162	170
Dry	1987	68	79	54	90	87	87	88	119
Critical	1988	41	60	35	35	35	35	35	63
Dry	1989	77	74	66	71	69	71	69	79
Critical	1990	24	9	8	12	15	9	16	62
Critical	1991	39	40	39	40	39	39	39	40
	sum	**1968**	**1878**	**1538**	**1903**	**1904**	**1920**	**1942**	**2230**

Lastly, I compared model results for scenario CWF H3+ to the D-1641 250 mg/L chloride threshold, which is evaluated at Contra Costa Canal at Pumping Plant No. 1. Table 3 below is revised from Table 8 of Antioch-202 Errata to include additional WaterFix model scenarios. CWF H3+ shows more exceedances of the 250 mg/L chloride water quality

[3] The NAA and EBC2 labels were switched in Antioch-202 Errata Table 3. Table 2 corrects this labeling error in addition to providing data for all WaterFix scenarios.

objective than WaterFix scenarios H3, H4, BA H3+, and Boundary 2 during 1989 (dry water year) and 1991 (critical water year), and more exceedances than scenarios H3, H4, and Boundary 2 in 1978 (normal water year). Over the sixteen-year simulation period as a whole, CWF H3+ results in 113 more days of exceedances than Scenario H3, 118 more days of exceedance than Scenario H4, 87 more days of exceedances than Scenario BA H3+, and 276 more days of exceedances than the Boundary 2 scenario.

Table 3. Number of days per water year that the D-1641 250 mg/L chloride water quality objective is ***not*** met (i.e., number of days it is exceeded) at Contra Costa Canal Pumping Plant No.1.

WY Type	WY	EBC2	NAA	Boundary 1	CWF H3+	H3	BA H3+	H4	Boundary 2
Critical	1976	26	0	0	0	0	0	0	0
Critical	1977	0	23	0	0	0	0	0	0
Normal	1978	6	78	85	84	56	84	73	0
Normal	1979	0	7	57	0	0	0	0	0
Normal	1980	45	24	18	0	0	0	0	0
Dry	1981	0	0	0	0	0	0	0	0
Wet	1982	2	2	8	0	6	0	0	0
Wet	1983	21	0	0	0	0	0	0	0
Wet	1984	0	0	0	0	0	0	0	0
Dry	1985	0	0	8	0	0	0	0	0
Wet	1986	15	21	0	0	0	0	0	0
Dry	1987	0	0	38	0	0	0	0	0
Critical	1988	0	0	0	0	0	0	0	0
Dry	1989	55	80	88	87	55	53	51	0
Critical	1990	23	18	0	0	0	0	0	0
Critical	1991	17	91	95	99	52	52	34	0
	sum	**210**	**344**	**397**	**276**	**163**	**189**	**158**	**0**

As described in Antioch-500 Errata (e.g., p. 14:8-10), the chloride concentrations simulated to occur at Antioch's intake under all modeled scenarios (including existing conditions EBC2, NAA, Boundary 1, Boundary 2, H3, and H4) are higher than "natural" salinity.[4] Chloride concentrations for Scenario CWF H3+ are also higher than "natural"

[4] As detailed in Antioch-500 Errata and Antioch-502, a large amount of data and information exist that can be used to determine "natural" or "historical" salinity conditions at Antioch. Antioch-500 Errata and Antioch-502 establish that all of the scenarios evaluated in Antioch's Part 1 and Part 2 Case in Chief

(footnote continued)

salinity. Similarly, chloride concentrations simulated to occur at Antioch's intake for Scenario CWF H3+ are higher than chloride concentrations under existing conditions (EBC2).

Higher salinity levels from CWF H3+ will alter existing and historical water quality conditions in the Delta such that it is expected that recreation and other public trust resources could be adversely impacted unless mitigated. As noted in the 2006 Bay-Delta Water Quality Control Plan (SWRCB-27) at p. 10, the D-1641 salinity objectives for municipal and industrial use are also intended to protect recreational uses, including both REC-1 (water contact recreation) and REC-2 (non-contact water recreation) beneficial uses. Thus, an increase in the number of simulated exceedances of the D-1641 250 mg/L chloride threshold for Scenario CWF H3+ indicates an increase in expected non-compliance with water quality objectives intended to protect both REC-1 and REC-2 uses.

Opinion 6. Total exports from the NDD and south Delta are greater during some months for CWF H3+ than all other scenarios, including the Boundary scenarios.

During the Part 1 proceedings, the Boundary 1 and Boundary 2 scenarios were presented "to provide a broad range of operational criteria anticipated to occur within the adaptive management process" (DWR-1010 p.9:3-5). In their Part 2 case in chief, DWR acknowledged that "Due to adaptive management, CWF H3+ operations could be refined in the future… and any outcome is anticipated to be within the range of alternatives analyzed in the EIR/EIS and within Boundary 1 and Boundary 2, as presented in Part 1 of the State Water Board hearings" (DWR-1010 p. 9:12-17). In DWR-1010 Figure 2, Scenario CWF H3+ is depicted as falling between the Boundary scenarios and between Scenarios H3 and H4 in terms of Delta outflow requirements.

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testimony (i.e., EBC2, NAA, H3, H4, Boundary 1, and Boundary 2) exhibit higher salinity at Antioch's intake than natural conditions. Scenario CWF H3+ similarly exhibits salinity at Antioch's intake that is higher than natural conditions.

To evaluate these statements, I used DWR's DSM2 model files to compute the volume of water exported from the Delta for all model scenarios and for each month in the 16-year simulation period. Figures showing the results of these calculations are included as Antioch-602. From these figures and DWR's model data, I also evaluated if the volume of water exported from the Delta under Scenario CWF H3+ fell between Boundary 1 and Boundary 2, and I also compared the total volume of water exported from the Delta in Scenario CWF H3+ to the total volume of water exported under the No Action Alternative (NAA) and existing conditions (EBC2). Results of this analysis are summarized in Table 4. As shown in Table 4, the total volume of water exported in Scenario CWF H3+ exceeds the volume exported in the Boundary 1 and Boundary 2 scenarios in 28 of 192 months (15% of the simulation period). The volume of water exported in Scenario CWF H3+ exceeds the volume exported in the NAA and EBC2 scenarios in 8 of 192 months (4% of the simulation period). Thus, I conclude that the operations of CWF H3+ are not bound by the Boundary 1 and Boundary 2 scenarios, and for a significant portion of the simulation period, the amount of water exported under CWF H3+ exceeds the amount of water exported under all the simulated scenarios, including Boundary 1, Boundary 2, H3, H4, as well as the NAA and existing conditions.

Table 4. Months when total exports (NDD and south Delta) are greater for CWF H3+ than for the Boundary scenarios and the NAA and EBC2 scenarios.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Percent of Year
1976			X										8%
1977													0%
1978					X					X	X	XX	33%
1979					X				XX				17%
1980										X	X		17%
1981			X						XX				17%
1982										X	X	X	25%
1983	XX	X	X	X									33%
1984										X	X		17%
1985									XX				8%
1986						X				X	XX		25%
1987									XX				8%
1988													0%
1989									XX	X	X		25%
1990													0%
1991													0%

Notes: "X" indicates that the total export flow rate is greater for Scenario CWF H3+ than for the Boundary 1 and Boundary 2 scenarios by a margin of at least 5%.

"XX" indicates that the total export flow rate for Scenario CWF H3+ is greater than for all other scenarios, including the EBC2 and NAA scenarios, by a margin of at least 5%.

Opinion 7. Water quality at Antioch's intake and in the western Delta will be worse than modeled for Scenario CWF H3+ if, through adaptive management, the Project is operated to Boundary 1.

The boundary scenarios have been only briefly mentioned[5] by DWR during the Part 2 proceedings due to DWR's focus on the preferred alternative, Scenario CWF H3+. However, as noted above, "Due to adaptive management, the CWF H3+ operations could be refined in the future" and "the modified operations would only be an outcome of the adaptive management process if the many agencies participating in that process determined that the changes would be protective of fish and wildlife; and any outcome is

[5] "…the Project Description presented in this testimony is now more narrowly focused on CWF H3+. Boundary 1 and Boundary 2, are not further discussed in the Part 2 hearing." DWR-1010, p. 9:8-9.

anticipated to be within the range of alternatives analyzed in the EIR/EIS and within Boundary 1 and Boundary 2, as presented in Part 1 of the State Water Board hearings." (DWR-1010 p.9:12-17).

As shown in Table 2 and as discussed in prior testimony, Boundary 1 results in the greatest water quality degradation at the City's intake. Boundary 1 operations reduce the number of useable water days in the 16-year simulation period by 430 compared to EBC2, and by 365 compared to CWF H3+. As shown in Table 3, Boundary 1 also results in the highest number of exceedances of the D-1641 250 mg/L chloride water quality objective at Contra Costa Canal in the western Delta. Further, the adaptive management process is designed solely for protection of fish and wildlife, and DWR has not testified or indicated that adaptive management will consider or protect municipal and industrial beneficial uses. Thus, if the Project is operated to the Boundary 1 Scenario during adaptive management, water quality impacts will be greater than those simulated for Scenario CWF H3+.

Executed on July 12, 2018 in Pasadena, CA.

Susan C. Paulsen, Ph.D., P.E., Principal Scientist and Practice Director at Exponent