Technical Response to Petitioners' Rebuttal Testimony in the WaterFix Proceedings

STKN-048

Technical Comments on Petitioner’s Rebuttal Testimony in the WaterFix Proceedings

STKN-048

Prepared for

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Acronyms and Abbreviations

DICU	Delta Island Consumptive Use
DOC	dissolved organic carbon
EC	electrical conductivity
fps	feet per second
WY	water year
NAA	No Action Alternative
HAB	harmful algal bloom
FEIR/EIS	Final Environmental Impact Report/Environmental Impact Statement

Opinion 1: DWR's representation of hydrodynamics and velocity in the Delta misses key features of Delta flows and leads to unsupported conclusions regarding water quality impacts to the City of Stockton.

1.1: Channel velocities will not change appreciably in the future because channel velocity in the central Delta is strongly influenced by tidal forcing, and tidal forcing will not change as a result of the WaterFix project. DWR's analysis, which focuses on daily maximum flow velocity and "15-minute absolute velocity (regardless of direction)," ignores important hydrodynamic characteristics that impact water quality within the Delta.

Both rebuttal report DWR-652, which focuses on water quality at Stockton's intake, and rebuttal report DWR-653, which focuses on the potential for harmful algal blooms, include analyses of the velocity of flows in Delta channels. For example, "The analysis presented below focuses on how the CWF [WaterFix] would affect daily maximum velocity and 15-minute absolute velocity (regardless of direction) in channels of the Delta. Daily maximum velocity is assessed because the Delta channels are tidal and thus flows are slowed, and can reverse direction in most channels daily, on the tidal cycle. As such, mathematical daily average velocity may approach zero when flows on the tidal cycle move in opposite directions, and thus is not very useful for determining how channel velocity affects cyanobacteria. In such tidally influences [sic] channels, daily maximum velocity and 15-minute absolute velocity (regardless of direction) are the parameters that best characterize the degree of channel mixing that occurs daily."[1] As detailed below, DWR-652 and DWR-653 presented a simplified analysis of Delta hydrodynamics and channel velocities, presenting only cumulative probability diagrams based on daily maximum and 15-minute absolute velocities. DWR's simplified analysis failed to capture details of Delta hydrodynamics, most notably the "sloshing" nature of tidally-driven flows within the Delta that are important to understanding water quality within the Delta.

To illustrate this point, Exponent has prepared several figures. Figure 1 presents the channel velocities predicted by the DSM2 model at Stockton's intake for water year (WY) 1987, a dry water year.[2] Figure 1 presents the simulated velocities both as 15-minute model output and as

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[1] DWR-653 at p. 13.

[2] See STKN-026 at pp. 8-9 for a discussion of water year classifications.

daily average (or net) velocity.[3] Figure 1 demonstrates that the flow at Stockton's intake reverses direction on a daily basis, with 15-minute velocities ranging from -1.64 feet per second (fps; upstream direction) to +1.81 fps (downstream direction). Thus, flow at Stockton's intake location "sloshes" back and forth twice daily as a result of tidal forcing. In contrast, daily average velocities are much lower, ranging from about -0.1 fps (upstream) to +0.25 fps (downstream). Thus, while instantaneous (15-minute) velocities can reach high levels, high velocities do not persist for long periods of time, and the net velocity, with tidal fluctuations removed, is much lower in this area of the Delta.

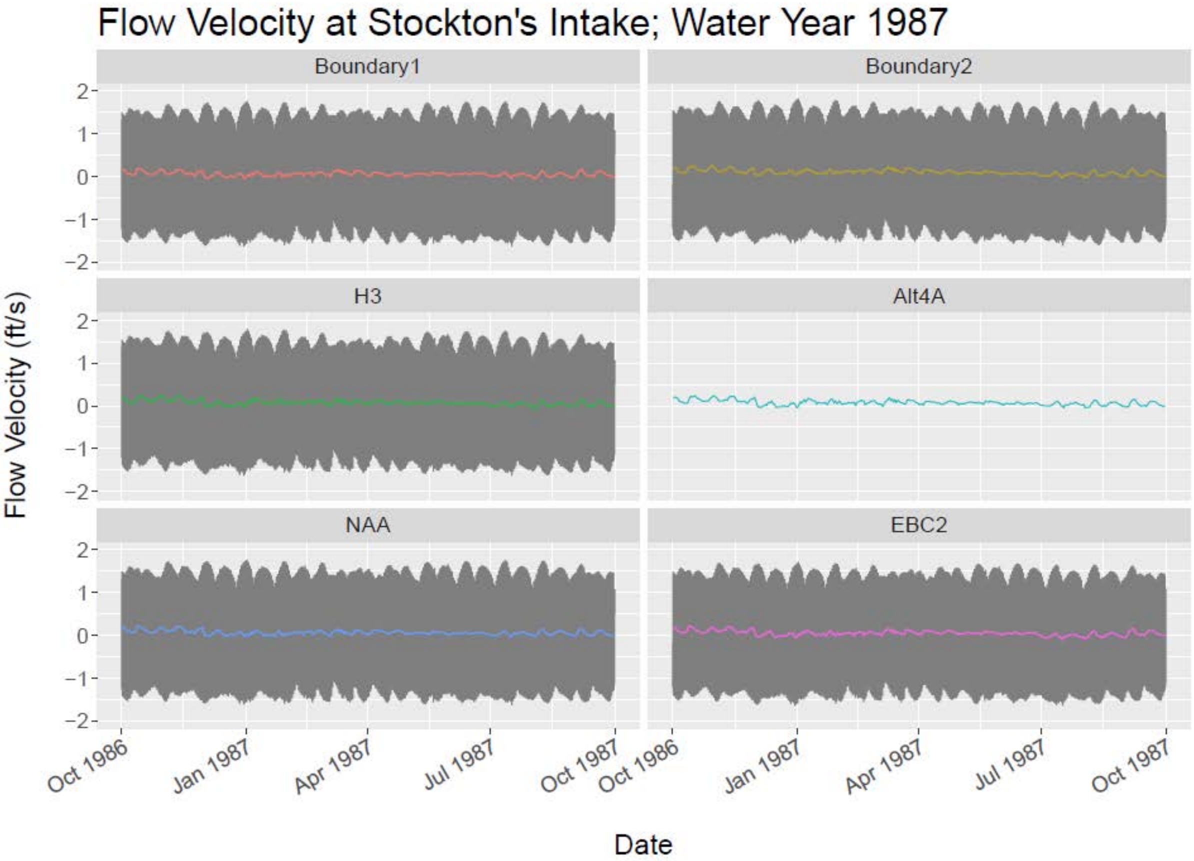

Figure 1 15-minute flow velocity (dark gray) and daily average flow velocity (colored lines) at Stockton's intake during water year 1987, a dry water year.

Figure 2 presents 15-minute and daily average velocities for the month of August 1987. Consistent with Figure 1, 15-minute velocities range from about -1.61 fps (upstream) to +1.75 fps (downstream direction), but daily average velocities range from about -0.1 fps (upstream) to +0.25 fps (downstream). Finally, Figure 3 presents 15-minute and daily average velocities for a

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[3] Note that only daily average velocity is presented in Figures 1-3 for Alt4A, as the model results provided by DWR did not include 15-minute DSM2 model output for the Alt4A scenario.

four-day period in August 1987; 15-minute velocities in Figure 3 range from -1.61 fps (upstream) to +1.55 fps (downstream).

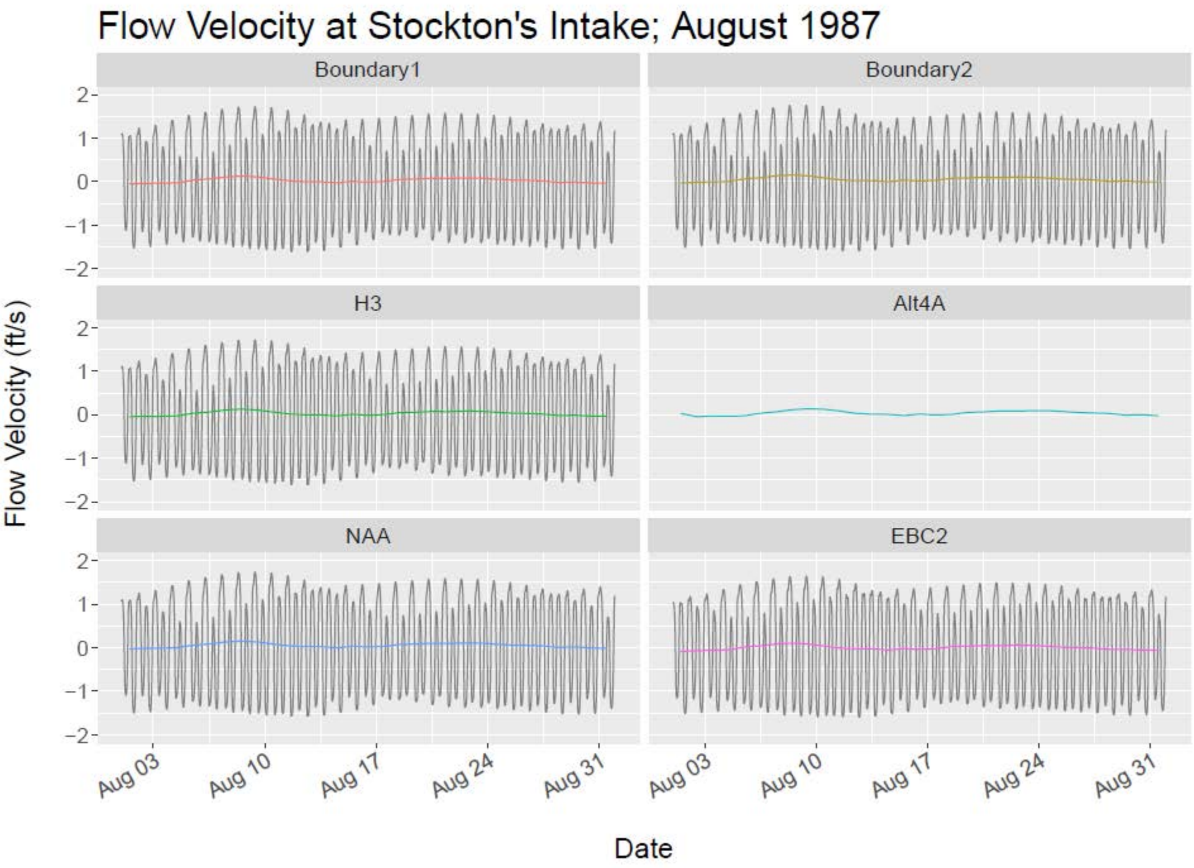

Figure 2 15-minute flow velocity (dark gray) and daily average flow velocity (colored lines) at Stockton's intake during August 1987.

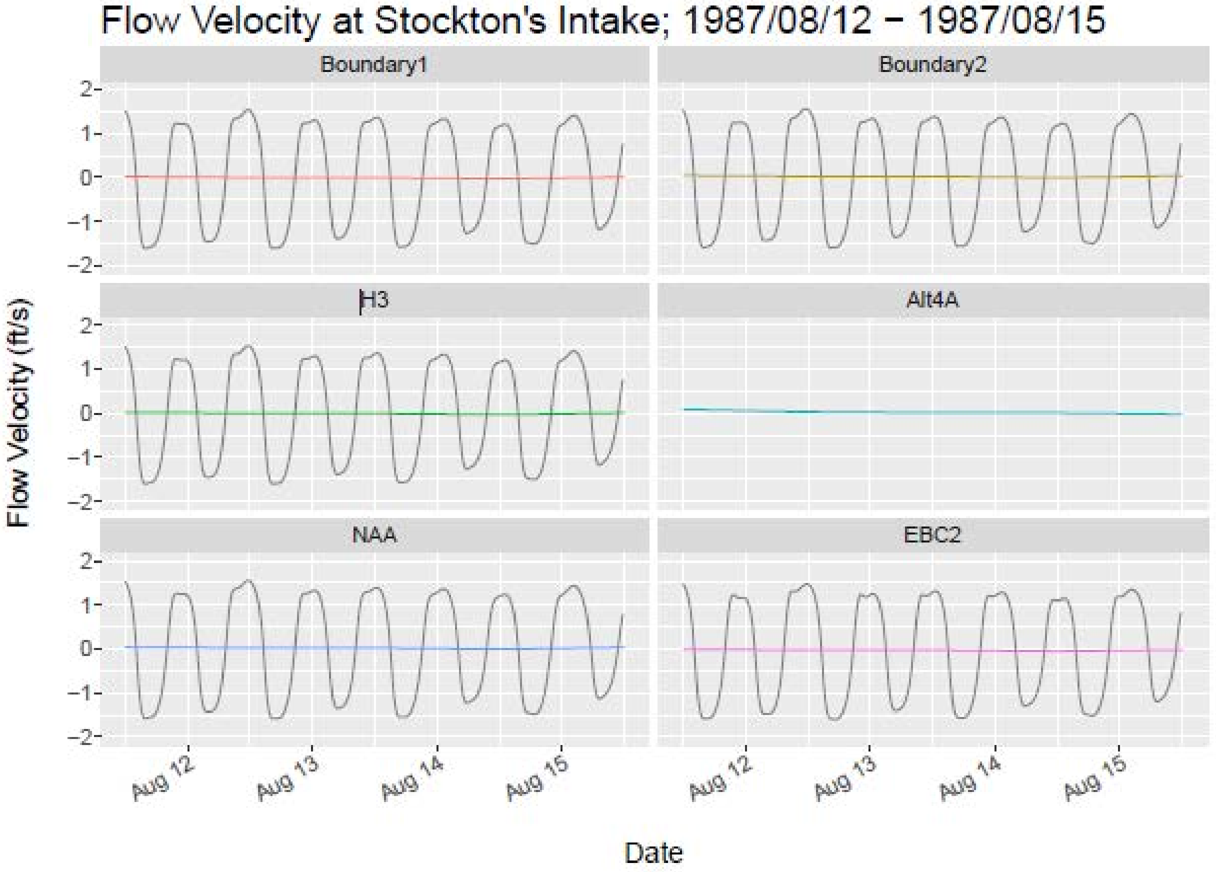

Figure 3 15-minute flow velocity (dark gray) and daily average flow velocity (colored lines) at Stockton's intake from August 11—16, 1987.

In contrast to Figures 1-3, which show the impact of tidal forcing on velocities in the vicinity of Stockton's intake, DWR-652 presented only exceedance probability plots of the daily maximum velocity for individual months over the entire 16-year simulation period (see, e.g., Figure 4, which reproduces DWR-652 Figure 49) or exceedance probability plots of "absolute values of daily velocities, on a 15-minute time step"[4] (see, e.g., Figure 5, which reproduces DWR-652 Figure 50). Note that Figures 4 and 5 present results for the month of August for the 1975-1991 simulation period; also note that DWR-653, which examined the impact of velocity on Microcystis blooms in the Delta, did not present information on velocity at Stockton's intake. Figure 4 indicates that the range of "daily maximum velocity" at Stockton's intake is simulated to vary from about +1.1 fps to about +1.8 fps (downstream), and that the "daily maximum velocity" is similar for the five model scenarios depicted. Figure 5 indicates that the "absolute

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[4] It is unclear exactly what quantity is presented in these figures, as the figure captions refer to "absolute values of daily velocities, on a 15-minute time step." Based on the range of values presented in DWR's figures and consistent with statements by DWR that they evaluated "15-minute absolute velocity (regardless of direction)," we understand that these graphics represent the absolute values of 15-minute DSM2 velocity output, presented on a cumulative probability diagram.

value of daily velocities” varies from about 0 fps to about +1.7 fps (downstream), and that the lines for the five model scenarios shown in this figure fall nearly on top of each other (i.e., are virtually indistinguishable). Neither Figure 4 nor Figure 5 indicates the “sloshing” nature of flows at Stockton’s intake, or the fact that daily average velocities range up to only about +0.25 fps and thus are far lower than the velocities depicted in Figure 4 and lower than all but about 5% of the “absolute values of daily velocities, on a 15-minute time-step.”

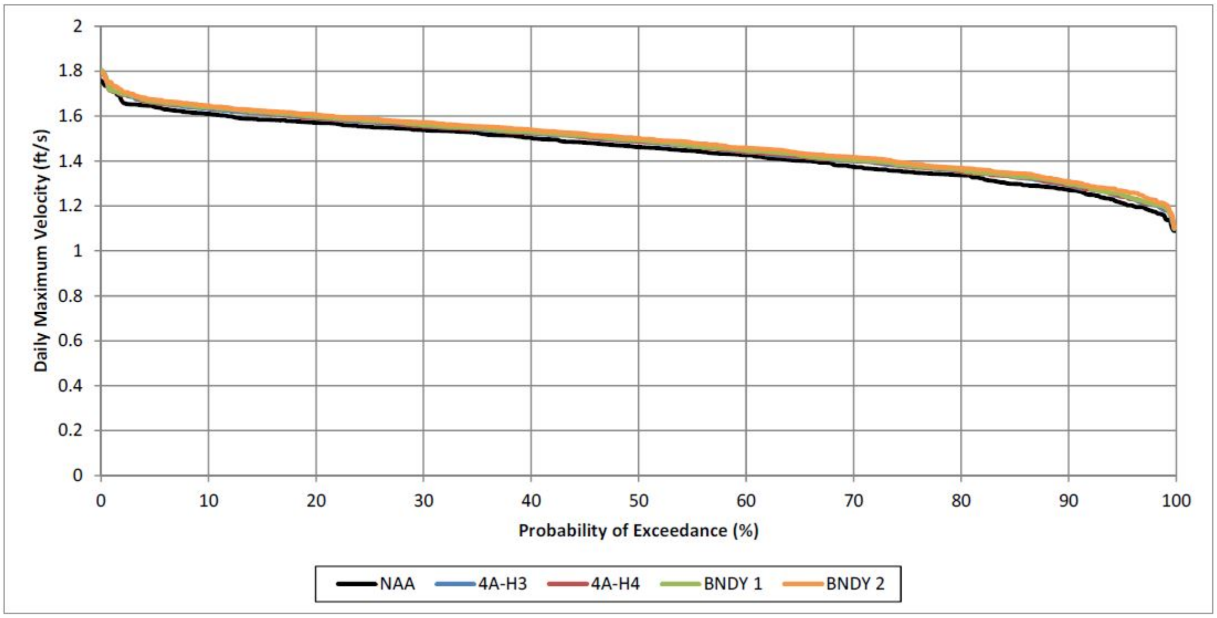

Figure 49. Probability of exceedance of daily maximum velocity in the San Joaquin River near the City of Stockton’s drinking water diversion location for August of the 1976–1991 period of record modeled.

Figure 4 Figure 49 from DWR-652 at p. 59.

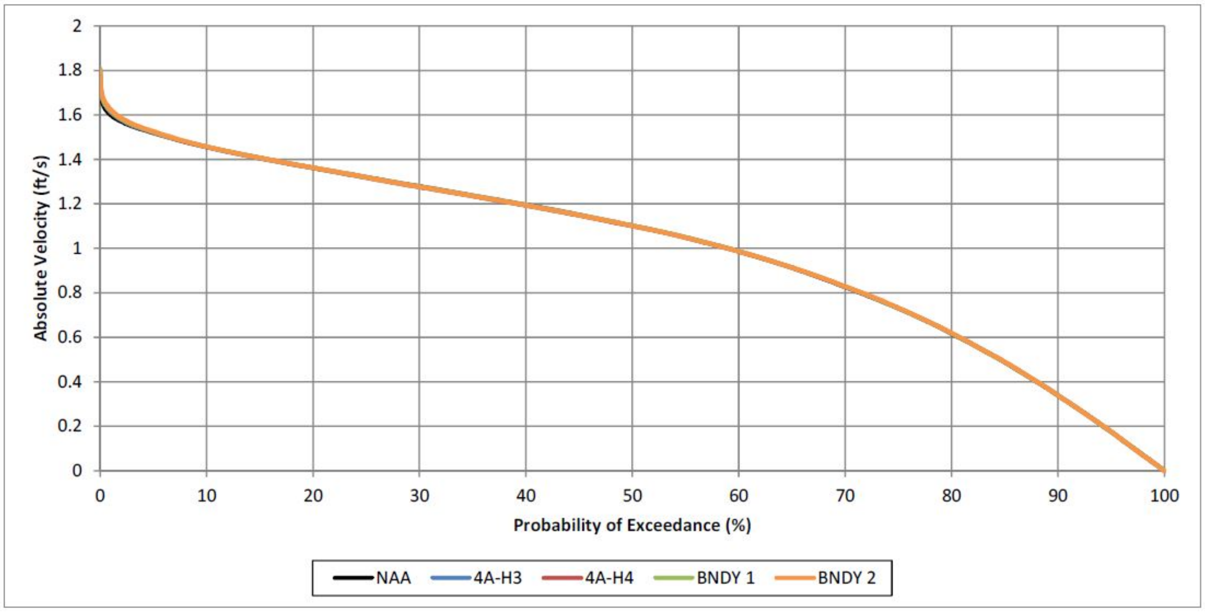

Figure 50. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the San Joaquin River near the City of Stockton's drinking water diversion location for August of the 1976–1991 period of record modeled.

Figure 5 Figure 50 from DWR-652 at p. 59.

DWR has stated that "…modeling shows that the CWF would not substantially increase the frequency with which low channel velocities would occur, relative to the NAA [No Action Alternative]."[5] Figure 1 to Figure 3 clearly indicate that low channel velocities occur approximately four times per day at Stockton's intake (i.e., as the sloshing flow changes direction), and that daily average velocities can be characterized as "low" relative to peak 15-minute velocities. Because the channel velocity typically passes through zero four times per day as a result of tidal forces, it is expected that the frequency of low channel velocities will not change significantly as a result of implementation of the WaterFix project. (After all, the WaterFix project will not change tidal forcing, which is driven by gravitational forces exerted on the earth by the sun and the moon.) For this reason, DWR's analysis of the frequency of low channel velocities is not meaningful in the context of hydrodynamics in the Delta.

DWR has also provided testimony stating that "Channel velocity also dictates residence time within a channel reach because velocities dictate the flushing rate for the reach."[6] Exponent agrees in general with this statement, as the net velocity (i.e., the velocity with tidal sloshing removed) is more strongly related to residence time than either the daily maximum velocity or "absolute values of daily velocities, on a 15-minute time step." However, DWR did not present information regarding either tidally- or daily-averaged net velocities or residence time, and such

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[5] DWR-653 at p. 12.
[6] DWR-653 at p. 13.

information cannot be derived or inferred from the velocity information presented in DWR-652 or DWR-653.

As shown in Figure 1 to Figure 3, the range of velocities over the course of the simulation period is similar for all modeled scenarios and indicative of strong sloshing, and the daily net velocity at Stockton is low for all modeled scenarios relative to the range in 15-minute velocities. Maximum daily flow velocities are relatively invariant between simulated scenarios, as is the frequency of low flows. Strong sloshing and low net flows are generally indicative of high residence times. As shown in STKN-026, the increase in Delta residence time that will be caused by the WaterFix project is greatest in August of dry years, increasing by approximately 37% for the Boundary 1 scenario relative to existing conditions (EBC2). (See Table 1 below, which reproduces Table 5 from STKN-026). The velocity information presented in DWR-652 and DWR-653 cannot be used to calculate or infer residence times within the Delta. DWR's statement that "channel velocity also dictates residence time" is true only if one uses the net velocity to evaluate residence time, but not if one attempts to use the "daily maximum velocity" or "absolute values of daily velocities, on a 15-minute time step" to infer information about residence time.

Table 1 Table 5 from STKN-026 (reproduced for convenience)

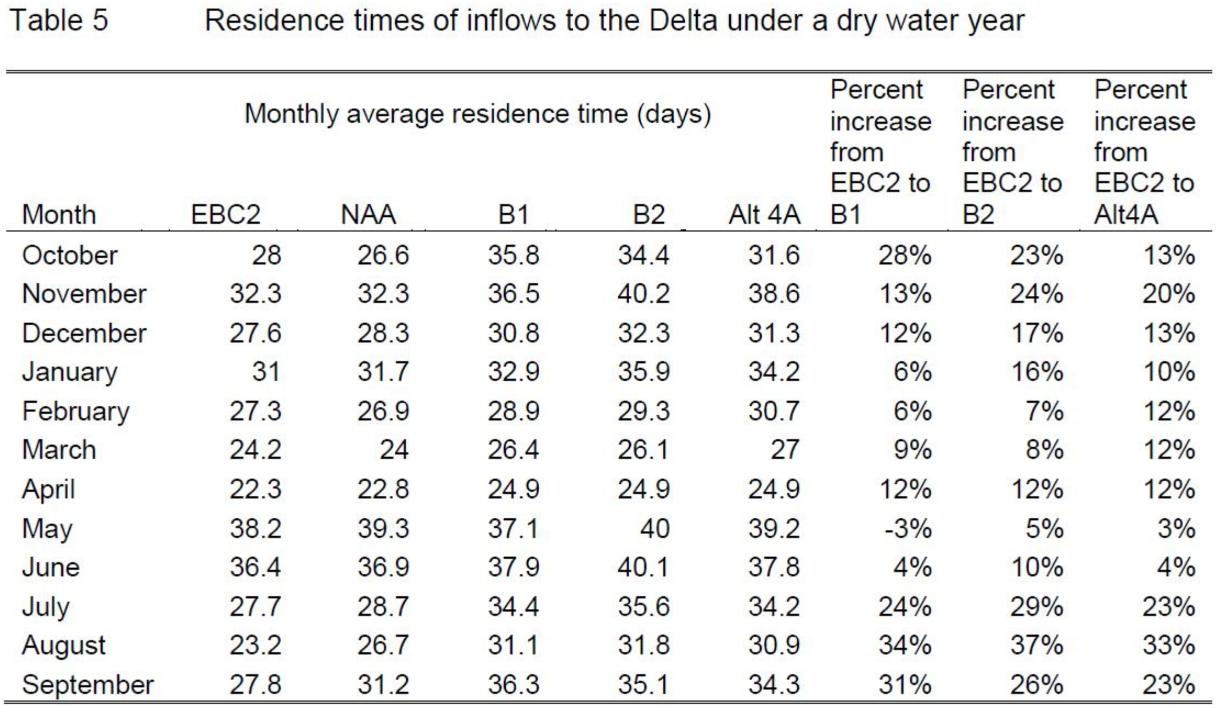

Table 5 Residence times of inflows to the Delta under a dry water year

Month	Monthly average residence time (days) EBC2	NAA	B1	B2	Alt 4A	Percent increase from EBC2 to B1	Percent increase from EBC2 to B2	Percent increase from EBC2 to Alt4A
October	28	26.6	35.8	34.4	31.6	28%	23%	13%
November	32.3	32.3	36.5	40.2	38.6	13%	24%	20%
December	27.6	28.3	30.8	32.3	31.3	12%	17%	13%
January	31	31.7	32.9	35.9	34.2	6%	16%	10%
February	27.3	26.9	28.9	29.3	30.7	6%	7%	12%
March	24.2	24	26.4	26.1	27	9%	8%	12%
April	22.3	22.8	24.9	24.9	24.9	12%	12%	12%
May	38.2	39.3	37.1	40	39.2	-3%	5%	3%
June	36.4	36.9	37.9	40.1	37.8	4%	10%	4%
July	27.7	28.7	34.4	35.6	34.2	24%	29%	23%
August	23.2	26.7	31.1	31.8	30.9	34%	37%	33%
September	27.8	31.2	36.3	35.1	34.3	31%	26%	23%

In summary, it is my opinion that the presentation of simulated velocity in DWR-652 and DWR-653 fails to describe the tidal nature of flows in the Delta and at Stockton’s intake. The velocity information in DWR-652 and DWR-653 cannot be used to assess flushing or residence time within the Delta or in the vicinity of Stockton’s intake. As detailed below, it is my opinion that DWR’s velocity analysis leads to incorrect conclusions regarding the water quality impacts of the WaterFix project on the City of Stockton.

1.2: DWR’s analysis does not consider changes in residence time, and residence time is critical in understanding water quality impacts in the Delta, including at Stockton’s intake

DWR has provided testimony stating that “Mr. Ringelberg, Mr. Burke, Mr. Lee and Mr. Shroshane [sic] did not provide any evidence to support their claims that the CWF would decrease flows and associated channel velocity and thus turbulence and mixing, and increase residence time, in the Delta.”[7] DWR further stated, “Mr. Burke provided insufficient information and Mr. Ringelberg did not provide any evidence to support their respective claims

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[7] DWR-653 at p. 11.

that residence times will increase due to the CWF, and thus the frequency and magnitude of cyanoHABs will be made worse by increased residence times."[8]

However, as described above, neither rebuttal report DWR-652 nor rebuttal report DWR-653 includes an analysis of residence time, and the information in those reports cannot be used to calculate or infer residence times. In contrast and as shown in Table 1, Exponent provided calculations of residence time in STKN-026, and concluded that DWR's model results indicate that residence time will increase significantly as a result of the WaterFix project. As will be shown in this testimony, residence time is an important indicator of water quality. With longer residence times, flushing of the Delta decreases. Certain water quality constituents, including chloride, electrical conductivity (EC), bromide, and organic carbon, are present in high concentrations in sources within the Delta (e.g., agricultural drainage) and can "build up" within the Delta over time. Thus, longer residence times correlate with higher concentrations of these constituents, and result in higher potential for *Mycrocystis* growth, as will be shown in Opinion 5.

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[8] DWR-653 at p. 31.

Opinion 2: DWR's opinions regarding salinity impacts at the location of Stockton's intake are incomplete and misleading. Exponent's analysis of DWR's modeling shows that the WaterFix project will have significant impacts to salinity at the City's intake location.

DWR conducted hydrodynamic and water quality modeling using the DSM2 model, as described in STKN-026. DSM2 model output includes EC, which can then be converted to chloride. Both EC and chloride concentrations are measures of salinity, and both will be addressed below.

2.1: DWR's testimony regarding the FEIR/EIS analysis of salinity impacts at Stockton's intake location is misleading. Exponent's analysis of DWR's modeling shows that the WaterFix project will have significant impacts on the source and quality of water at Stockton's intake.

Even though water quality at the Stockton intake location was not assessed in the Final Environmental Impact Report/Environmental Impact Statement (FEIR/EIS) for WaterFix, DWR has continued to assert that the FEIR/EIS analysis shows that the impacts of WaterFix will be less-than-significant and non-adverse at the City of Stockton's intake location.[9] DWR has also continued to assert that water quality at the locations evaluated in the FEIR/EIS are "representative" of water quality at Stockton's intake location.[10] Specifically, DWR asserted

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[9] See rebuttal report DWR-652 at p. 5: "when the EIR/EIS showed non-adverse effects of the CWF at its assessment locations across the Delta or for a portion of the Delta, such findings were used to make less-than-significant (CEQA)/non-adverse (NEPA) impact determinations to beneficial uses for the entire Delta or defined portions of the Delta, based on the representative nature of the individual assessment locations. Hence, when the EIR/EIS assessment showed less-than-significant/non-adverse impacts of the CWF at its assessment locations across the Delta with regard to the MUN use, it showed less-than-significant/non-adverse impacts of the CWF to the MUN use at the City of Stockton's WTP intake location as well."

[10] See rebuttal report DWR-652 at p. 5-6: "In summary, by determining the CWF-driven changes in water quality at the geographically distributed assessment locations, as well as the Bay-Delta WQCP assessment locations for EC and chloride, and comparing those changes to the Thresholds of Significance listed above for the purposes of making impact determinations, the EIR/EIS assessment determined (among other things) whether the CWF would adversely impact the MUN beneficial use of the San Joaquin River, or any segment of it. In so doing, the EIR/EIS assessment appropriately addressed whether the CWF would impact the City of Stockton's beneficial use of San Joaquin River water by its diversion and treatment of river water for municipal supply use (i.e., the MUN beneficial use at the City's WTP location)."

that the locations of Prisoners Point and Buckley Cove "are representative for purposes of assessing the effects of the CWF on water quality."[11]

As detailed in STKN-026, water quality at Stockton's intake location was not evaluated in the FEIR/EIS. STKN-026 established definitively that both the composition and salinity of water at Buckley Cove also differs from the composition and salinity of water at Stockton's intake location.

To address the assertion that Prisoners Point is representative of Stockton's intake location and consistent with the analyses presented for Buckley Cove in STKN-026, Exponent evaluated the source water composition and chloride levels for two baseline scenarios (EBC2 and the NAA) at Prisoners Point (see Appendix A for additional model runs from Prisoner's Point). Figure 6 shows the chloride concentrations that are simulated for Prisoners Point and Stockton's intake in four hydrologic year types. As shown in Figure 6, chloride concentrations simulated at Prisoners Point range to higher salinity (as chloride) values compared to water at Stockton's intake. For example, daily average chloride concentrations at Prisoners Point in the NAA scenario exhibit peak values of 135 mg/L (critical years), 122 mg/L (dry years), 173 mg/L (normal years), and 138 mg/L (wet years), while daily average chloride concentrations at Stockton's intake exhibit peak values of 99 mg/L (critical years), 93 mg/L (dry years), 136 mg/L (normal years), and 89 mg/L (wet years)—i.e., peak concentrations of chloride for the NAA scenario are higher at Prisoners Point than at Stockton's intake in all hydrologic year types.

Thus, I conclude that neither Buckley Cove (see STKN-026) nor Prisoners Point (see Figure 6 and figures in Appendix A) are representative of Stockton's intake location. I further conclude that, consistent with STKN-026, the FEIR/EIS did not properly evaluate water quality impacts at Stockton's intake location.

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[11] DWR-652 at p. 5.

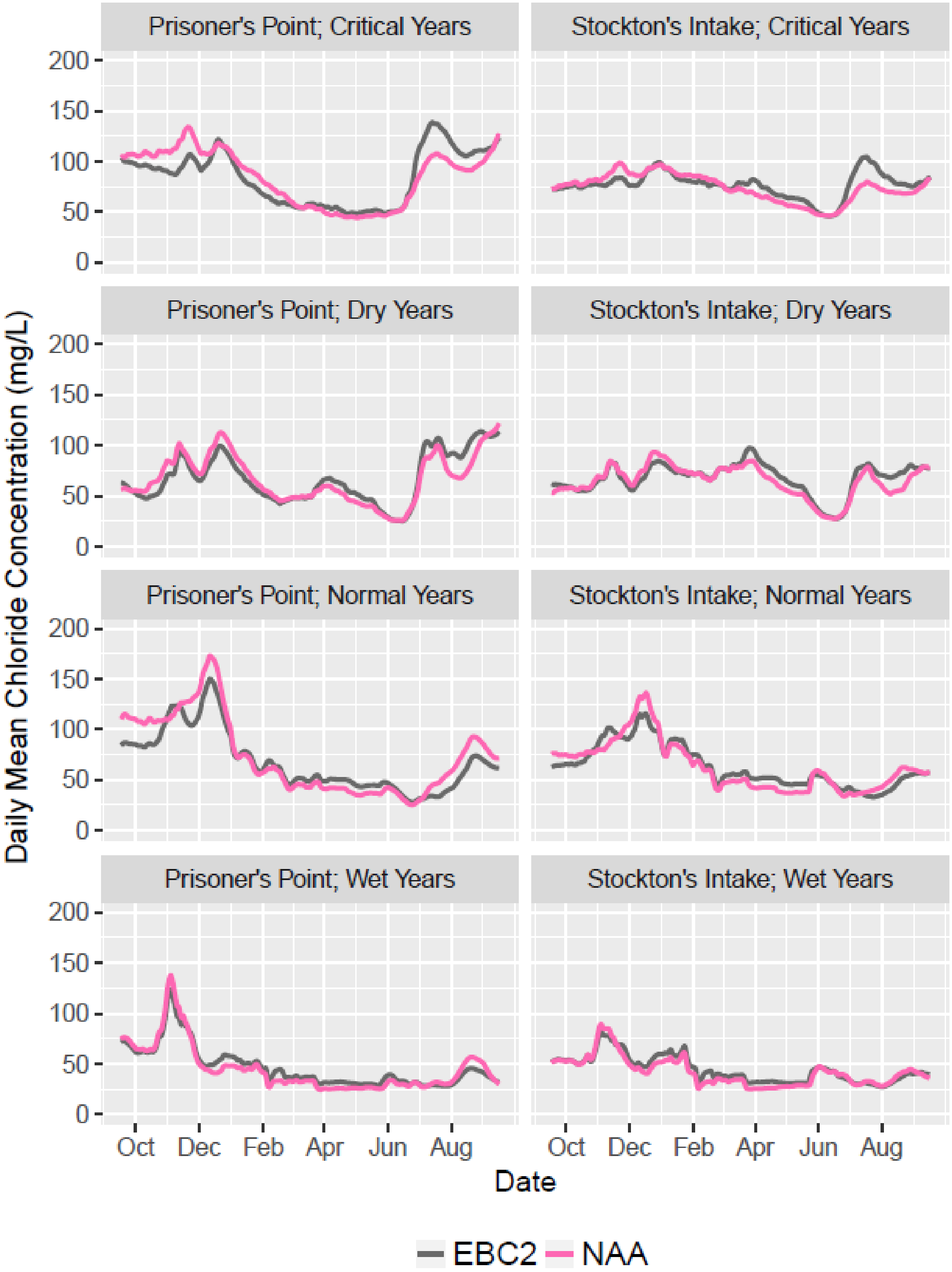

Figure 6 Daily mean chloride concentrations, averaged by hydrologic year type, for the NAA and existing condition (EBC2) scenarios at Prisoners Point and at Stockton’s intake

As detailed in STKN-026, the FEIR/EIS did not fully evaluate the water quality impacts of the Boundary 1 or Boundary 2 scenarios, which DWR has asserted both in WaterFix testimony[12] and in the FEIR/EIS[13] are representative of the range of impacts that can be expected from the WaterFix project. The FEIR/EIS did find that impacts for scenarios representative of Boundary 1 and Boundary 2 operating conditions would be "significant and unavoidable (any mitigation not sufficient to render impact less than significant)" and "adverse."[14] Thus, contrary to the statements in rebuttal reports DWR-652 and DWR-653, it is not clear that the FEIR/EIS actually concluded there would be "less-than-significant/non-adverse" impacts at Stockton's intake.

In contrast to DWR's conclusions, STKN-026 shows significant impacts to water quality at Stockton's intake. Nothing presented in DWR's rebuttal case has altered these conclusions.

2.2: DWR's evaluations of chloride impacts at Stockton's intake in DWR-652 are insufficient to determine impact. A more detailed analysis of DWR's model results shows significant increases in chloride concentrations at Stockton's intake as a result of the WaterFix project.

DWR-652 analyzed a number of water quality constituents at Stockton's approximate intake location. Results for salinity were presented for chloride in DWR-652 Section 3.3.2 as long-term averages (e.g., "maximum modeled mean monthly chloride concentrations") for both the 16-year simulation period and for hydrologic year types within that simulation period.[15] DWR evaluated the potential impacts to Stockton using three chloride thresholds: the secondary MCL (250 mg/L), upper level (500 mg/L), and short-term level (600 mg/L).[16]

We have three primary concerns regarding DWR's analysis of chloride impacts at Stockton's intake.

First, the thresholds used by DWR to evaluate water quality impacts to Stockton are inappropriate. Stockton has provided testimony on multiple occasions that its operations are affected at a threshold of 110 mg/L, and that the City must generally use an alternative source of water, such as purchased water or groundwater, when chloride levels exceed 110 mg/L.[17] However, DWR has not evaluated water quality impacts using the 110 mg/L chloride threshold.

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[12] See STKN-026 at pp. 13-14.

[13] See STKN-026 at pp. 29-30.

[14] See STKN-026 at pp. 31-32.

[15] See DWR-652, pp. 21-31.

[16] DWR-652 at p. 21.

[17] STKN-026 at p. 9; and STKN-039 at p. 3.

Second, as detailed in STKN-026, monthly mean chloride concentrations are insufficient to evaluate water quality impacts to a drinking water operator such as Stockton. STKN-026 demonstrates that DWR's model runs show significant water quality impacts when results are evaluated on a daily basis, including for the period as a whole and for hydrologic year types.[18]

Third, DWR has not evaluated chloride concentrations for a representative existing condition model scenario, such as the EBC2 scenario, that a drinking water operator such as Stockton can understand impacts relative to current conditions.

STKN-026 demonstrates that DWR's model runs show significant water quality impacts when results are evaluated on a daily basis, including for the period as a whole and for hydrologic year types.[19]

2.3: DWR's assertions that the primary source of chloride in the Delta is seawater intrusion is only true in some portions of the Delta, and chloride can exceed 110 mg/L at Stockton's intake even when seawater is not present. Internal sources of chloride within the Delta are important in areas of the Delta not frequently influenced by seawater intrusion.

DWR has stated that "The primary source of chloride in the Delta is seawater intrusion."[20]

In my experience, seawater intrusion is an important source of chloride, particularly in the western Delta. But DWR's testimony is misleading in that it does not clearly indicate that there are several high chloride sources of water other than seawater in the Delta, including both the San Joaquin River and agricultural return waters. For example, rebuttal report DWR-652 indicates that the mean chloride concentration is 136 mg/L for agricultural return waters, and 81.4 mg/L for San Joaquin River water.[21]

However, DWR's DSM2 model simulates the salinity of the San Joaquin River as a function of the flow in the river, and DSM2 model input files demonstrate that San Joaquin River water is simulated to have chloride concentrations in excess of the long-term average value. For example, as shown in Figure 5, DSM2 model input files show a chloride concentration for San

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[18] See STKN-026 at pp. 33-39.

[19] See STKN-026 at pp. 33-39.

[20] DWR-652 at p. 8.

[21] DWR-652 at p. 21.

Joaquin River inflow of up to 133 mg/L.[22] Because San Joaquin River water itself has, on occasion, concentrations exceeding the City's threshold of 110 mg/L, the San Joaquin River water can provide a significant concentration of chloride at the City's intake.

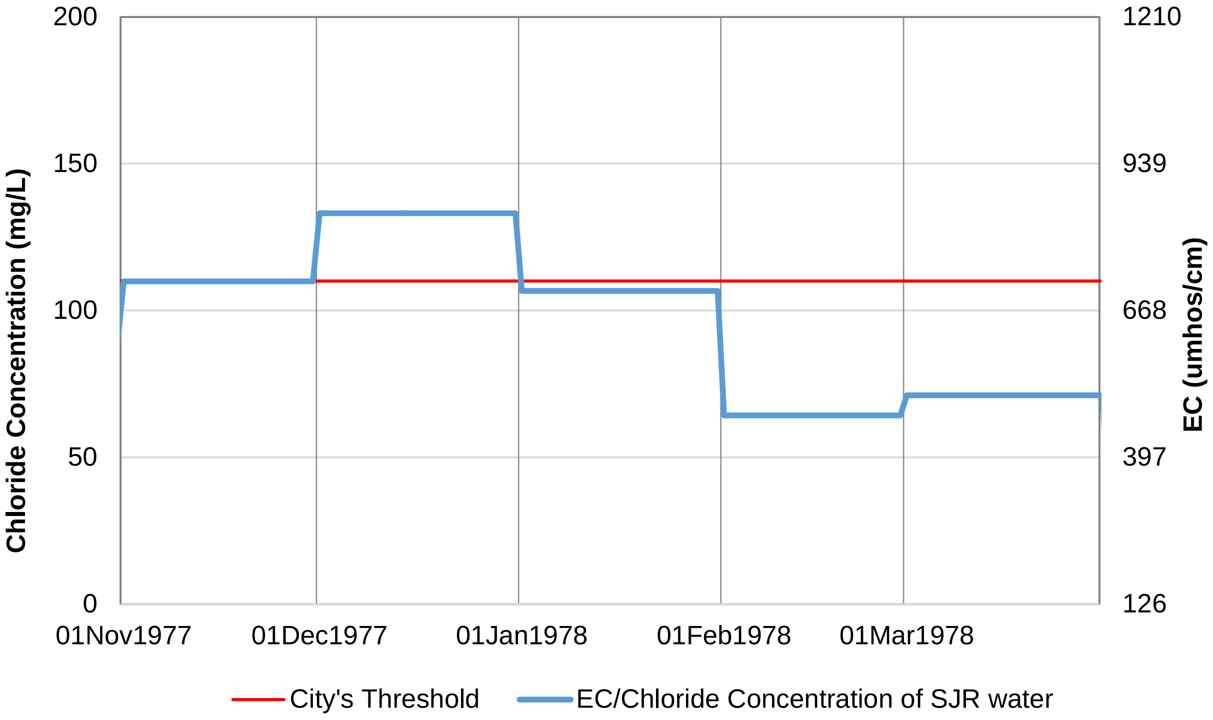

Figure 7 Chloride concentration (and EC) of the San Joaquin Rivera at Vernalis from November 1977 to April 1978, from DSM2 model input files.

Similarly, the DSM2 model simulates the salinity of agricultural drainage within the Delta as part of the "Delta Island Consumptive Use" (DICU) module within DSM2. Drainage nodes near Stockton's intake as simulated within DSM2 to have chloride concentrations as high as 291 mg/L (see Figure 8, which shows the chloride concentrations in agricultural drainage in DSM2 model input files for the 16-year period). Because agricultural drainage water has, on occasion, concentrations well in excess of the City's threshold of 110 mg/L, San Joaquin River water can provide a significant concentration of chloride at the City's intake.

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[22] As discussed in Opinion 2.4 different conversion factors can be used to convert EC to chloride. Figure 7 shows the salinity of the San Joaquin River inflows in the DSM2 model both as EC (unconverted direct model output) and as chloride converted using the relationship of Guivetchi (1986).

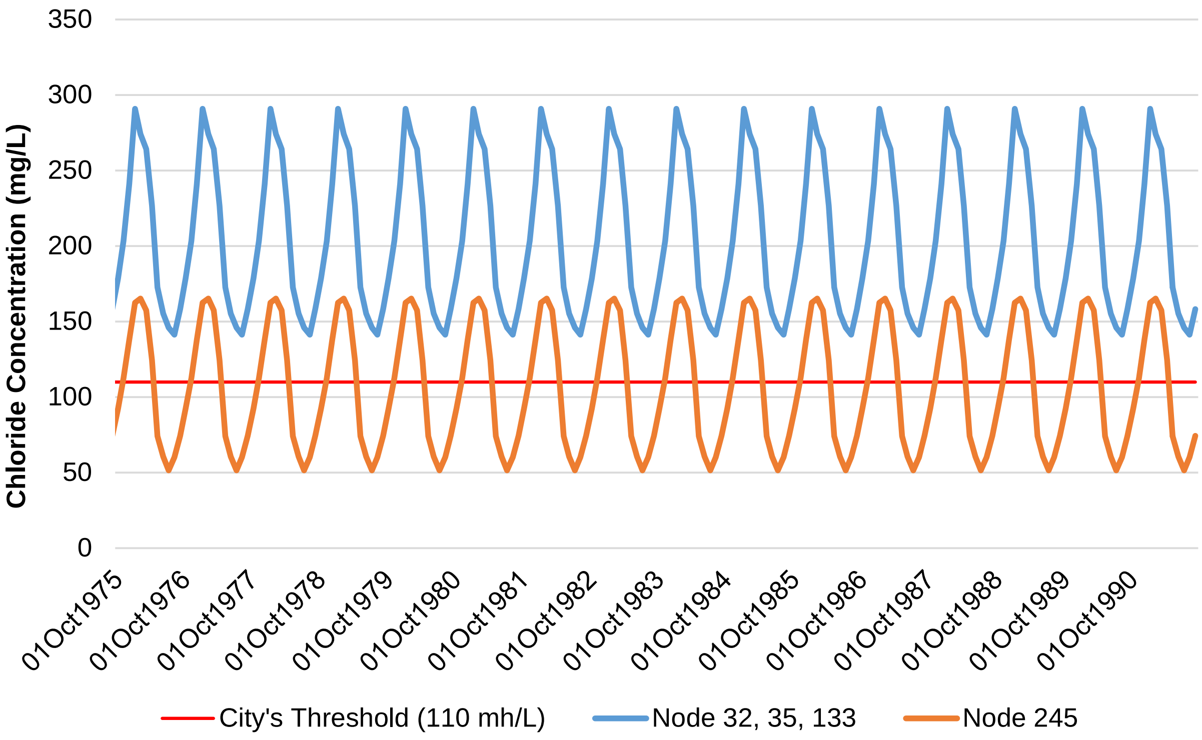

Figure 8 Chloride concentrations in agricultural drainage (DICU) simulated at DSM2 nodes 32, 35, 133, and 245, near Stockton's intake

Finally, DWR's model results show that chloride concentrations can exceed the City's threshold of 110 mg/L even when Bay water is nearly absent at the City's intake location (i.e., concentrations <0.1%). Figure 9 shows chloride concentrations simulated at the City's intake for the Boundary 1 scenario in January-March 1978. On February 8, chloride concentrations were simulated to be approximately 120 mg/L but the concentration of Bay water was almost zero at the City's intake. During this period of early 1978, water residence times in the Delta are estimated to be 8.5 days, using the methods described in STKN-026 Section 4.5.

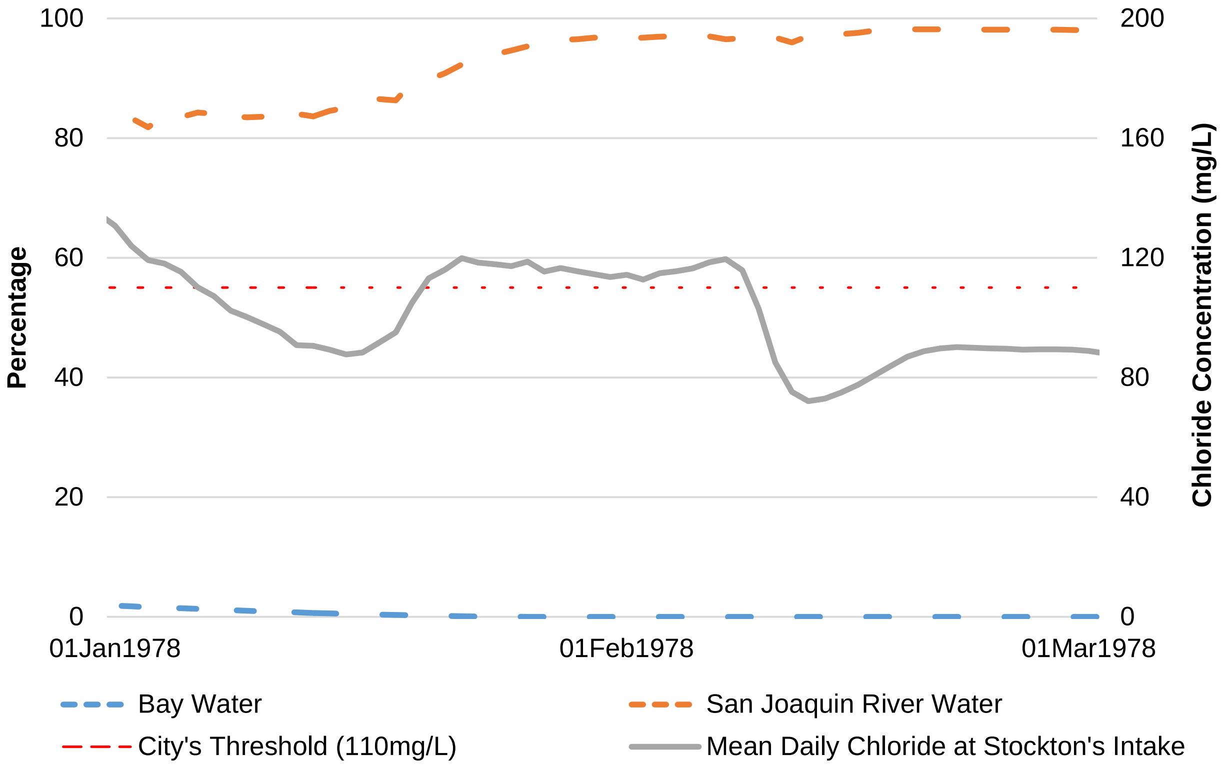

Figure 9 DSM2 model results showing the volumetric percentage of water sources, and the mean daily chloride concentration at Stockton's intake.

2.4: DWR's assertion that differences in the conversion factor used to convert EC model output to chloride may be responsible for the apparent exceedances of water quality thresholds is misleading. Our analysis shows that the conversion factors used by DWR and Exponent are similar.

When asked about chloride exceedances of the D-1641 250 mg/L chloride threshold, as discussed in Brentwood-102 Figure 5, Dr. Nader-Tehrani responded as follows:

> Two things I want to say is I guess the more important thing, this is coming from a – not my analysis; it's Ms. Paulsen which used it – and I want to repeat, different EC-to-chloride conversions. So when Mr. Aladjem refers to exceedances, it's based on not DWR's analysis; it's based on somebody else's analysis…[23]

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[23] SWRCB California WaterFix Water Right Change Petition Hearing Transcript Volume 43, p. 56:17-23. May 11, 2017.

Although DWR's testimony was in response to Exponent's testimony for Brentwood, we anticipate that similar concerns may be raised concerning Exponent's analysis for Stockton. Exponent used the EC conversion at RSAN035 (near Stockton's intake) from Guivetchi (1986),[24] while DWR used a slightly different conversion factor.[25] Figure presents a plot of the two conversion factors. As shown in Figure 10, Exponent's conversion factor is very similar to the conversion factor used by DWR at low chloride concentrations. Above chloride concentrations of about 65 mg/L, the conversion equation used by Exponent becomes increasingly conservative (i.e., results in lower chloride concentrations). Thus, if Exponent had used the same conversion equation as DWR, chloride impacts would appear slightly worse.

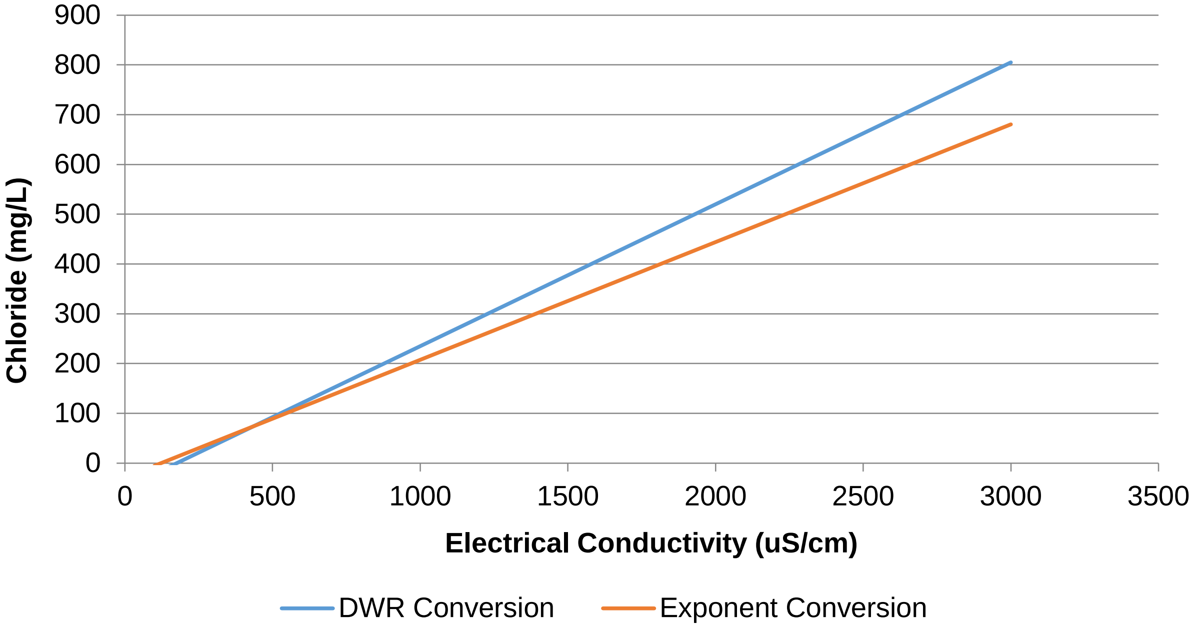

Figure 10 Comparison of EC to salinity conversion equations used by DWR and Exponent in post-processing DSM2 data.

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[24] The EC to chloride conversion for RSAN035 in Guivetchi (1986) is Cl = -28.9 + (0.23647*EC).

[25] DWR used the conversion equation of Cl = -50 + (0.285*EC) as described in DWR-509.

2.5: Similar to chloride, DWR's evaluation of EC at Stockton's intake in DWR-652 is insufficient to determine impacts. A more detailed analysis of DWR's model results shows significant increases in EC concentrations at Stockton's intake resulting from the WaterFix project.

As with chloride, DWR presented results for EC in DWR-652 as long-term averages ("maximum modeled mean monthly chloride concentrations") for the 16-year period and for the hydrologic year types within that period.[26]

DWR summarized the results of their analysis as follows:

> Collectively, the information presented below indicates that the CWF is anticipated to result in EC levels at the City's WTP intake location that would sometimes be higher and other times lower than that for the NAA, with long-term average EC levels for the CWF and NAA being similar (within 5%), and thus would not substantially degrade water quality with regard to EC. The increases in EC levels that would be anticipated to occur at this site for the CWF, relative to the NAA, would not be of a magnitude that would cause an exceedance of the applicable drinking water MCLs, on a mean monthly basis, with the exception of a single month in the modeled period of record (1976-1991) for Boundary 1 for the 900 uS/cm MCL.[27]

Consistent with the comment provided in Section 2.2 for chloride, it is my opinion that DWR's presentation of monthly average EC values is insufficient to determine impacts at Stockton's intake because it does not provide information on a timescale relevant to a drinking water operator in the Delta. In addition, DWR-652 clearly discloses increases in EC at Stockton's intake, including one month within the simulation period where the monthly average chloride concentration in the Boundary 1 scenario is simulated to the MCL of 900 μS/cm.[28]

Also consistent with our analysis in Section 2.2 for chloride, the EC thresholds that should have been used by DWR correspond to 110 mg/L chloride. The EC level that corresponds to a chloride concentration of 110 mg/L is 587 μS/cm (using the conversion equation of Guivetchi (1986)) and 561 μS/cm (using the conversion equation of DWR-509).

As with chloride, DWR presented DSM2 model results for EC in the form of long-term averages. DWR's long-term averages indicate that the WaterFix project will cause increases in EC. Increases on a daily basis will at times exceed the long-term average increases. In summary,

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[26] DWR-652 at p. 26.

[27] DWR-652 at p. 31.

[28] DWR-652 at p. 31.

as with chloride, DWR’s DSM2 model results for EC indicate that salinity will increase at Stockton’s intake as a result of the WaterFix project. See also STKN-026.

Opinion 3: The information provided by DWR regarding bromide is insufficient to determine impacts to Stockton but indicates that bromide concentrations will increase.

DWR presented bromide concentrations at Stockton's intake in the form of long-term monthly averages for both the 16-year modeling period and for hydrologic year types. As detailed in Exponent's prior testimony,[29] long-term averages are generally not suitable for assessing impacts to drinking water operators; greater impacts result from higher concentrations that will occur on shorter time-steps. Additionally, DWR failed to analyze existing condition bromide concentrations, and thus its analysis does not provide a sufficient baseline with which to compare and evaluate impacts against Stockton's current operations.

DWR evaluated bromide concentrations at the Stockton intake using two methods: a mass-balance methodology and an approach employing a relationship between EC and bromide.[30] DWR described the first method as follows:

> The first approach was mass-balance methodology, in which the DSM2-modeled source water fractions were multiplied by long-term average bromide concentrations in each source water to estimate the concentration at the site for each scenario."[31]

The source water bromide concentrations apparently used by DWR in this analysis are provided in Table 1 of DWR-652 and indicate bromide concentrations of 251 μg/L for San Joaquin River water and 456 μg/L for agricultural return flows.[32]

DWR's mass-balance methodology does not consider variability in bromide concentrations, i.e. it appears to assume constant long-term average bromide concentrations for each source, regardless of changes in flow rates or other factors that may affect bromide concentrations.[33] In fact, bromide concentrations in San Joaquin River water are expected to vary considerably with flow rate, much like EC varies in the San Joaquin River with flow rate. Extensive real-time bromide measurements in the San Joaquin River show that concentrations have ranged above 600 ug/L in the past (see Figure 11). Additionally, concentrations as high as 106,000 ug/L have

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[29] See STKN-026 at pp. 16-20. See also Section 2.2 above.

[30] DWR-652 at p. 8-9.

[31] DWR-652 at p. 8.

[32] DWR-652 at p. 7.

[33] Table 1 in DWR-652 at p. 7 lists a single bromide concentration for each water source with the exception of Bay water, which is listed as having a bromide concentration of 13,149-32,951 ug/L. DWR-652 does not provide additional detail regarding the mass balance methodology, so it is unclear what concentration was used to represent long-term average bromide concentrations in Bay water.

been reported in the Delta near agricultural drains.[34] The use of long-term average bromide concentrations in the mass balance methodology does not consider variability in bromide concentrations and will underestimate bromide concentrations within the central Delta that would result from higher-than-average bromide levels in source flows. DWR recognized this fact for chloride concentrations in the San Joaquin River by using a flow-dependent chloride relationship for San Joaquin River inflows to the Delta, but DWR's mass balance methodology did not consider relationships between bromide and flow.

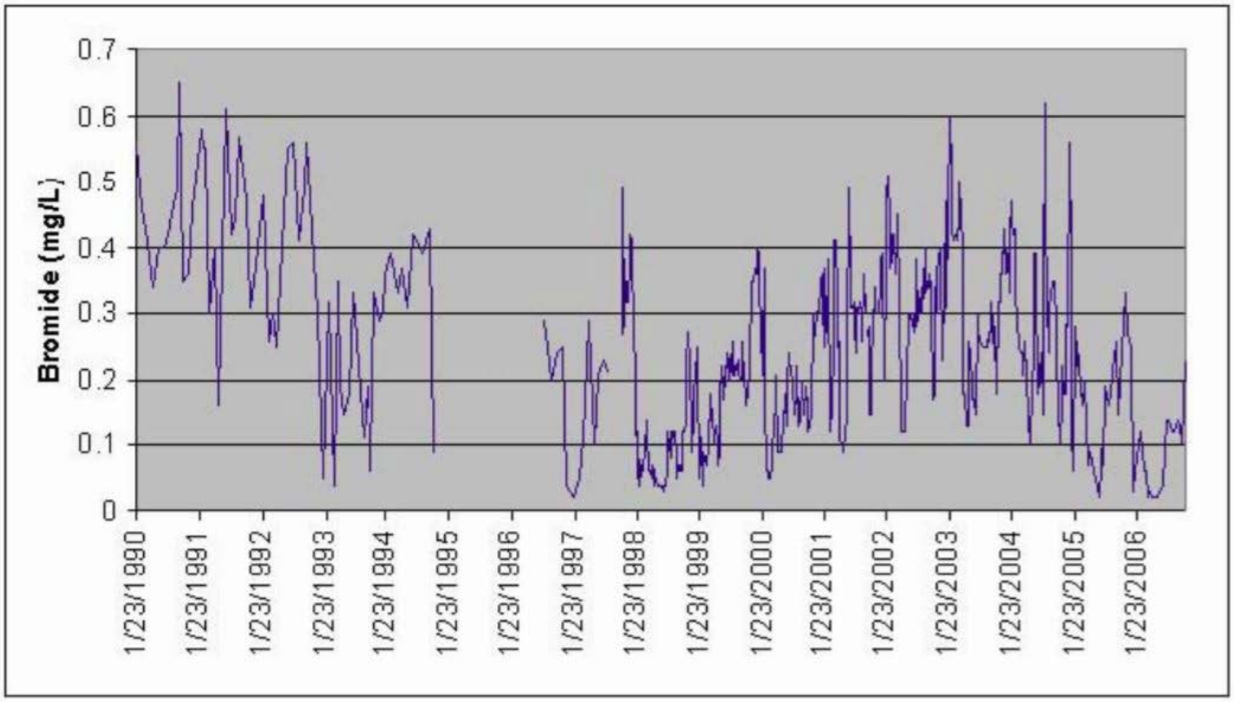

Figure 11 Bromide concentrations for the San Joaquin River near Vernalis, 1990-2006. Source: CALFED (2007), Figure 14.

DWR describes its second method for evaluating Delta bromide concentrations as follows: "The second methodology uses a relationship between bromide and EC (with EC modeled directly by DSM2) to estimate bromide concentrations at the site for each scenario."[35] No additional detail is provided in DWR-652, and DWR has not provided the bromide-EC relationship it used to calculate bromide concentrations. DWR's description ("a relationship between bromide and EC") implies that DWR used a single relationship. However, a single, fixed relationship between EC and bromide may not accurately capture the variations in the relationship noted by others. For example, CALFED (2007) states that there is "a predictable relationship between EC and bromide…at the diversion points [e.g., the H.O. Banks Pumping Plant] although it appears

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[34] U.S. Department of the Interior, Bureau of Reclamation (2005). San Luis Drainage Feature Re-evaluation, Draft Environmental Impact Statement, May. P. 5-29.

[35] DWR-652 at p. 9.

to be bimodal suggesting more than one major source of salts contributes to the observed conductivity."[36] Without additional detail, it is not possible to validate DWR's second calculation approach.

Finally, DWR's written description of its analysis appears to contradict the graphics in the testimony. For example, DWR summarized its bromide analysis results for below normal years (reproduced as Figure 12), stating, "Based on these findings, the CWF would be expected to result in similar or lower mean monthly bromide concentrations at the site when concentration would be 300 µg/L or greater for the NAA."[37] However, Figure 12 appears inconsistent with this summary statement. For example, the Boundary 1 scenario shows a bromide concentration significantly higher than the NAA bromide concentration when the NAA concentration exceeds approximately 150 ug/L, and the maximum monthly bromide concentration for the Boundary 1 scenario is approximately 100 ug/L higher than the maximum monthly bromide concentration for the NAA scenario. Figure 12 also indicates that roughly half the time, the bromide concentration will be between about 40 ug/L to 100 ug/L higher for the Boundary 1 scenario than for the NAA scenario.

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[36] CALFED (2007) at p. 25.

[37] DWR-652 at p. 16.

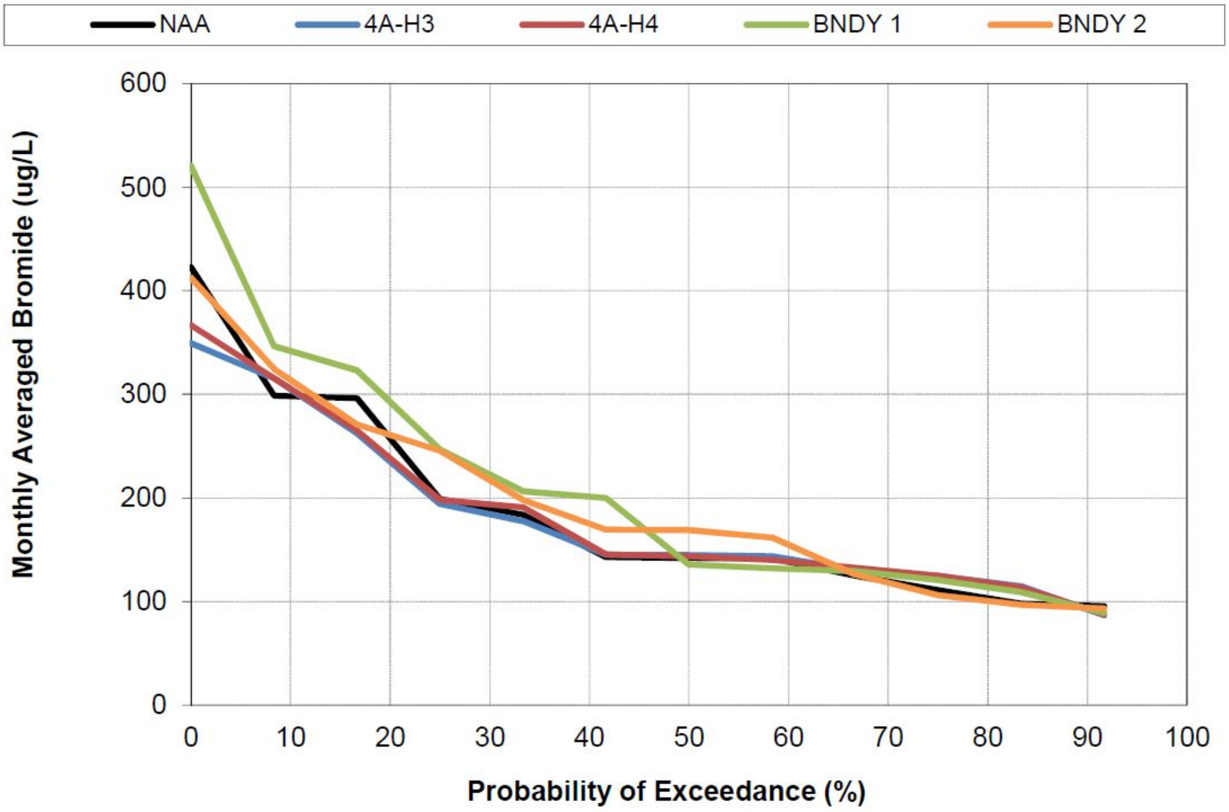

Figure 12 Probability of exceedance plot for monthly average bromide concentrations in the San Joaquin River at the City of Stockton's drinking water diversion location for below normal years (1978, 1980), based on EC-to-bromide relationship. Source: DWR-652, Figure 10, p. 16.

Similarly, DWR characterized the results presented in Figure 13 (showing monthly average bromide concentrations in dry years) as follows: "Based on these findings, the CWF would be expected to generally result in similar or somewhat higher mean monthly bromide concentrations at the site in dry years, relative to the NAA."[38] However, Figure 13 appears to show that, in fact, bromide concentrations for the WaterFix scenarios would be <u>substantially</u> higher in dry years than NAA concentrations for most months in the simulation period. For example, in the range of 6% to 55% probability of exceedance, bromide concentrations for all CWF alternatives would be higher than those for the NAA, and the Boundary 2 and 4A-H4 alternatives would yield concentrations that exceed the NAA concentrations by between about 33 ug/L and 150 ug/L (i.e., bromide concentrations in this range would be about 15-40% higher for these WaterFix scenarios than for the NAA).

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[38] DWR-652 at p. 17.

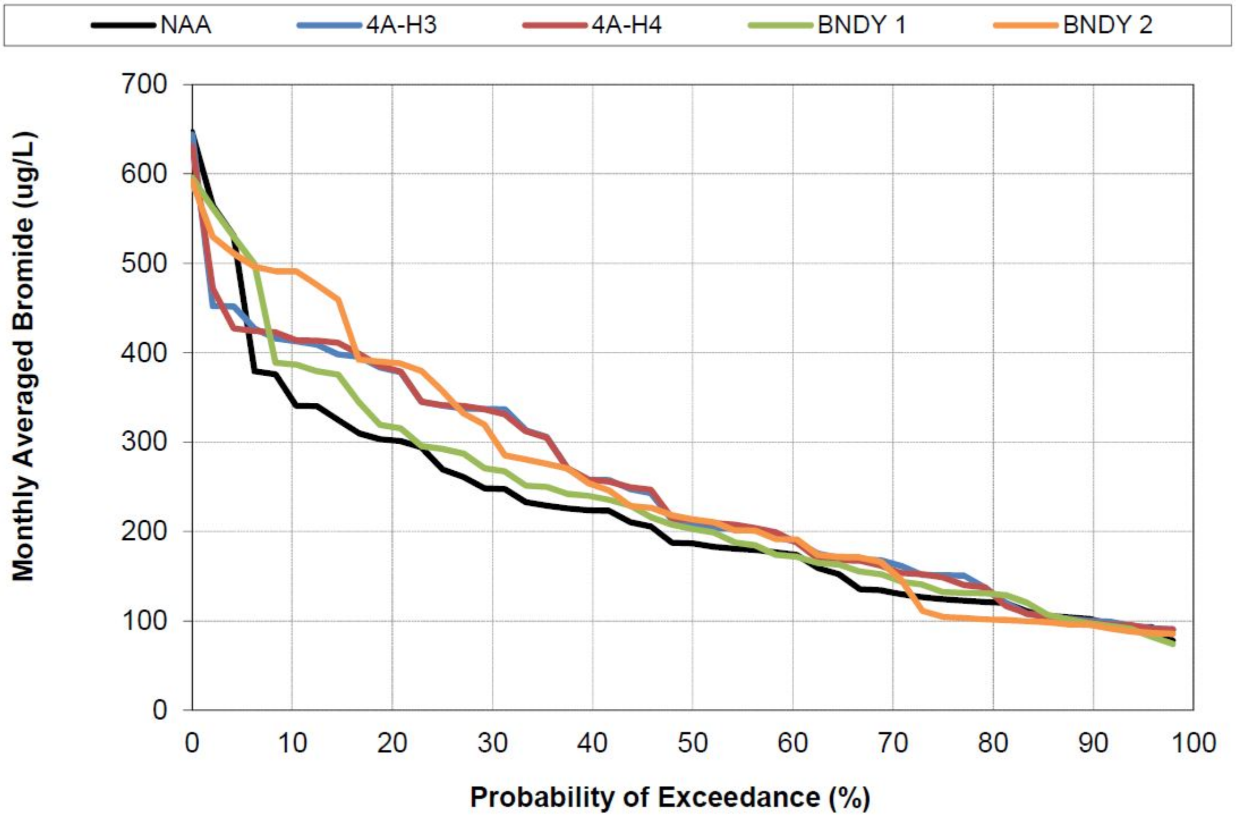

Figure 13 Probability of exceedance plot for monthly average bromide concentrations in the San Joaquin River at the City of Stockton's drinking water diversion location for dry years (1981, 1985, 1987, 1989), based on EC-to-bromide relationship. Source: DWR-652, Figure 11, p. 17.

Finally, bromide concentrations in critical years were depicted in Figure 4 (below) and characterized by DWR as follows: "Based on these findings, the CWF would be expected to result in similar or somewhat higher mean monthly bromide concentrations at the site in critical years, relative to the NAA."[39] In contrast to this description, Figure 4 shows that in critical years the CWF alternatives would yield significantly higher monthly average bromide concentrations than the NAA at some probabilities of exceedance. For example, at the 20% exceedance level, the Boundary 2 alternative would yield a bromide concentration approximately 100 ug/L higher than the NAA (a difference of approximately 30%).

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[39] DWR-652 at p. 17.

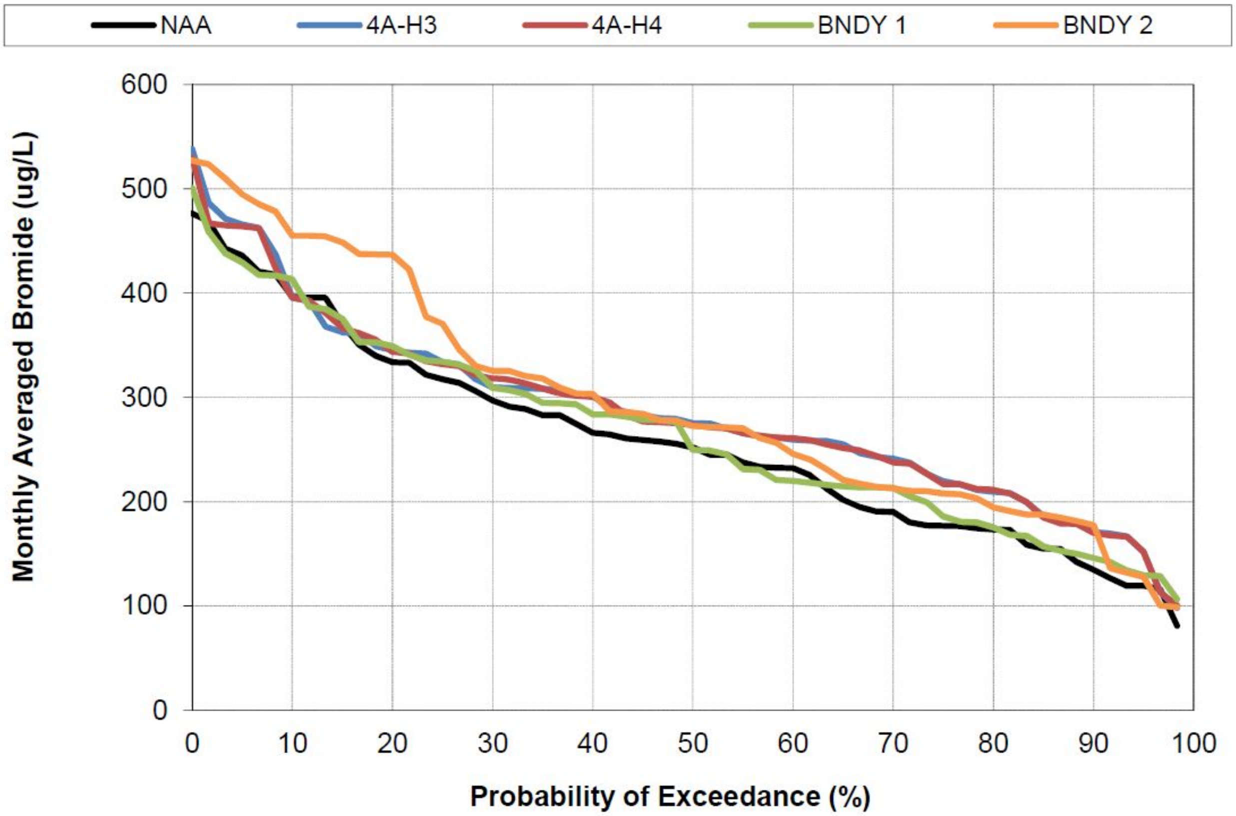

Figure 14 Probability of exceedance plot for monthly average bromide concentrations in the San Joaquin River at the City of Stockton's drinking water diversion location for critical years (1976, 1977, 1988, 1990, 1991), based on EC-to-bromide relationship. Source: DWR-652, Figure 12, p. 18.

Based on the information contained in rebuttal report DWR-652, Exponent concludes that the WaterFix project would result in significant increases in bromide concentrations at Stockton's intake. Although better and more accurate methods should have been used to support DWR's testimony (e.g., determination of impacts using daily concentrations, incorporating variations between bromide and EC in the mass balance methodology, comparing to an appropriate existing condition baseline (EBC2)) as outlined in this opinion, DWR's own results show a significant increase in predicted bromide concentrations at Stockton's intake. Further, this impact is only apparent upon close inspection of the figures in DWR-652 and does not appear to be fully or appropriately disclosed in the text or conclusions of DWR-652.

Opinion 4: The information provided by DWR regarding organic carbon is insufficient to determine impacts at Stockton's intake location but indicates that organic carbon concentrations will increase.

DWR-652 indicates that "The DSM2 model was used to directly model DOC [dissolved organic carbon] concentrations at the City's diversion location."[40] As with other water quality constituents, DWR's analysis for organic carbon is presented as long-term monthly averages for both the entire 16-year simulation period and for hydrologic year types. DWR-652 also notes that "the Final EIR/EIS (chapter 8, p. 8-955-957) stated that long-term average DOC concentrations for some Delta interior locations are predicted to increase by as much as 0.2 mg/L."[41] (DWR-652 at p. 46)

STKN-039 notes that increased TOC in source water from the CWF would require Stockton to change to water treatment processes such as enhanced coagulation or granular activated carbon adsorption, or to find alternative sources of water. These issues have been presented previously in Stockton's testimony and in comments to the BDCP and EIR/EIS.

DWR has not provided sufficient information for us to assess the modeling or model results for organic carbon. DWR-652 does not present the methodology used to assess organic carbon. Although we have identified some model input files for DOC, we have not to date identified DSM2 model output for organic carbon, and thus we have been unable to analyze model results for shorter than monthly periods. (If we have overlooked this output, we would request that DWR direct us to the model files that contain this information.) Figure 15 presents DSM2 model inputs describing organic carbon concentrations in certain inflows to the Delta. As shown in Figure 15, the San Joaquin River is simulated by DWR to have DOC concentrations as high as 11 mg/L or greater (i.e., in excess of the significance thresholds). Because San Joaquin River water is the dominant source of water at the City's intake during some periods under WaterFix, it is possible that these concentrations of DOC will cause an exceedance of the 4 and 7 mg/L DOC thresholds at the City's intake.

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[40] DWR-652 at p. 42.

[41] DWR-652 at p. 46.

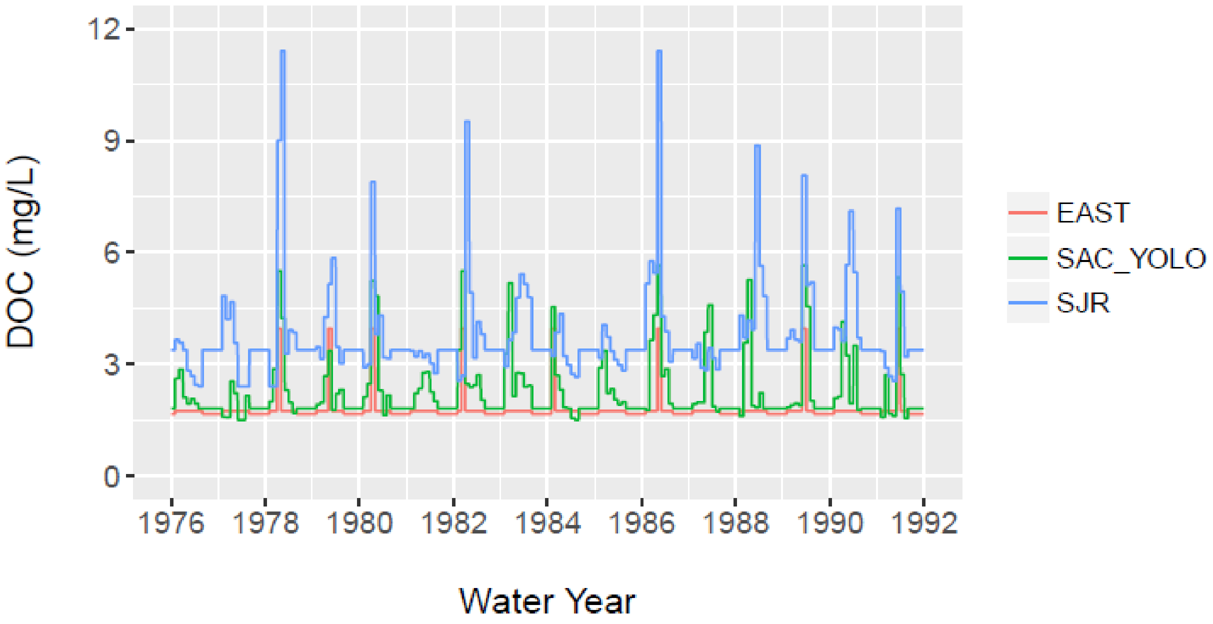

Figure 15 Dissolved organic carbon (DOC) concentrations in Delta inflows (eastside streams (red), Sacramento River at Yolo Bypass (green), and San Joaquin River at Vernalis (blue), from DSM2 model input files.

As noted for other water quality constituents, presentation of model results in the form of monthly averages is insufficient to determine the impacts of the WaterFix project on a drinking water operator such as the City of Stockton. Even so, DWR-652 indicates that "long-term average DOC concentrations for some interior Delta locations are predicted to increase by as much as 0.2 mg/L," and even greater increases can be expected on shorter timescales.

Opinion 5: DWR's conclusions that the WaterFix project will not impact the frequency or magnitude of *Microcystis* blooms in the future are unfounded. Our analysis indicates that the WaterFix project increases the likelihood of *Microcystis* blooms in the future.

5.1: DWR oversimplifies the multiple factors which interact to promote the formation of *Microcystis* blooms within the Delta.

Formations of blooms of *Microcystis* and other cyanobacteria are the result of multiple competing factors (see Figure 16), all of which combine to alter the likelihood of bloom formation. As no comprehensive models are available to model bloom formation for the Delta[42], the potential effects of WaterFix must be evaluated by looking at changes in the major controlling factors that may be induced by the WaterFix project, with the understanding that any of the controlling factors may be limiting at a given time in a given location.

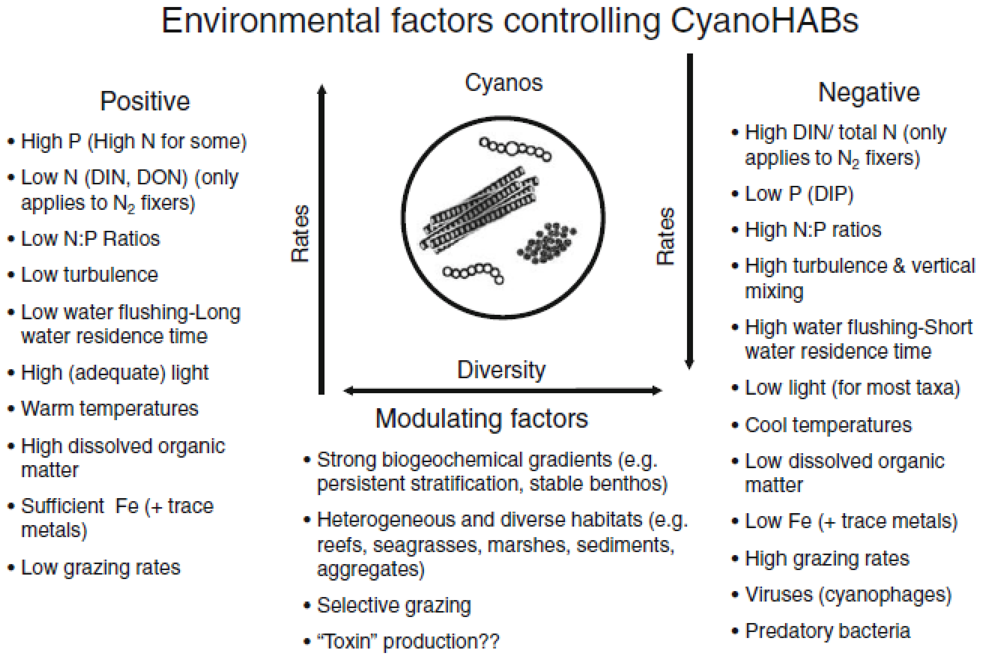

Fig. 6 Suite of positive and negative effectors as well as modifying environmental and ecological factors that influence CyanoHAB potentials in aquatic ecosystems

Figure 16 Factors affecting CyanoHAB potentials in aquatic ecosystems, reproduced from Figure 6 of Paerl and Otten (2013)

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[42] See DWR-653 at p. 8, and Mioni et al. (2011).

DWR-653 identifies:

> "five primary environmental factors that trigger the emergence and subsequent growth of Microcystis in the water column of Delta waters, which are: 1. Water temperatures >19°C (66.2°F), 2. Low flows and channel velocities resulting in low turbulence and long residence times, 3. Water column irradiance and clarity >50 micromoles per square meter per second (μmoles/m^2/s), 4. Sufficient nutrient availability (nitrogen and phosphorus), and 5. Salinity below 10 ppt."[43]

These five factors are generally consistent with lists of cyanobacterial controls reported in the literature. For example, Berg and Sutula (2015) identify "favorable salinity, ample supply of nutrients, calm water and stratified conditions, plenty of irradiance and warm water temperatures"[44] as factors influencing cyanobacterial blooms.

Mioni et al. (2011) state, "The literature suggests that the success of cyanobacteria is a result of complex and synergistic environmental factors rather than a single dominant variable."[45] For *Microcystis* blooms to occur, all of these factors must be favorable. However, DWR rebuttal testimony treats velocity as the primary controlling factor, when it indirectly may affect these five factors. Additionally, "low turbulence and long residence times" should be treated separately, as one affects growth and the other accumulation. Low turbulence is likely an indirect factor, as turbulence can increase mixing, which in turn may alter nutrients, light, temperature, etc. Longer residence times increase accumulation (which is the difference between cell input due to flow and growth and cell output due to death and flow out), which is necessary for bloom formation.

Overall, an analysis of the factors that are important to controlling *Microcystis* blooms should take the approach that multiple factors are required for a bloom (temperature, light, nutrients, residence time, salinity), and each of these can be limiting in a particular circumstance. Changes in Delta hydrodynamics that remove a limiting factor (e.g., an increase in residence time, which will increase accumulation) will increase the likelihood of a bloom occurring, even though a bloom will not occur 100% of the time that change is applied, because other factors may be limiting.

DWR's focus on velocity as the controlling variable for *Microcystis* blooms[46] is an oversimplification, as the effects of velocity on *Microcystis* bloom formation are indirect and may occur via multiple pathways associated with the five factors discussed above. For example, in one system, an increase in velocity may result in the loss of water column stratification,

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[43] DWR-653 at p. 3.

[44] Berg and Sutula (2015) at p. 21.

[45] Mioni et al. (2011) at p. 2.

[46] DWR-653, p. 12-30.

resulting in mixing of *Microcystis* below the euphotic zone, resulting in reduced growth and/or a competitive disadvantage due to light limitation,[47] while in a well-mixed system that was not stratified in the first place, the same change in velocity could have little effect on the *Microcystis* growth rate. In my experience in the Delta, the water column is not strongly stratified, thus removing one of the major mechanisms for velocity changes to inhibit growth of *Microcystis*.

A change in velocity will not have the same effect on *Microcystis* growth in all water bodies, because of the differing physical and ecological characteristics of each system. Any analysis of the effects of velocity on *Microcystis* bloom formation needs to consider each of these factors separately, because, as noted above, not all apply to all locations within the Delta.

5.2: DWR's testimony has improperly conflated channel velocity with residence time. Our analysis indicates that the overall velocity regime of the Delta is unlikely to change in the future, but residence times will increase with the WaterFix project.

DWR asserts that "Insufficient residence time (due to high channel velocities) results in what cells are produced being flushed from the area before a "bloom" can form, and high velocities result in turbulent, well mixed channel flows where cyanobacteria generally cannot out-compete green algae or diatoms."[48] DWR further describes velocity as being important "regardless of direction of flow" "because it is not the volume of water moving through a channel, but rather the velocity with which the water moves that most affects the ability of cyanobacteria to out-compete other algae."[49]

As discussed in Section 5.1, treating velocity as the single or primary controlling factor for *Microcystis* blooms confuses effects that are related to growth (e.g., mixing) with those related to accumulation (e.g., residence time). Opinion 1 demonstrates that DWR's focus on maximum channel velocities, or on the probability of exceedance for 15-minute absolute velocities, yields no useful information regarding the residence time of water in the Delta, because maximum velocities and absolute values of velocity are unrelated to residence time in a "sloshing" tidal system. Rather, if DWR had wanted to use velocity as a surrogate for residence time, DWR should have used the tidally- or daily-averaged velocity, which is much lower than the maximum channel velocity throughout most of the Delta.

In fact, as discussed in Opinion 1, the net channel velocity near Stockton's intake is low, indicating low rates of flushing, and the WaterFix project is expected to lead to significant

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[47] Mitrovic et al. (2003), Paerl and Otten (2013).

[48] DWR-653 at p. 31-32.

[49] DWR-653 at p. 12.

increases in residence time within the Delta. Thus, I conclude that DWR’s testimony is fundamentally incorrect.

5.3: Because of the complex and indirect nature of velocity effects on *Microcystis* growth and accumulation, DWR’s application of very limited “critical velocities” from the literature to predict effects of the WaterFix is inappropriate.

To analyze the effect of velocity on *Microcystis* bloom formation, DWR compares daily maximum velocities with channel velocities associated with bloom prevention and/or disruption in other systems and in other types of systems. DWR states:

> “The analysis presented below focuses on how the CWF would affect daily maximum velocity and 15-minute absolute velocity (regardless of direction) in channels of the Delta. Daily maximum velocity is assessed because the Delta channels are tidal and thus flows are slowed, and can reverse direction in most channels daily, on the tidal cycle. As such, mathematical daily average velocity may approach zero when flows on the tidal cycle move in opposite directions, and thus is not very useful for determining how channel velocity affects cyanobacteria. In such tidally influences [sic] channels, daily maximum velocity and 15-minute absolute velocity (regardless of direction) are the parameters that best characterize the degree of channel mixing that occurs daily.”[50]

Opinion 1 details the concerns with DWR’s use of the daily maximum velocity and the 15-minute absolute velocity; in sum, DWR’s use of these parameters fails to capture the “sloshing” nature of tidal flows in the Delta and DWR’s analysis of velocity cannot be used to characterize flushing or residence time.

In evaluating *Microcystis* effects, DWR compares the average velocities discussed above to “critical velocities” obtained from several studies reported in the literature. The limited literature on critical flow velocities that is used for the detailed velocity analysis[51] is from only two systems, both of which are different from the Delta in important ways:

1. Lower Darling River, Australia. In this freshwater system, which is a nutrient-limited Australian river with seasonal flow controlled by a series of weirs and without tidal effects, two studies evaluated how changes in river velocity altered blooms of *Anabaena circinalis*. The studies found a “critical flow velocity of 0.03 m/s to suppress the formation of persistent thermal stratification in the weir pool” with an order of magnitude higher velocity (0.3 m/s) required to disrupt an already

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[50] DWR-653 at p. 13.

[51] DWR-652 at p. 12-30.

formed bloom.[52] In some cases, the reported velocities were required to be sustained for days to be effective.[53]

2. Zhongxin Lake, China. Investigators set up a series of mesocosms with artificial flow in this Chinese lake. These experimental chambers were 1.5 x 0.4 x 1.5 m enclosures in which water circulated continuously. Flow was not tidally influenced and was controlled by submerged pumps that the authors suggest may have contributed additional turbulence and potentially caused cell damage.[54] Changes in cyanobacterial survival were seen in flowing water compared to still water, but the authors noted that changing temperatures may have controlled the shift in dominant phytoplankton in the experiments.[55] The critical flow velocity of 0.06 m/s reported by Zhang et al. was based on an overall decrease in phytoplankton abundance with an associated increase in periphyton, not a specific community shift away from *Microcystis*.[56]

Both of these systems differ in important ways from the tidally influenced Delta. In the case of the Lower Darling River, Mitrovic's interpretation of critical velocity was associated with the disruption of thermal stratification[57], which is not expected to be significant in the Delta.[58] In addition, Mitrovic's studies were based on an organism that is not *Microcystis*. *Anabaena* is a nitrogen-fixing cyanobacteria with a different colony morphology than *Microcystis*[59], and *Anabaena* may be differently suited to environmental conditions.[60] In the case of Zhongxin Lake, the mesocosms were closed systems operated for a short period of time with no replacement of the water, and the critical velocity was interpreted as a combination of changes in turbidity due to suspended sediments and a loss of phytoplankton due to damage from the pumps.[61] Both Li et al. and Zhang et al. noted that there may not be a universal critical flow rate applicable to all systems.

Microcystis blooms currently occur in the Delta, despite the fact that flow in the Delta routinely exceeds the "critical velocities" cited in DWR-653, and despite the lack of significant stratification in the water column.[62] The presence of *Microcystis* blooms currently thus suggests

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[52] Mitrovic et al. (2003), Mitrovic et al. (2011).

[53] Mitrovic et al. (2011).

[54] Li et al. (2013).

[55] Li et al. (2013).

[56] Zhang et al. (2015).

[57] Mitrovic et al. (2011) at p. 237-238.

[58] Lehman et al. (2017).

[59] Reynolds et al. (1987).

[60] Mitrovic et al. (2011).

[61] Li et al. (2013); Zhang et al. (2015).

[62] Lehman et al. (2017).

that either the use of maximum channel velocities misses a critical component of the Delta hydrology which allows for blooms, or that the critical velocities in the Delta are higher than those reported in other systems. In fact, as noted above, Li et al. (2013) state, "The present study highlights that a universal critical velocity for suppressing algae growth probably does not exist in freshwater bodies, for each has its unique physical, chemical and ecological characteristics."[63]

DWR's testimony emphasizes the importance of using site-specific models to predict *Microcystis* blooms in the Delta: "Moreover, by the above-cited statement, he [Mr. Ringelberg] also acknowledges that we cannot simply apply a model developed for the Potomac River to the Delta, but rather have to develop Delta specific models."[64] Yet the critical velocities cited in the testimony are not based on studies of the Delta.

The DWR testimony argues that the role of velocity in controlling *Microcystis* is through mixing: "Because all algae present are mixed from the channel surface to bottom in turbulent flowing water, *Microcystis* cells cannot control their location in the water column and thus cannot as readily, if at all, form the dense collection of cells and colonies at the water's surface as occurs in calm waters."[65]

As discussed above, mixing throughout the water column is only one mechanism by which velocity affects *Microcystis*. Turbulence which causes mixing to depth may be less important in shallow areas where the euphotic zone reaches the sediment. This is supported by studies of mixing as a mitigation measure in freshwater lakes: "A change in composition from cyanobacterial dominance to green algae and diatoms can be observed if the imposed mixing is strong enough to keep the cyanobacteria entrained in the turbulent flow, the mixing is deep enough to limit light availability and the mixing devices are well distributed horizontally over the lake."[66] However mixing to prevent stratification is only a reasonable method to inhibit blooms if stratification is present in the first place: "stratification is probably less important in SFE [San Francisco Estuary], where a combination of tide, current and wind mix the water column daily."[67]

Based on the lack of a relevant critical velocity threshold and the existence of *Microcystis* blooms in the current condition (under which DWR argues that conditions for blooms are unfavorable), DWR's detailed analyses comparing the various scenarios to the two literature values noted above are not conclusive and seem misguided.

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[63] Li et al. (2013) at p. 64.

[64] DWR-653 at p. 8.

[65] DWR-653 at p. 12.

[66] Visser et al. (2016).

[67] Lehman et al. (2017).

5.4: DWR's testimony acknowledges the effect of residence time on the potential for *Microcystis* accumulation, but suggests that because residence time is insufficient to cause a bloom it is unimportant. This is inconsistent with known controls on bloom formation and DWR's testimony on bloom formation in the Delta.

DWR appears to deemphasize the potential role of increased residence time on the formation of *Microcystis* blooms, instead focusing on factors which change the *Microcystis* growth rate:

> "Hydraulic residence times may increase in parts of the southern and central Delta for the CWF, relative to the NAA. Increased residence time provides the opportunity for cyanobacteria to accumulate in areas. However, other factors such as daily in-channel absolute velocities, turbulence, and mixing; competition with other algal species; and grazing losses to zooplankton, fish, and clams exert their own effects on cyanobacteria accumulation… Hence, greater residence time provides the opportunity for cyanobacteria to accumulate in areas of the Delta, without getting flushed from the area, but because of the other factors identified above that also affect the ability of cyanobacteria to accumulate in areas, a given magnitude increase in residence time will not always equate to a given magnitude increase in bloom size, or an increase in bloom size at all."[68]

DWR also asserts that "Additional *Microcystis* research would be needed before definitive determinations regarding how modeled changes in residence time caused by the CWF would affect the magnitude of *Microcystis* blooms in the Delta can be made."[69]

As summarized in Opinion 1, Exponent in STKN-026 calculated residence times and showed significant increases in residence time in the Delta as a result of WaterFix, which could result in an increase in *Microcystis* blooms. Exponent agrees with DWR that residence time is only one of several limiting factors which need to be favorable for *Microcystis* blooms, but it is important to distinguish between "does not cause" and "necessary but not sufficient." *Microcystis* blooms will always depend on multiple factors. Temperature, nutrients, and irradiance affect the growth rate of *Microcystis*. Changes in residence time affect accumulation (see Opinion 5.2). Having sufficient residence time will always increase the likelihood of a bloom compared to a case where the residence time is insufficient.

Similarly, DWR focuses on the fact that an increase in residence time is not an absolute predictor of a *Microcystis* bloom: "Long residence time does not always translate into large

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[68] DWR-653 at pp. 31, 33.

[69] DWR-653, at p. 31.

Microcystis blooms."[70] For example, DWR cites a study by Spier et al. (2013) which looked at a 2012 bloom in an area of the Delta with a "long residence time," but no bloom in other years with similar residence times. Spier et al. (2013) discuss other parameters which differ between the years and which may have prevented bloom formation in the Delta in 2009 and 2011. DWR's testimony focuses on the finding of Spier et al. (2013) that residence time alone cannot predict blooms, but it misses the equally important point that greater residence time makes blooms more likely.

DWR implies that since residence times may change with WaterFix only in areas where *Microcystis* blooms already form, no increase in the number of blooms would be seen: "Hence residence times beyond the minimum required for bloom initiation (e.g., increased residence times in areas where blooms have historically occurred) primarily affects how much biomass a bloom can accumulate in an area after a bloom has initiated."[71] This is incorrect. An increase in residence time can lead to greater accumulation in the absence of other changes. In addition, as shown in STKN-026, residence times would increase throughout the Delta due to WaterFix, including in areas where *Microcystis* blooms do not currently form. If residence time were the factor limiting bloom initiation and formation in those areas, it would be possible for a change in residence time to trigger a bloom where one may not have formed in the past, assuming all other parameters stayed constant. Finally, changes in the intensity of a bloom (which could be driven by increased residence times) can be significant. *Microcystin* toxin concentrations generally increase with *Microcystis* biomass (though not linearly), and larger blooms are more likely to produce toxin concentrations above relevant water quality guidelines.[72]

DWR's rebuttal testimony implied that changes in Delta residence times that are smaller than those discussed in Lehman et al. (2017) are not significant:

> "The Lehman et al. (2017) study shows that very large reductions in flow (i.e., a factor of three lower) and associated very large increases in residence times can contribute to increased magnitude and duration of *Microcystis* blooms because the cells and colonies are not being flushed from the area as rapidly as would occur with lower residence times, and thus they accumulate in an area over time."[73]
>
> "As shown in Section 4.2 of this report, the effects of CWF on channel velocities in the Delta is small compared to the large three-fold reduction in flow and commensurate

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[70] DWR-653 at p. 32.

[71] DWR-653 at p. 32.

[72] Rinta-Kanto et al. (2009). Kaardinal and Visser (2005)

[73] DWR-653 at p. 32.

> effects to velocity and residence time observed between 2014 and other years, where large effects on *Microcystis* were observed."[74]

DWR's testimony appears to misrepresent the results reported in the Lehman et al. (2017) study, which did not suggest that a three-fold flow reduction was required to "contribute to increased magnitude and duration of *Microcystis* blooms." Rather, Lehman et al. (2017) showed that a larger increase in residence time resulted in a larger bloom (see above). The more modest changes in flow in other reported years also showed a change in *Microcystis* concentration.[75] Small changes in residence time may be important and should not be dismissed without consideration.

Because Exponent's analysis has showed that up to a 37% increase in residence time in the Delta can be expected to occur as a result of the WaterFix project (see Opinion 1.1 and STKN-026), and because the increases in residence time occur during warm months (see also Opinion 5.5), I conclude that the likelihood of *Microcystis* blooms will increase as a result of the WaterFix project.

5.5: Because temperature is considered an important controlling factor for *Microcystis* growth and bloom occurrence in the Delta, it is important to consider temperature on appropriate time and spatial scales when predicting the effect of the WaterFix on the Delta.

DWR's testimony acknowledges the strong influence that temperature has on *Microcystis* bloom formation: "Although other factors (nutrients, surface irradiance) generally become sufficient for *Microcystis* growth between March and June, water temperature is generally the limiting factor that prevents Microcystis formation in the Delta until water temperatures exceed 19°C, which typically does not happen until June (Lehman et al. 2013)."[76] Other studies have also found a strong control of temperature on *Microcystis* growth in general[77] and in the Delta: "Because of the large effects of temperature and irradiance on accelerating, and decelerating, the growth rates of cyanoHABs, these two factors appear to exert key roles in the regulation of the onset of blooms."[78]

However, the lack of detail in DWR's temperature analysis prevents drawing any conclusions regarding potential effects of temperature changes on *Microcystis* blooms at specific locations in

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[74] DWR-653 at p. 32.

[75] Lehman (2017).

[76] DWR-653 at p. 10.

[77] Berg and Sutula (2015), Reynolds (2006), Robarts and Zohary (1987), Mioni et al. (2011).

[78] Berg and Sutula (2015) at p. 48.

the Delta. Specifically, DWR-653 presents long-term monthly average simulated temperatures for the 16-year simulation period as a whole and for various water year types. DWR-653 does not present shorter-term (e.g., daily) simulated temperatures. DWR-653 also presents simulated temperatures for only two scenarios: the NAA and the PA (Preferred Alternative, or Alternative 4A). DWR did not simulate temperatures for the Boundary 1 or Boundary 2 scenarios, or for additional scenarios evaluated in DWR-653 and in the FEIR/EIS. Finally, DWR did not (to my knowledge) provide the DSM2 model output used to calculate the long-term average monthly temperatures, and DWR did not provide model output or temperature analysis for the location of Stockton's intake.

Despite these shortcomings, DWR's analysis indicates that monthly average water temperatures will increase for the PA relative to the NAA, particularly in warm weather months. For example, DWR-653 indicates that "Modeling shows that for the full simulation period (1922-2003), the period mean temperatures in the San Joaquin River at Prisoners Point for the CWF would be up to 0.1°C (0.18°F) higher than that modeled for the NAA for each month of the May through October period of the year… In September, the modeled maximum mean monthly temperature for the CWF would be about 0.3°C (0.6°F) higher than that modeled for the NAA..."[79] The increases in water temperature on shorter timescales, and in different year types, are expected to be higher than the long-term average temperature increases.

DWR's model analysis indicates that long-term average temperatures will increase as a result of the WaterFix project. Further, these increases in temperature will occur in the warmer months of the year, when the residence time of water in the Delta will also increase as a result of the WaterFix project (see Opinion 1.1 and STKN-026). Thus, I conclude that the likelihood of *Microcystis* blooms in the Delta will increase as a result of the WaterFix project.

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[79] DWR-653 at p. 35.

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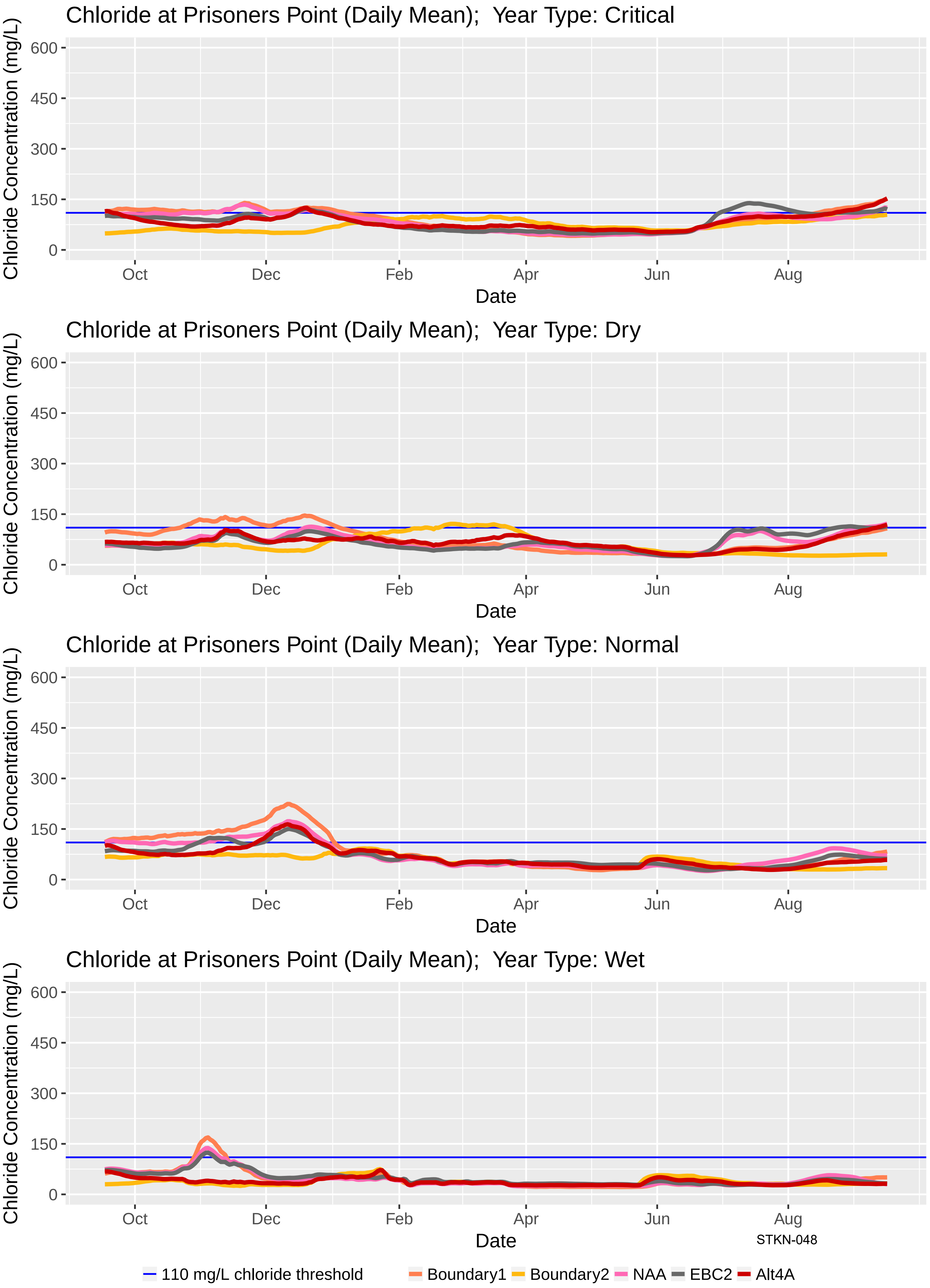
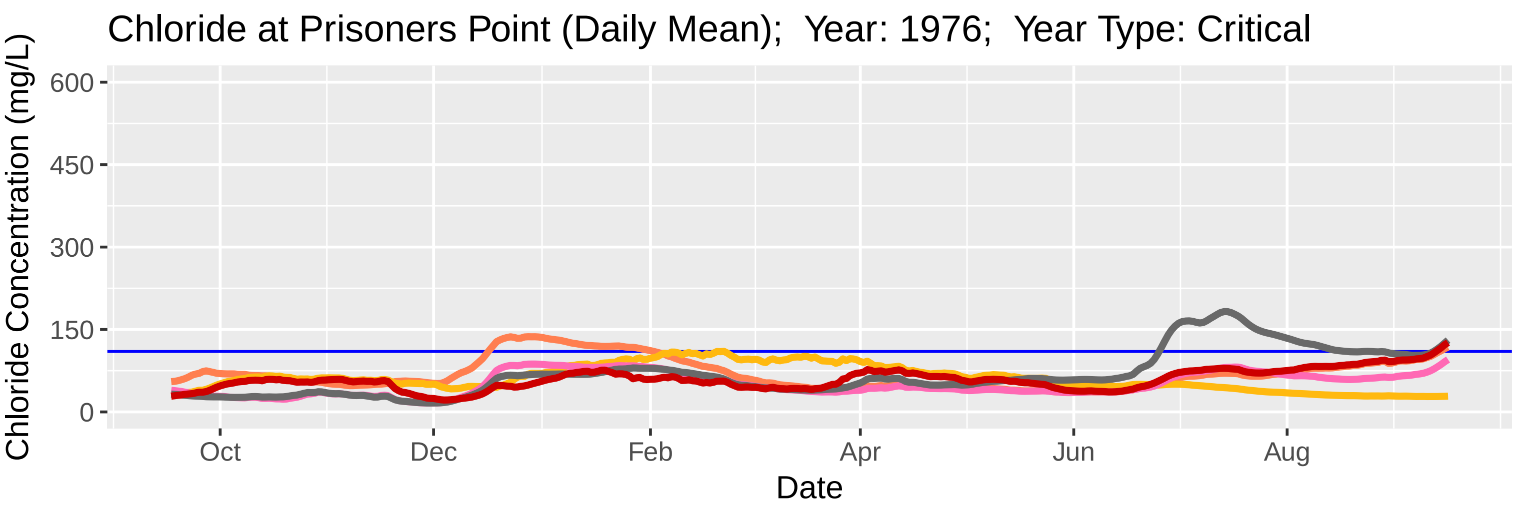
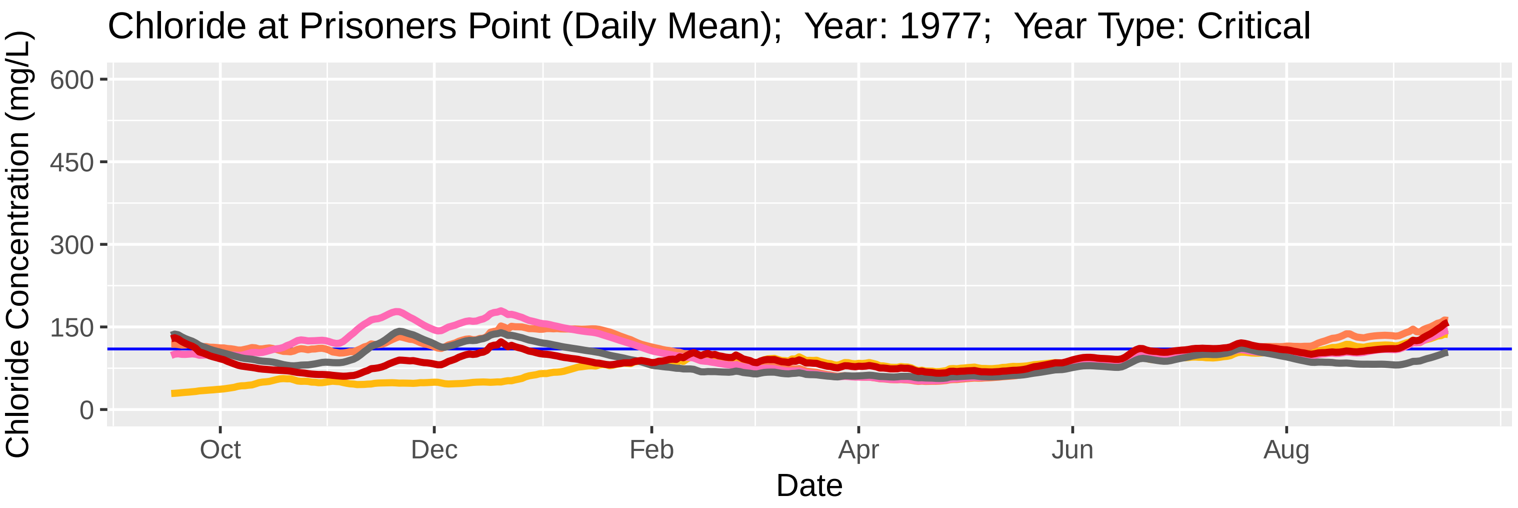
Appendix A

Additional DSM2 Salinity and Fingerprinting Results at Prisoner's Point




Chloride at Prisoners Point (Daily Mean); Year: 1976; Year Type: Critical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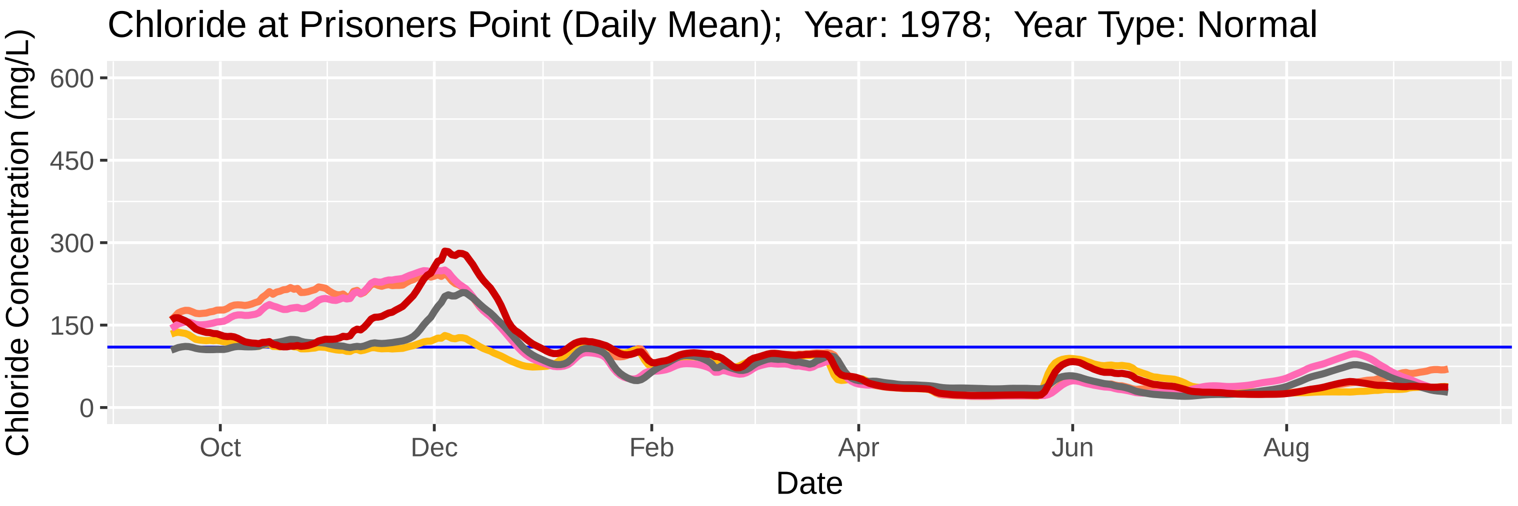
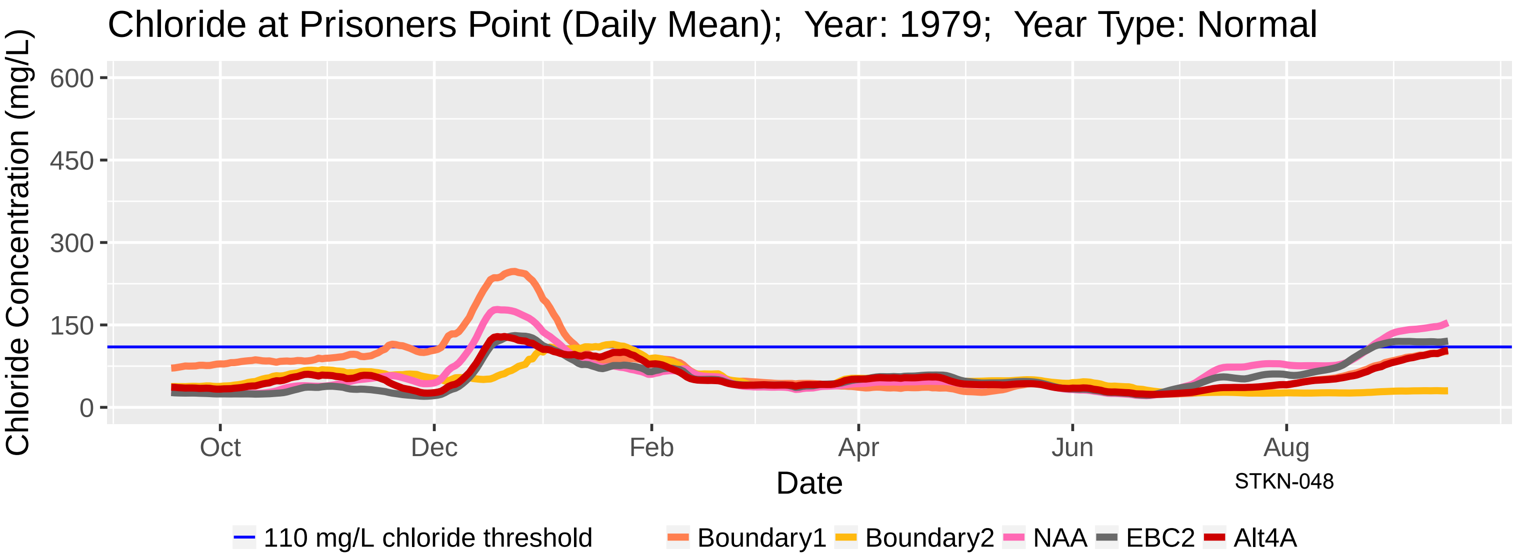
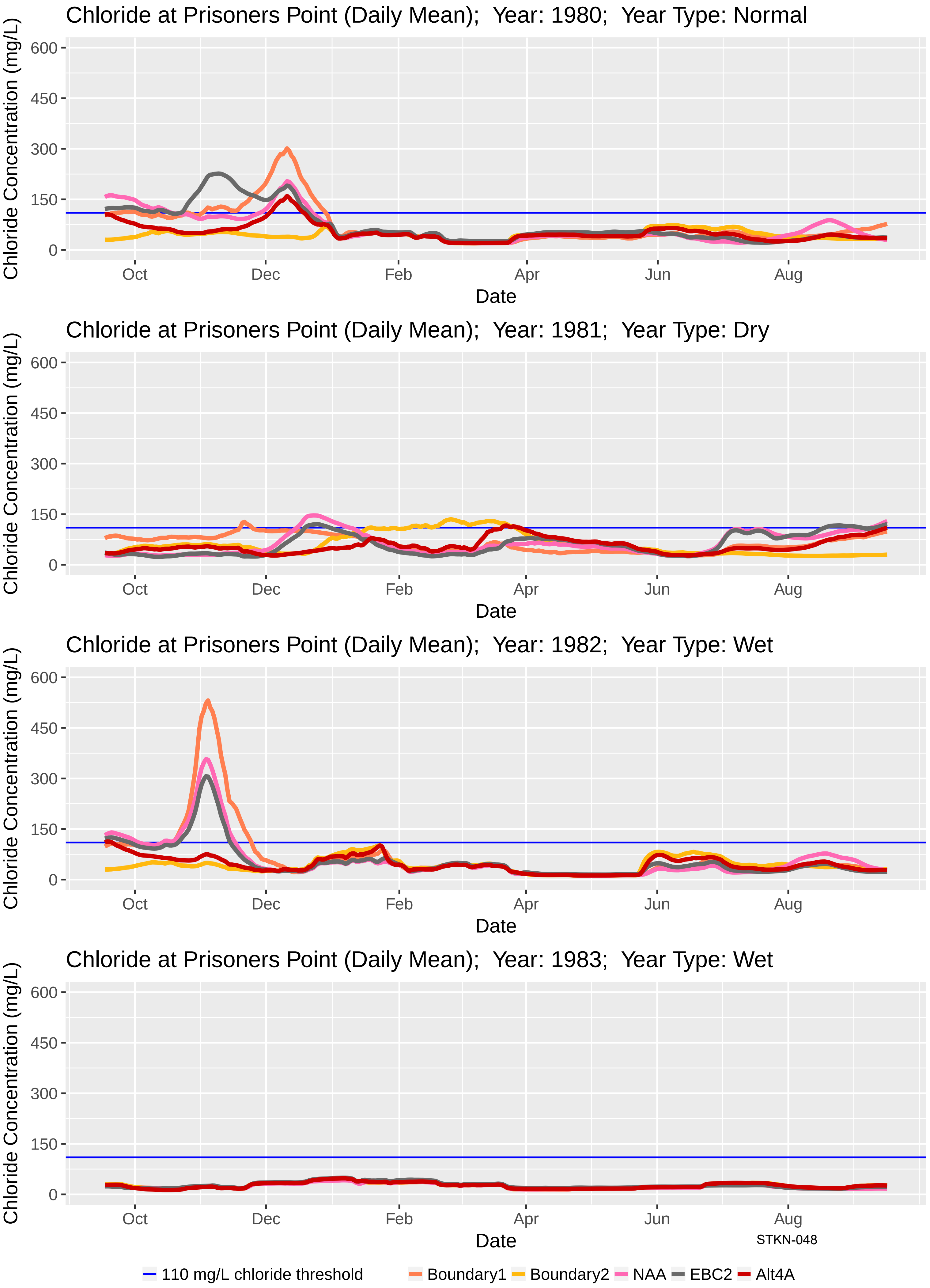
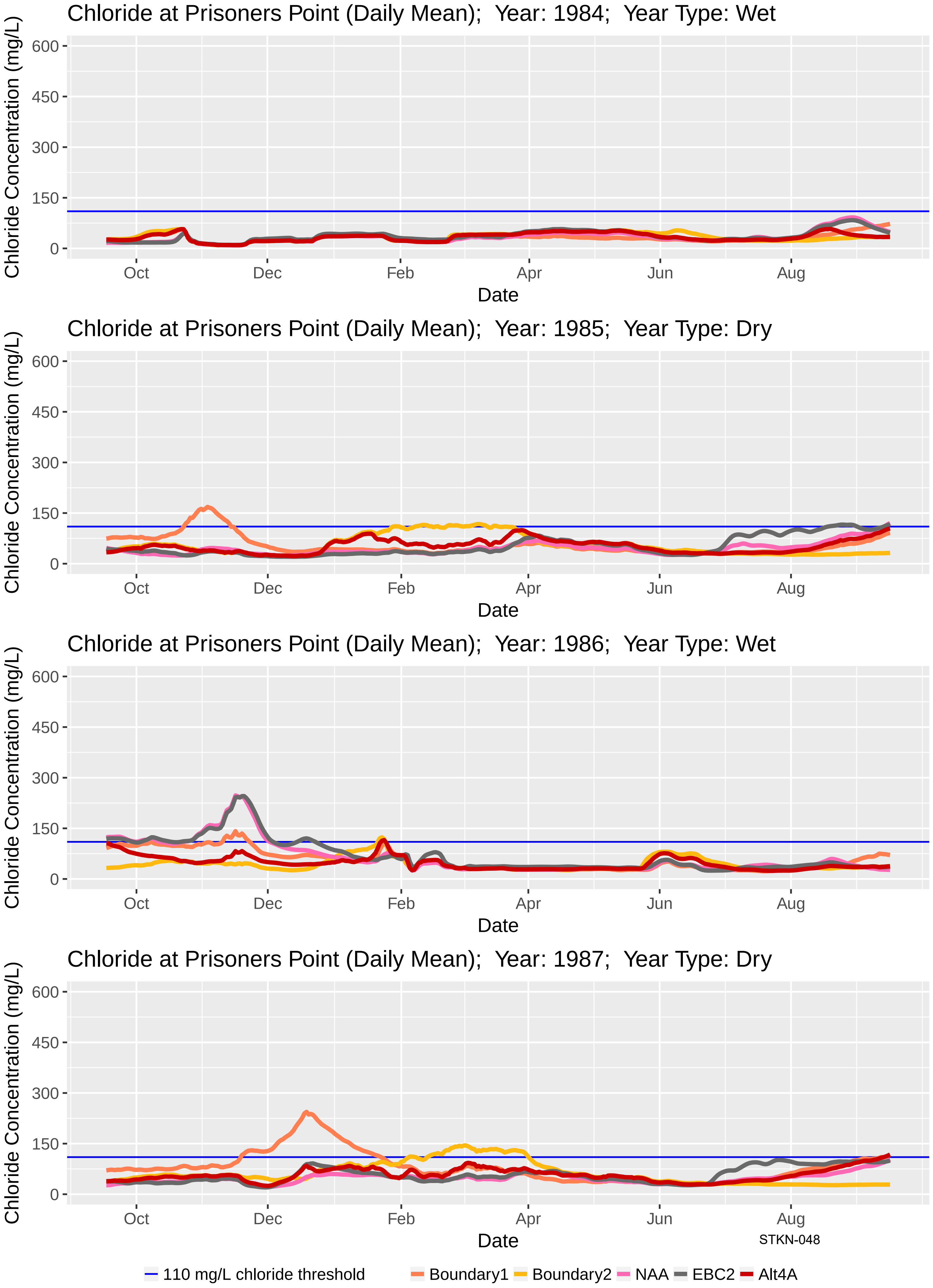

Chloride at Prisoners Point (Daily Mean); Year: 1978; Year Type: Normal


Chloride at Prisoners Point (Daily Mean); Year: 1979; Year Type: Normal

STKN-048


Chloride at Prisoners Point (Daily Mean); Year: 1980; Year Type: Normal
Chloride at Prisoners Point (Daily Mean); Year: 1981; Year Type: Dry
Chloride at Prisoners Point (Daily Mean); Year: 1982; Year Type: Wet
Chloride at Prisoners Point (Daily Mean); Year: 1983; Year Type: Wet
Chloride Concentration (mg/L)
600
450
300
150
0
Oct
Dec
Feb
Apr
Jun
Aug
Date
110 mg/L chloride threshold
Boundary1
Boundary2
NAA
EBC2
Alt4A

STKN-048



Chloride at Prisoners Point (Daily Mean); Year: 1984; Year Type: Wet

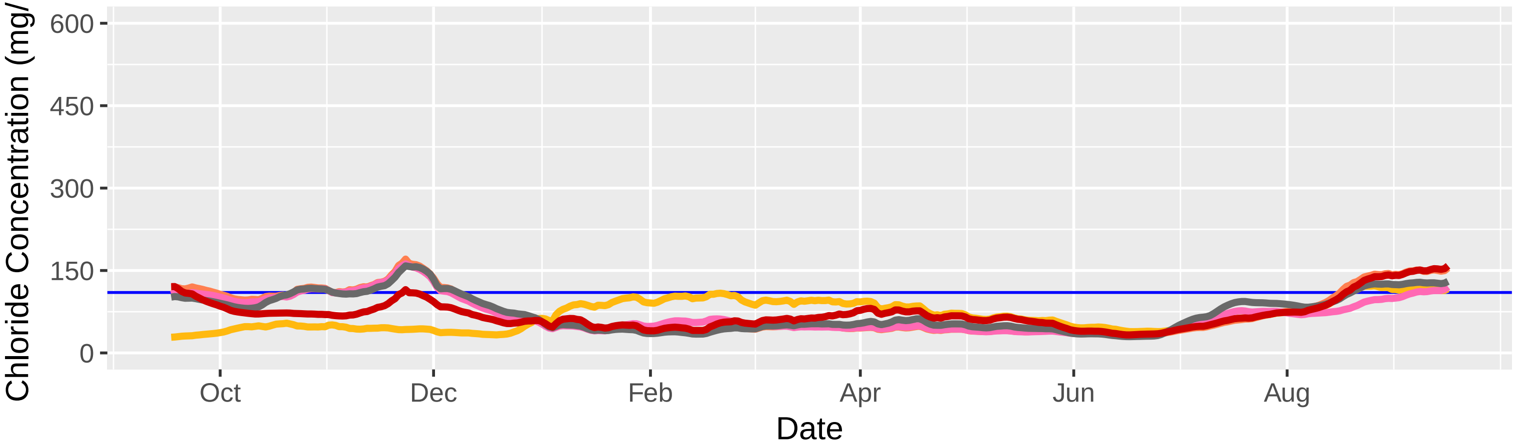
Chloride at Prisoners Point (Daily Mean); Year: 1985; Year Type: Dry

Chloride at Prisoners Point (Daily Mean); Year: 1986; Year Type: Wet

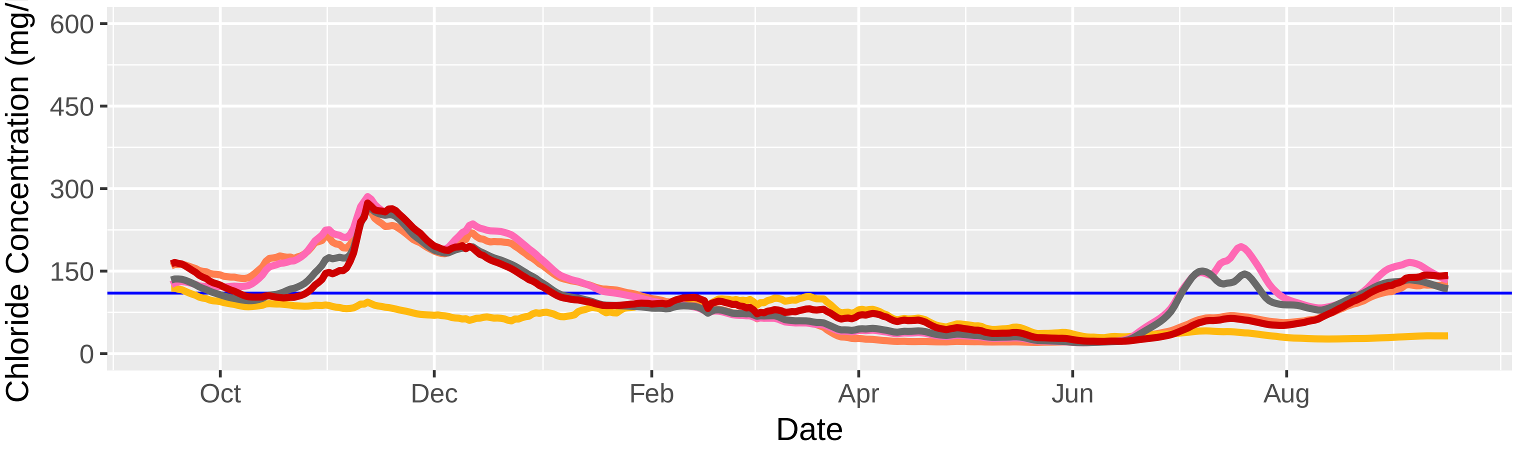
Chloride at Prisoners Point (Daily Mean); Year: 1987; Year Type: Dry

STKN-048

Chloride at Prisoners Point (Daily Mean); Year: 1988; Year Type: Critical



Chloride at Prisoners Point (Daily Mean); Year: 1989; Year Type: Dry



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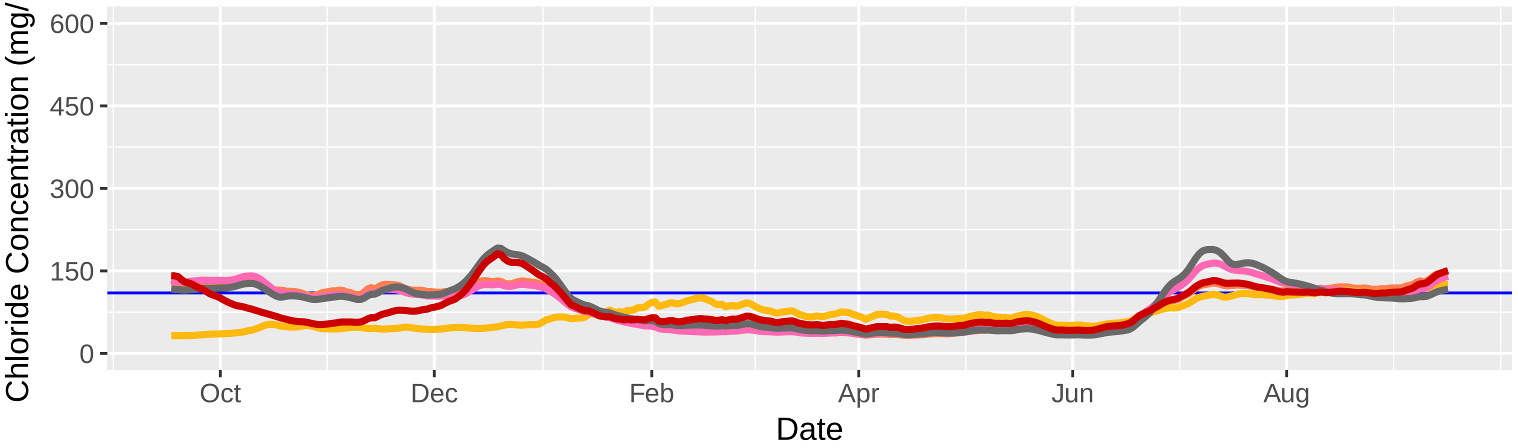

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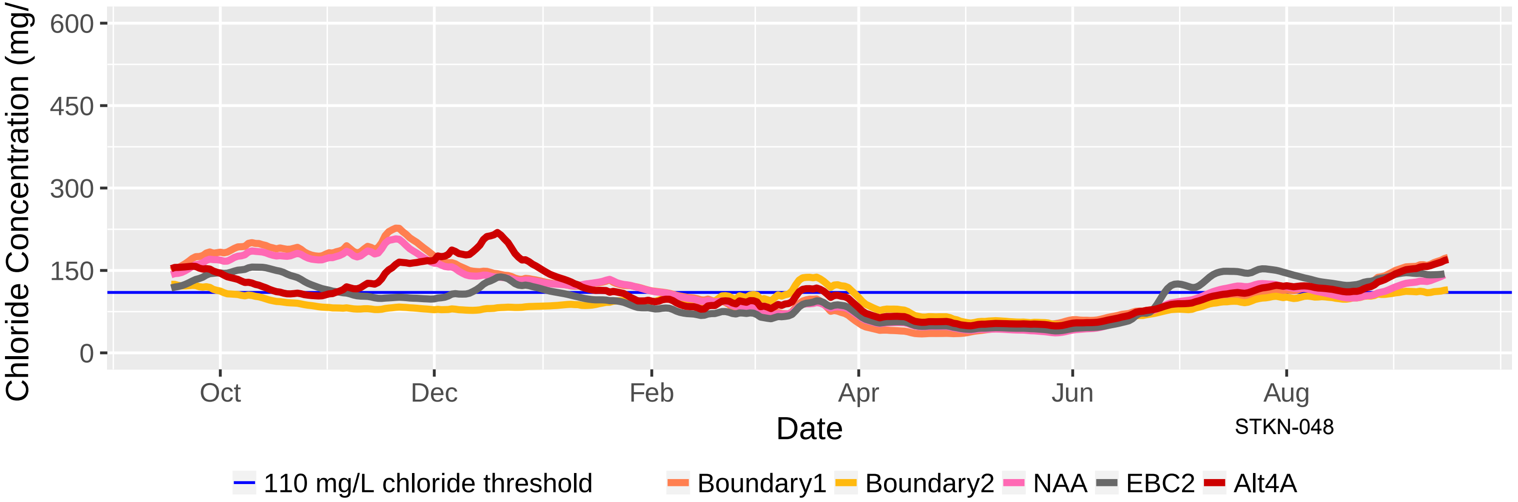
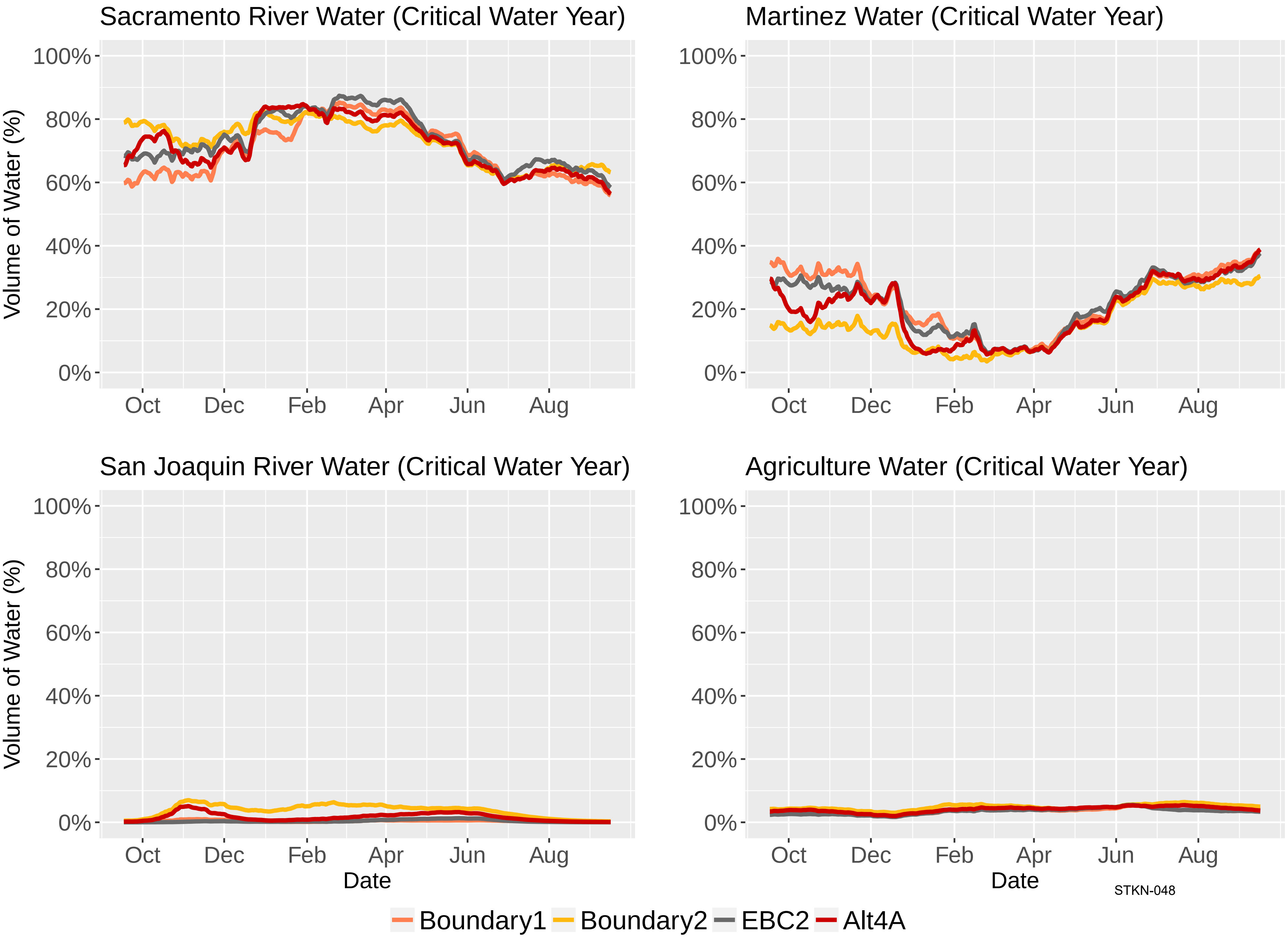


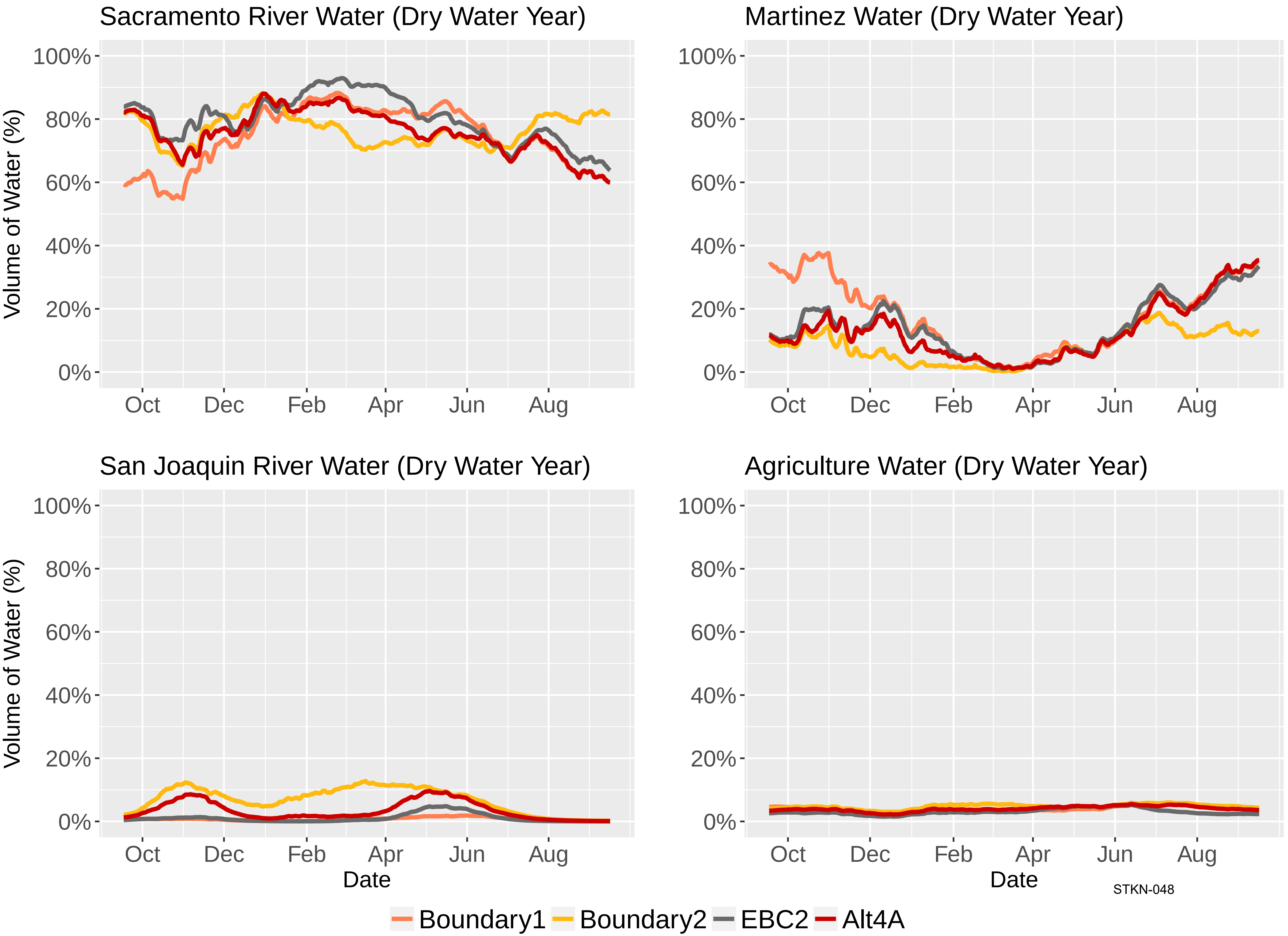
STKN-048


Sacramento River Water (Critical Water Year)

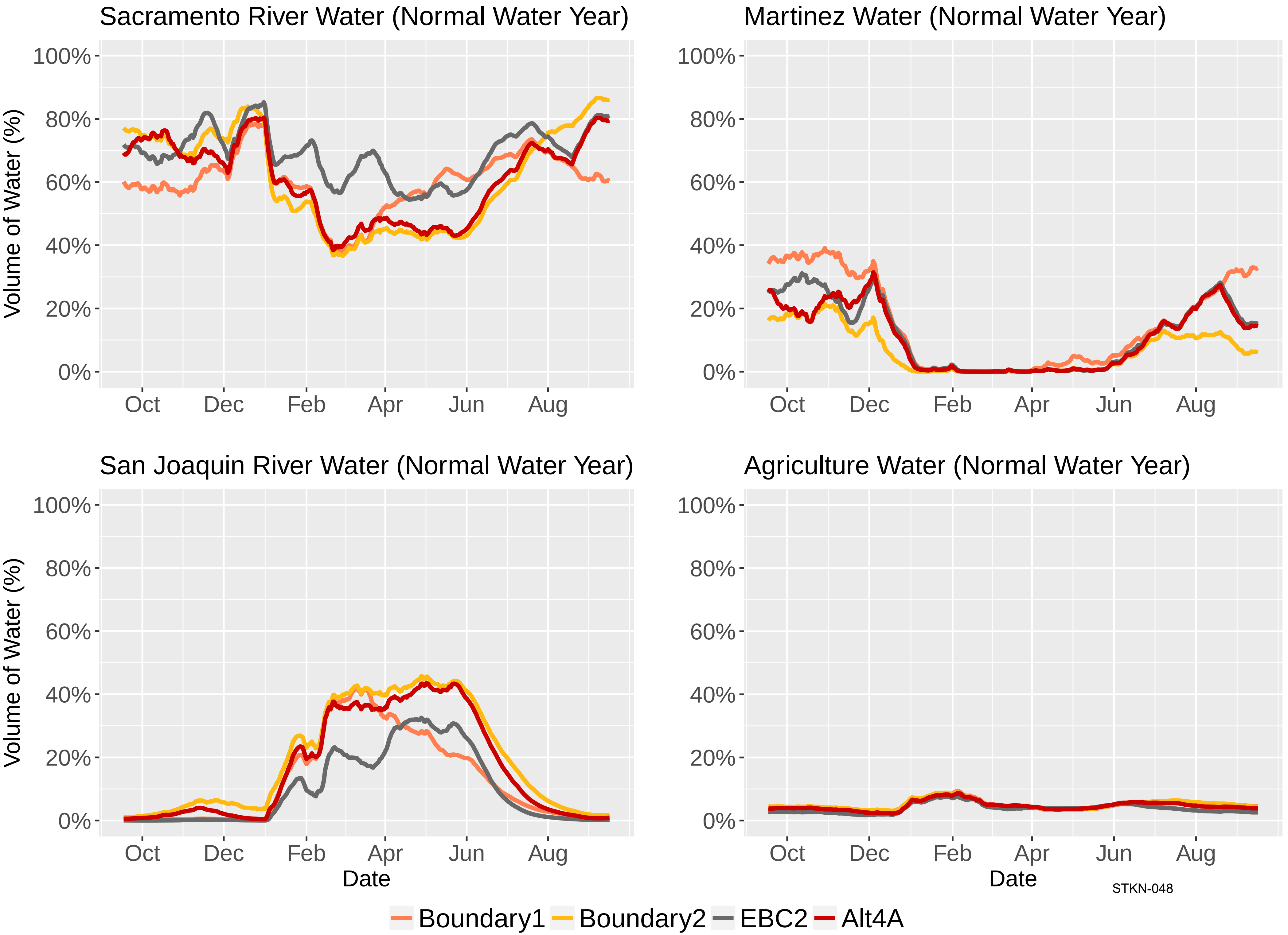
Martinez Water (Critical Water Year)

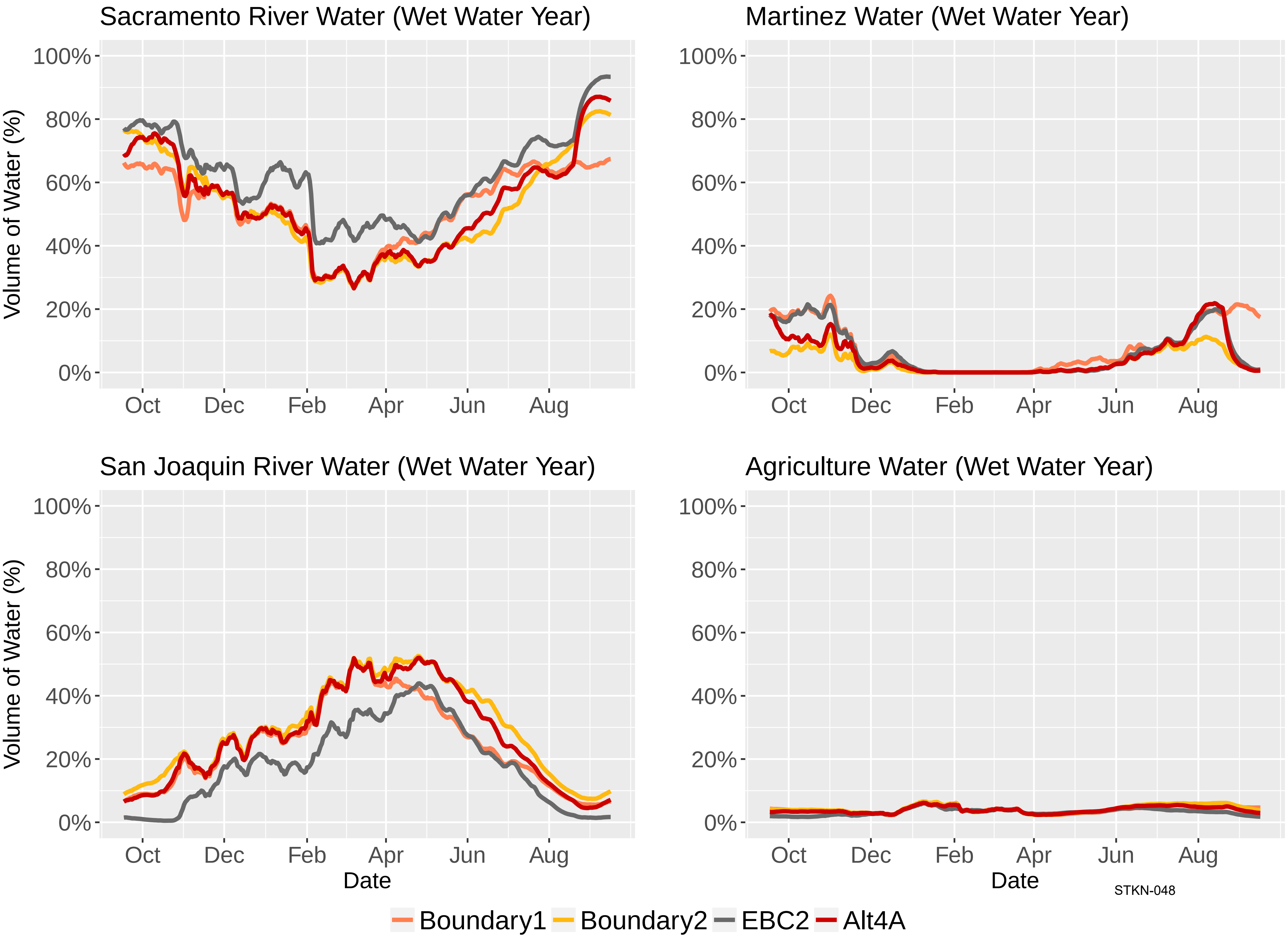
San Joaquin River Water (Critical Water Year)

Agriculture Water (Critical Water Year)


Sacramento River Water (Dry Water Year)
Martinez Water (Dry Water Year)
San Joaquin River Water (Dry Water Year)
Agriculture Water (Dry Water Year)
Volume of Water (%)
100%
80%
60%
40%
20%
0%
Oct
Dec
Feb
Apr
Jun
Aug
Date
Boundary1
Boundary2
EBC2
Alt4A

STKN-048


Sacramento River Water (Normal Water Year)
Martinez Water (Normal Water Year)
San Joaquin River Water (Normal Water Year)
Agriculture Water (Normal Water Year)
Volume of Water (%)
100%
80%
60%
40%
20%
0%
Oct
Dec
Feb
Apr
Jun
Aug
Date
STKN-048
Boundary1
Boundary2
EBC2
Alt4A


Sacramento River Water (Wet Water Year)
Martinez Water (Wet Water Year)
San Joaquin River Water (Wet Water Year)
Agriculture Water (Wet Water Year)
Volume of Water (%)
100%
80%
60%
40%
20%
0%
Oct
Dec
Feb
Apr
Jun
Aug
Date
STKN-048
Boundary1
Boundary2
EBC2
Alt4A