Delta Flow Criteria Informational Proceeding

Before the

State Water Resources Control Board

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Exhibit CCWD-5
Summary of Testimony

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My name is Gregory Gartrell, and I am Assistant General Manager at Contra Costa Water District. My Statement of Qualifications is provided in Exhibit CCWD-1. This Exhibit CCWD-5 summarizes my testimony, which is presented in Exhibit CCWD-6. Exhibit CCWD-8 provides true copies of references used in Exhibit CCWD-6 that may not be readily available to the State Water Board and its staff. Exhibit CCWD-6 was written and compiled either by me or under my direct supervision. Other authors of Exhibit CCWD-6 are Deanna Sereno (CCWD-3), Leah Orloff (CCWD-2), and Richard Denton (CCWD-4).

Exhibit CCWD-6, Contra Costa Water District's report on "Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay," presents a detailed review of more than 100 years of studies, monitoring data, scientific reports, and modeling analyses that establish an historical record of the salinity conditions in the western Delta and Suisun Bay.

The objective of Exhibit CCWD-6 is to answer two major questions regarding the historical extent of fresh water and salinity in the western Delta and Suisun Bay:

- What was the extent of fresh water and what were the salinity conditions prior to large-scale reservoir operations and water diversions (i.e., prior to early 1900's) and prior to structural changes in the Delta (i.e., prior to the 1860's)?
- What are the effects of large-scale water management practices (reservoir operations and diversions) on salinity conditions in the western Delta and Suisun Bay?

Available data were used to characterize historical and present-day fresh water extent and salinity intrusion into the Delta. The data examined in Exhibit CCWD-6 include paleohistorical records (over geologic time scales) of river flow and salinity (Section 2), instrumental observations of hydrology and salinity (Section 3), and literature reports on the extent of fresh water in the Delta (Section 4). Additional detail and supplemental information are presented in the Appendices of Exhibit CCWD-6.

While Exhibit CCWD-6 presents the results of numerous studies on historical flows and salinity in the Delta, it does not make recommendations as to what those levels should be in the future. The primary purpose of Exhibit CCWD-6 is to provide the State Water Board and its staff with a clear understanding of the past flow and salinity regime in the Delta in order to put any flow criteria in the proper perspective.

The major conclusions of Exhibit CCWD-6 are:

1. Human activities during the last 150 years, including extensive deposition and subsequent erosion of sediments from hydraulic mining, channelization of the Delta, elimination of tidal marsh, construction of deep ship channels, and diversion of water have resulted in increased salinity levels in the Delta and Suisun Bay. The distribution and severity of salinity intrusion during the last 100 years has been among the highest experienced over the past 2,500 years, and there is evidence that the prior period, from 4,000 years ago to 2,500 years ago, was even fresher. For the 2,500 years prior to anthropogenic changes that started in the last half of the 19th Century, the Delta was predominantly a freshwater tidal marsh. Comparison of historical outflow estimates with unimpaired outflow estimates show that diversions and reservoir operations have steadily and almost uniformly reduced Delta outflow, on a five-year running average basis, since the early 1930's (when substantial diversions were already taking place).
2. With the increase in diversions for consumptive use, the Delta became progressively saltier and reached historical highs in the 1928-1934 drought. Conditions in the Delta during the early 1900's (i.e., prior to 1918) were much fresher than current conditions for hydrologically similar periods. The historical record and published studies uniformly demonstrate that the Delta now has much less outflow and is now managed at a salinity level that is much higher than would have occurred under pre-1900 conditions. Operation of reservoirs to meet beneficial uses reduces salinity intrusion relative to what would occur in the absence of salinity management; however, current salinity levels still exceed salinity levels in the early 1900's under similar hydrological conditions. Salinity typically intrudes 3 to 15 miles farther into the Delta today than it did prior to 1918, depending on hydrological conditions.
3. Seasonal and inter-annual variation in salinity has also been changed. Major causes include reduced freshwater flows into the Delta and changes to Delta geomorphology. At any given location in the western Delta and Suisun Bay, the percentage of the year when fresh water is present has been greatly reduced or, in some cases, largely eliminated.

Pre-1900 flow and salinity conditions in the Delta.

Prior to human influence, the historical distribution of salinity in the Delta[1] was controlled primarily by the seasonal and inter-annual distribution of precipitation, the geomorphology of the Bay and Delta, daily tides, the spring-neap tidal cycle, and the mean sea level at Golden Gate.[2] Studies and salinity measurements confirm that despite salinity management efforts, Delta salinity is now at or above the highest salinity levels found in the past 2,500 to 4,000 years.[3] For example, studies on the quantification and taxonomic identification of diatom frustules,[4,8] plant seeds and roots,[5,8] plant pollen,[6,8] and measurement of peat carbon isotope ratios[7,8] show that, while there are several very dry periods in the past 2,500 years (some lasting a century or more),

[1] The Delta as we know it started to form about 6,000 years ago as sea level rose following the last ice age. (Atwater *et al.*, 1979, found in CCWD-8)
[2] CCWD-6, pp. 2-6
[3] CCWD-6, pp. 9-17
[4] Byrne *et al.*, 2001; Starratt, 2001; Starratt, 2004
[5] Goman *et al.*, 2008
[6] May, 1999; Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004
[7] Byrne et al., 2001; Malamud-Roam and Ingram, 2004
[8] The preceding published papers are provided in CCWD-8. They are summarized in CCWD-6, pp. 14-18.

the most saline period in the Delta has been in the past 100 years. Analysis of tree rings[9] shows that:

- The period from the late 1800's to about 1910 was wetter than average.
- The period from 1917 to 1936 was the driest 20-year period in the past 400 years.
- The period from 1928 to 1934 was the driest 6-year period in the past 1,000 years.

Extended wet and dry periods are both evident in the historical record.

Since about 1860, a number of morphological changes to the Delta landscape and operational changes of reservoirs and water diversions have affected flows and the distribution of salinity within the Delta.[10] Between 1860 and 1920, there was significant modification of the Delta by humans:

- marsh land was reclaimed,
- hydraulic mining caused extensive deposition and then erosion of sediment, and,
- Delta channels were widened, interconnected and deepened.

While paleosalinity data uniformly show that the past 100 years are among the most saline periods in the Delta and Suisun Bay, examination of these data also shows that the response of the system has changed. For example, while substantial salinity intrusion is evident from pollen samples on Roe Island within Suisun Bay for long periods in the historical record (for example, from about 1100 CE to 1400 CE), the same level of salinity intrusion is not evident in the western Delta at Brown's Island[11] during those periods, but it is evident at both sites during the last 100 years. One likely cause of this change in response is the draining of tidal marshland in the Delta and the channelization of the Delta; both actions alter the tidal response in a way that will increase the distribution and severity of salinity intrusion.[12] Consequently, not all the recent salinity intrusion is the direct result of reduced outflow from hydrologic conditions and water diversions.

Salinity and Flow Records Since 1920

Large-scale reservoir construction began in about 1920 and continued through the 1970's, changing the timing and magnitude of flows to the Delta. Large volumes of water began to be diverted for agricultural use upstream of and within the Delta in the same time period. During more recent times, California's Delta water resources have been extensively managed to meet the water supply needs of the State's municipal, industrial, and agricultural water users while also attempting to provide flow and water quality conditions to meet fishery needs.[13]

Comparison of historical estimates of Delta outflow with unimpaired[14] outflow estimates provides a measure of the reduction in freshwater flow out of the Delta and into San Francisco Bay due to water management activities such as diversions and reservoir operations. Since unimpaired flow does not measure what would have occurred in the absence of all anthropogenic

[9] CCWD-6, pp. 10-13 and Meko *et al.*, 2001a, provided in CCWD-8.
[10] CCWD-6, pp. 1-4
[11] CCWD-6, p.16-17 and Malamud-Roam and Ingram, 2004, provided in CCWD-8.
[12] CCWD-6, pp. 3
[13] CCWD-6, pp. 4-6
[14] Unimpaired flow represents the natural water production of the river basin, unaltered by water diversions, reservoir storage and operation, or by export of water to or import of water from other basins.

changes, such comparisons must be used with care. Short term comparisons (less than a few months) will not be completely accurate, but they can reveal seasonal trends. Longer term comparisons (for example, five-year running averages) can reveal long term trends.

Figure 3-5[15] shows such a comparison. Several important trends are evident:

- The long-term trend for unimpaired outflow shows an *increase* of about 5.9 million acre-feet per year (MAF/year) over the past 75 years; the precipitation in the basin has increased substantially.
- The long-term trend for actual net Delta outflow has *decreased* by about 3.5 MAF/year over the same period.
- The long-term trend over the past 75 years is a net loss of outflow due to water diversions of about 9.4 MAF/year; when diversions upstream and within the Delta prior to the 1930's are included in the comparison, the total amount of water removed from the system is about 13 or 14 MAF/year).
- The five-year running average shows that the reduction in outflow is nearly linear; actual outflow decreases steadily compared to unimpaired outflow over the entire period.
- The reduction in outflow is greatest in winter and spring.
- Outflow was generally above unimpaired conditions in the fall of most years from about 1940 to about 1975; since 1975, the entire year is in a deficit outflow condition compared to unimpaired conditions, except for the wettest years such as 1983, 1995 and 1998.

The last point is also seen in Figure 3-7,[16] where long-term trends of the difference between actual monthly outflow and unimpaired monthly outflow are seen for selected months; since about 1980, all months except a few fall months of the very wettest years indicate actual outflow has been reduced significantly from unimpaired conditions.

Similar trends are seen for Delta salinity, as measured by X2, the location of the 2 part per thousand salinity line, as measured in kilometers from the Golden Gate. Figure 3-11[17] shows X2 calculated from unimpaired and historical (actual) outflow estimates. This figure shows:

- The early period from 1930 until about 1940 exhibits very high salinity; this is due to a combination of hydrologic conditions (this is a very dry period), diversions from the system upstream and within the Delta (largely agricultural), and the morphological changes to the Delta that occurred largely between 1850 and 1920.
- Between 1940 and 1975, X2 was larger (saltier Delta) in most months of the year. During some fall months, X2 was smaller (fresher Delta), corresponding to greater outflow; this was caused by reservoir operations (fall releases to meet flood control reservation levels) and hydrologic conditions (early fall precipitation in these years).
- Since 1980, X2 is larger (saltier Delta) in almost every month except the fall months of the wettest years.
- The effect of water management activities on X2 is greatest in hydrologically dry periods, indicating the degree to which hydrology plays a role (for example, compare the 1987-1992 dry period with the 1995-2000 wet period).

[15] CCWD-6, p. 25
[16] CCWD-6, p. 27
[17] CCWD-6, p. 36

Under equivalent hydrological conditions, the boundary between salt and fresh water is now 3 to 15 miles farther into the Delta than it would have been without the increased diversions of fresh water and other anthropogenic changes that have taken place in the past 150 years.

Variability of Delta salinity and outflow

Reservoir operations artificially manage salinity intrusion to conditions that are saltier than had been experienced prior to the early 1900's. While these managed conditions are certainly fresher than would occur in today's altered system if operated without any salinity management, they are still saltier than what the Delta experienced under similar hydrological conditions in the past.

For example, the 1928-1934 drought was one of the driest periods in the past 1,000 years, and it occurred after tidal marshes within the Delta had been reclaimed and water diversions began removing substantial amounts of fresh water from the Bay-Delta system. Nonetheless, the Delta freshened during the winter in those drought years.[18] This winter freshening of the Delta did not occur during recent droughts (1976-1977, 1987-1992, and 2007-2009), yet winter salinity during this most recent dry period (2007-2009) is reduced from the previous drought levels (1976-1977 and 1987-1992) due to compliance with the X2 standard.

While salinity intrusion into the Delta during the fall was previously only seen in the driest years, significant salinity intrusion now occurs in nearly every year – exceptions are only found in the wettest conditions.[19] In 21 of the past 25 years, salinity intrusion into the Delta during the fall has been substantial and reached levels seen previously only in dry years. Yet the effect of hydrological conditions remains important; half of the most recent 25 years have been either dry or critically dry. This is a disturbing trend, which is similar to the very dry period of 1920-1940. It is unknown at this time if this climatological trend will continue.

The variability of fresh and saline conditions in the Delta has considerably changed because of upstream and in-Delta water diversions and water exports.[20] This change in variability results largely from the lack of freshwater conditions in Suisun Bay and the western Delta, especially in the winter and spring. This is seen dramatically in Figure 3-10.[21] In this figure, the distance to fresh water (50 parts per million chloride concentration, measured from the C&H sugar refinery in Crockett, California, near the western end of Suisun Bay) is plotted for three similar hydrological periods. For the period 1908 through 1918, data are from C&H Sugar, and the data show long periods of fresh water to the west of the Delta in every winter. For the two more recent periods (distances based on salinity measurements in the Delta and Suisun Bay), the fresh periods in winter and spring are much reduced in the length of time. In recent decades, salinity intrudes earlier and farther into the Delta than was seen in the early 1900's. The entire character of the salinity regime has been changed substantially; today, salinity intrudes farther into the Delta and stays for longer periods of time than even in the recent past.

[18] CCWD-6, Fig. 3-17, p.41
[19] CCWD-6, Fig. 3-18, p. 41
[20] Enright and Culberson, 2009, provided in CCWD-8
[21] CCWD-6, p. 33