

BDCP WORKING DRAFT OF CONSERVATION STRATEGY CHAPTER 3
Attachment 1 - Historical Salinity at Antioch & Western Delta

Historical Salinity at Antioch and other parts of the Western Sacramento - San Joaquin Delta, prepared by Flow Science Inc., Pasadena, CA for the City of Antioch

Summary

- Pre-1918, freshwater was available at least at low tide during almost the entire year; relatively wet hydrologic conditions prevailed in the upstream watersheds of the Delta before 1918, as indicated by observed precipitation records and paleo records derived from tree rings.
- Between 1918 and the late 1930s, drought conditions and upstream water diversions resulted in the presence of high salinity water at Antioch's intake.
- By 1940 the drought receded, but salinity at Antioch's intake never returned to historic (pre-1918) levels. In fact, salinity continues to increase.
- Antioch can take water at its intake when salinity is less than 250 mg/L chlorides (equivalent to about 1000 $\mu\text{S}/\text{cm EC}$)¹. Over time, the fraction of time that water at the City's intake is below this salinity threshold has declined.
- Available information indicates that the "historic" Delta was significantly fresher than the current Delta. This may have implications not only for Antioch's ability to use their intake, but also for species that may be adapted to pre-1918 salinity conditions.

1. Salinity before 1918

In 1920, the Town of Antioch filed a lawsuit against upstream irrigation districts alleging that the upstream diversions were causing increased salinity intrusion at Antioch (Town of Antioch v. Williams Irrigation District (1922, 188 Cal. 451)). Anecdotal testimony² from this lawsuit indicates that in the late 1800s, water at Antioch was known to be brackish at high tide during certain time periods, but Antioch was apparently able to pump fresh water at low tide throughout the year, with the possible exception of the fall season during one or two dry years. Water at Antioch was apparently fresh at low tide at least until around 1915 (when the pumping plants started pumping continuously, regardless of tidal stage).

¹ The freshwater salinity threshold of 250 mg/L chlorides at the San Joaquin River at Antioch is based on the 1968 agreement between the City of Antioch and DWR. This threshold is approximately equivalent to 1000 $\mu\text{S}/\text{cm EC}$, based on the site-specific empirical relationships between chloride concentration and EC (K. Guivetchi, DWR Memorandum dated June 24, 1986).

² Mr. Dodge, Mr. Cary Howard and Mr. Dahnken testified on the salinity conditions during the 1860s to 1900; Mr. William E. Meek, Mr. James P. Taylor and Dr. J. W. DeWitt testified on the salinity conditions from the early 1900s to the 1920s.

Anecdotal information from the Antioch lawsuit is consistent with several literature reports which indicate extensive availability of freshwater in the western Delta prior to 1918. Relevant information from some of these literature reports is presented below:

Location: Western Delta
Source(s): DPW (1931)
Quotation: *“The dry years of 1917 to 1919, combined with increased upstream irrigation diversions, especially for rice culture in the Sacramento Valley, had already given rise to invasions of salinity into the upper bay and lower delta channels of greater extent and magnitude than had ever been known before.”* (DPW, 1931, pg. 22)
Quotation: *“It is particularly important to note that the period 1917-1929 has been one of unusual dryness and subnormal stream flow and that this condition has been a most important contributing factor to the abnormal extent of saline invasion which has occurred during this same time.”* (DPW, 1931, pg. 66)
Summary: Salinity intrusion into the Delta during the period 1917-1929 was unprecedentedly large.

Location: Pittsburg, CA
Source(s): Tolman and Poland (1935) and DPW (1931)
Quotation: *“There was an inexhaustible supply of river water available in the New York Slough [near Pittsburg at the confluence of the Sacramento and San Joaquin Rivers], but in the summer of 1924 this river water showed a startling rise on salinity to 1,400 ppm of chlorine, the first time in many years that it had grown very brackish during the dry summer months.”* (Tolman and Poland, 1935, pg. 27)
Quotation: *“From 1880 to 1920, Pittsburg (formerly Black Diamond) obtained all or most of its domestic and municipal water supply from New York Slough offshore.”* (DPW, 1931, pg. 60)
Summary: Prior to the 1920s, the water near the City of Pittsburg was sufficiently fresh for the City to obtain all or most of its fresh water.

Location: Antioch, CA
Source(s): DPW (1931)
Quotation: *“From early days, Antioch has obtained all or most of its domestic and municipal water supply from the San Joaquin River immediately offshore from the city. This supply also has always been affected to some extent by saline invasion with the water becoming brackish during certain periods in the late summer and*

early fall months. However, conditions were fairly satisfactory in this respect until 1917, when the increased degree and duration of saline invasion began to result in the water becoming too brackish for domestic use during considerable periods in the summer and fall.” (DPW, 1931, pg. 60)

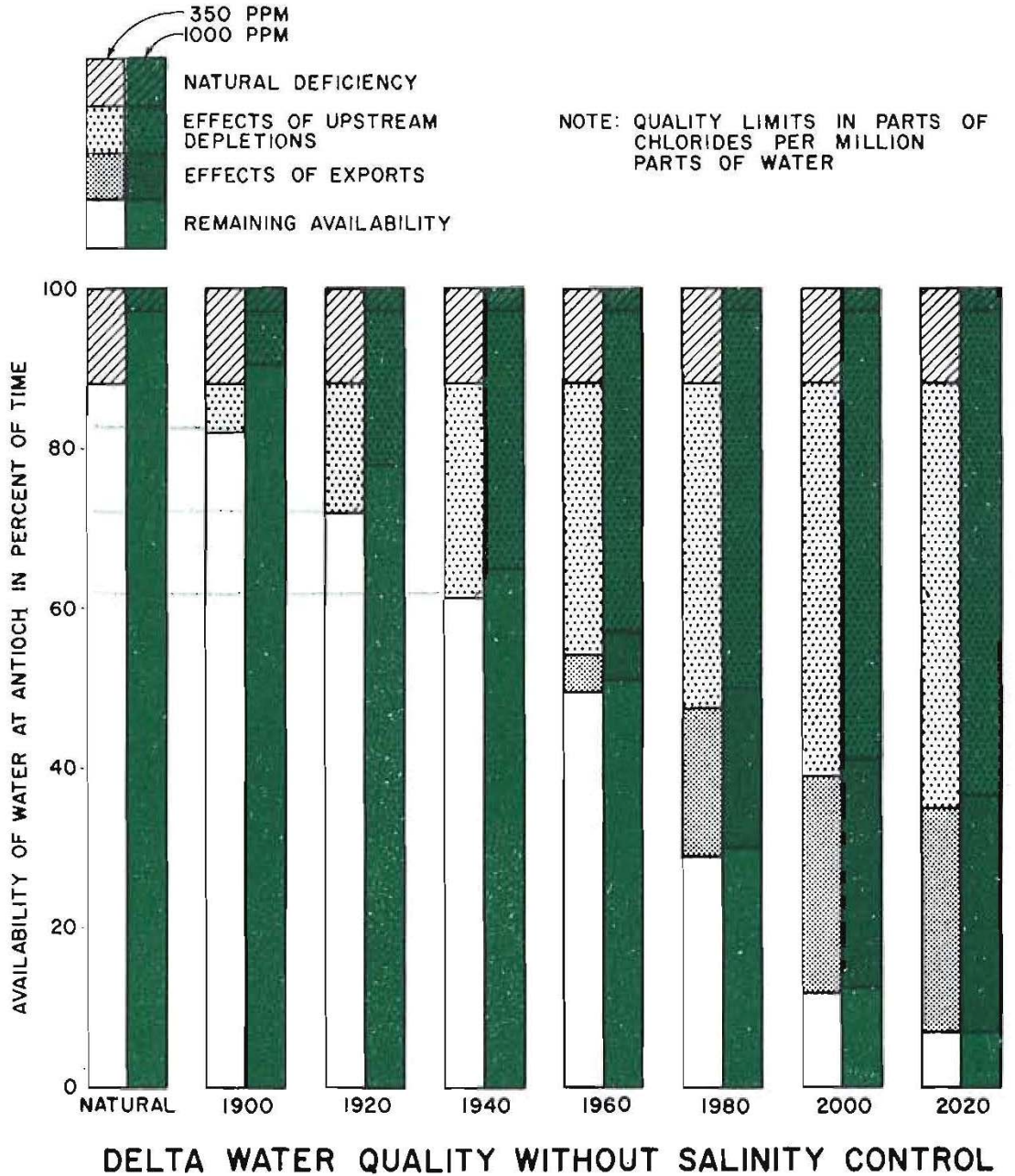
Summary: Until 1917, the City of Antioch obtained all or most of its freshwater supplies directly from the San Joaquin River. Salinity intrusion prevented domestic use of water at the Antioch intake in summer and fall after 1917.

2. Changes in salinity at the City of Antioch’s Intake

DWR (1960) estimated that water with a chloride concentration of 350 mg/L or less would be available about 85% of the time under “natural” conditions (**Figure 1**). DWR (1960) estimated that chloride concentrations at Antioch would be less than 350 mg/L about 80% of the time in 1900 about 60% of the time by 1940; DWR also projected further deterioration of water quality in 1960 and later, but did not include the effects of reservoir releases for salinity control.

Figure 1 – Salinity on the San Joaquin River at Antioch (DWR, 1960)

DWR estimated the percent of time that a certain quality of water (with less than 350 mg/L chlorides; or less than 1,000 mg/L chlorides) would be available in the river without reservoir releases to provide salinity control. The estimates for 1960, 1980, 2000, and 2020 assume the reservoirs do not make releases for salinity control.



3. Current Salinity Conditions

Salinity at Antioch (and also in the western Delta) varies substantially with the tide. Generally, the greatest salinity is observed near high tide and the lowest salinity is observed at low tide. **Figure 2** indicates that for water year 2000 (an above normal water year) water at the City of Antioch’s intake was below 1000 $\mu\text{S}/\text{cm}$ EC all day for about four-and-a-half months (early February through mid-June) and for a portion of the day at low tide for another three and half months (mid-June through September). For the remaining four months (October-January), water at the City’s intakes exceeded 1,000 $\mu\text{S}/\text{cm}$ EC for the entire day, regardless of tidal stage. **Figure 3**³ indicates that during 10 of the 20 years between 1983 and 2002 salinity was less than 1,000 $\mu\text{S}/\text{cm}$ EC at low tide for only about eight months of the year. Also, during the driest 5 years between 1983 and 2002, salinity was less than 1,000 $\mu\text{S}/\text{cm}$ for only about four months per year (i.e., no fresh water was available at any time of the day for about eight months of the year).

Observations of salinity at Antioch from the Interagency Ecological Program (IEP, <http://iep.water.ca.gov/dss/>) indicate the number of days when water at the City of Antioch’s intake had a daily average EC less than 1000 $\mu\text{S}/\text{cm}$; see **Table 1**. Although the number of days with suitable water quality varies with hydrologic conditions, the number of days of suitable quality is significantly less, even in wet periods, than for historic (pre-1918) conditions. As noted in Section 1, anecdotal testimony from the Antioch lawsuit indicates that Antioch was able to pump fresh water at low tide year-round in the late 1800s, with the possible exception of the fall season during one or two dry years. Thus, freshwater is currently available at Antioch far less frequently than prior to the 1920s.

Table 1: Number of days with EC < 1000 $\mu\text{S}/\text{cm}$ in the San Joaquin River at Antioch

Source of the data is <http://iep.water.ca.gov/dss/>. Note that data records from IEP had several missing data and hence these numbers could be underestimates.

Time period	Average days per year with daily average EC < 1000
WY 1965-1969	275
WY 1970-1974	279
WY 1975-1979	158
WY 1980-1984	277
WY 1985-1989	114
WY 1990-1994	71
WY 1995-1999	236
WY 2000-2004	167

³ Data Source: Interagency Ecological Program, HEC-DSS Time-Series Databases. Station RSAN007. Agency: DWR-ESO-D1485C. Measurement: 1-hour EC. Time Range: May 1, 1983 through September 30, 2002

Figure 2 – Salinity variations in the San Joaquin River at Antioch, water year 2000

Fresh water (less than 1,000 $\mu\text{S}/\text{cm}$ EC) was available at Antioch during low tide for only about eight months of the year during water year 2000 (an above normal water year). No freshwater was available at any stage of the tide during five months of the year. Source of the data is <http://iep.water.ca.gov/dss/>

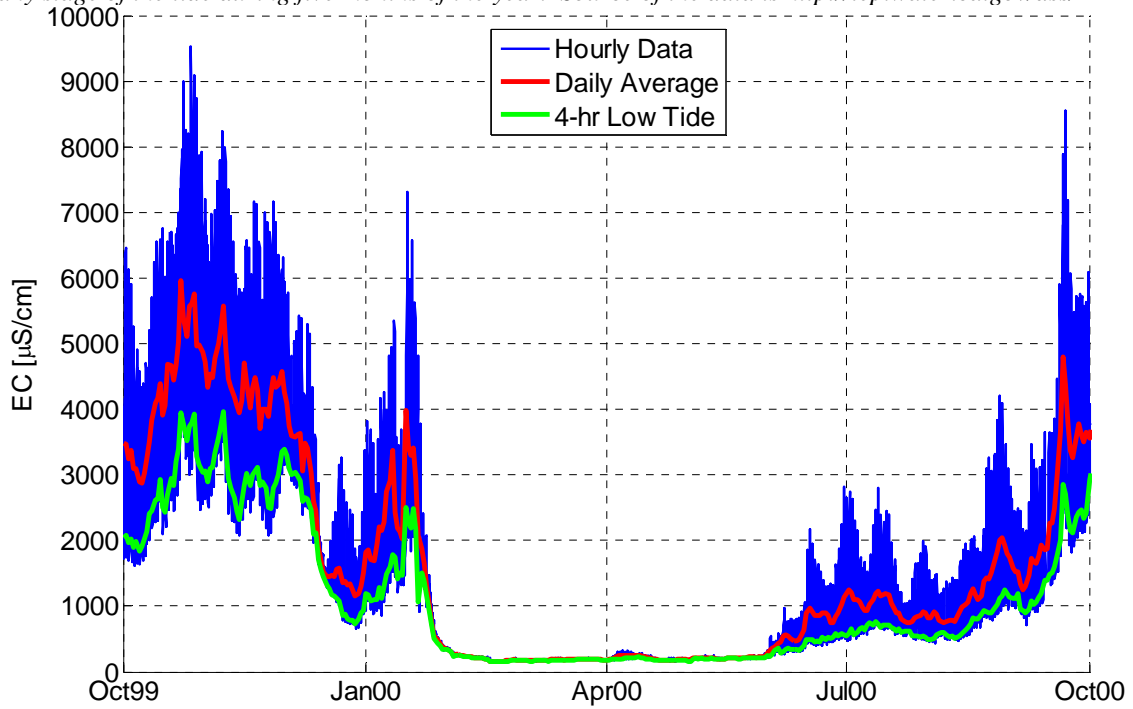
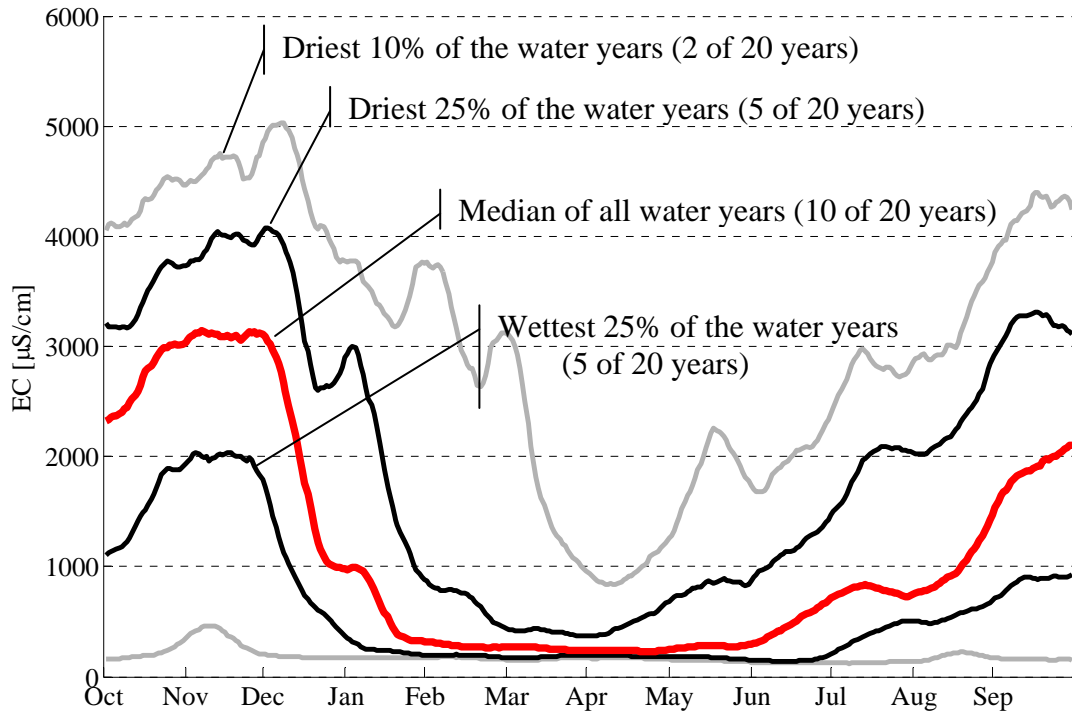


Figure 3 – Seasonal Distribution of observed low-tide salinity at Antioch, 1983-2002

Low tide salinity (salinity during the freshest 4-hours of each day) for water years 1983-2002 indicates that on average (in 50% of the water years) low tide salinity exceeds 1,000 $\mu\text{S}/\text{cm}$ EC from late-August through December. During the driest 25% of the years (5 out of 20 years), low tide salinity exceeds 1,000 $\mu\text{S}/\text{cm}$ EC from June through January, leaving Antioch with no fresh water for eight months of the year. Source of the data is <http://iep.water.ca.gov/dss/>



References

- [DPW] Department of Public Works. 1931. *Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay*. Bulletin No. 27. State of California, Department of Public Works, Division of Engineering and Irrigation. See <http://www.archive.org/details/variationcontrol27calirich>
- [DWR] Department of Water Resources. 1960. *Delta Water Facilities*. Bulletin No. 76. State of California. See [http://www.deltacorridors.com/uploads/Bulletin No. 76 Delta Water Facilities-Color.pdf](http://www.deltacorridors.com/uploads/Bulletin%20No.%2076%20Delta%20Water%20Facilities-Color.pdf)
- Tolman, C. F. and J. F. Poland. 1935. *Investigation of the Ground-Water Supply of the Columbia Steel Company Pittsburg, California*. Stanford University, California, May 30, 1935.

Town of Antioch v. Williams Irrigation District (1922, 188 Cal. 451).