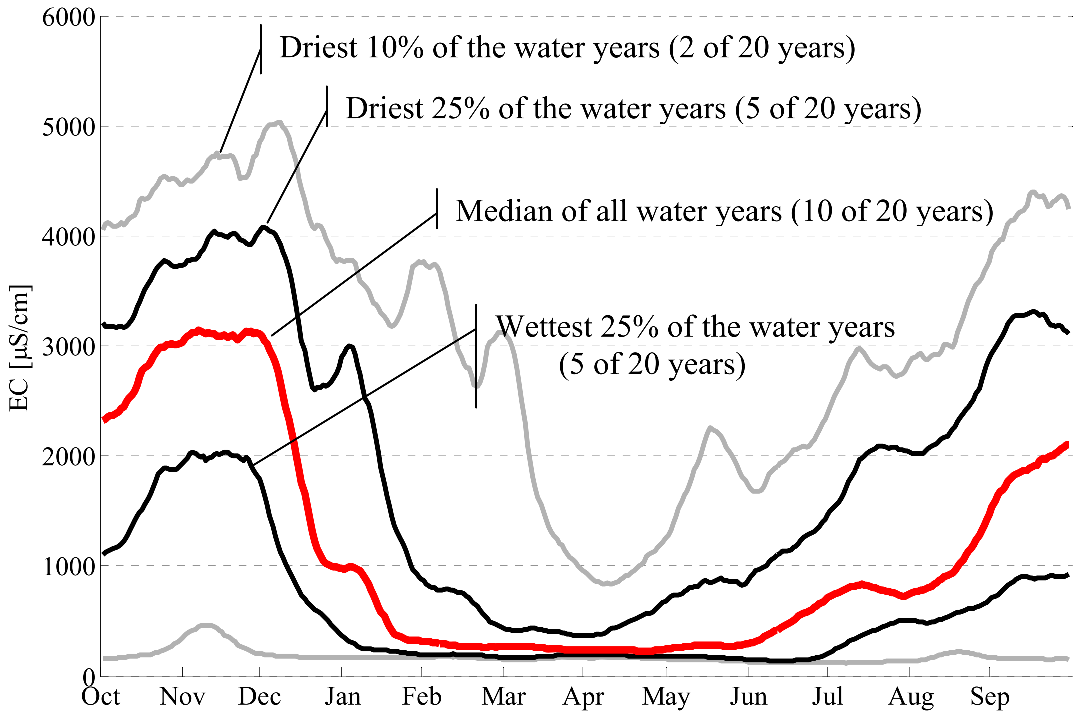


Figure E-3 – Seasonal Distribution of low-tide salinity at Antioch, 1983-2002

Conclusions

- The window, when Antioch is able to pump water with salinity less than 1,000 µS/cm EC, has substantially narrowed in the last 125 years.
- Antioch was apparently able to pump fresh water at low tide year-round in the late 1800's, with the possible exception of the fall season during one or two dry years.
- During 10 of the 20 years between 1983 and 2002, salinity was less than 1,000 µS/cm EC at low tide for only about eight months of the year.
- During the driest 5 years between 1983 and 2002, salinity was less than 1,000 µS/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.

E.2.3. Salinity at Kentucky Point on Twitchell Island – then and now

The appellants in the Antioch Case, representing the upstream diverters, identified one resident of Twitchell Island who reported the water at Kentucky Landing was brackish on "one or two occasions" between 1870 and 1875 during August and September. During this time, he had to travel up the San Joaquin River to Seven Mile Slough (the eastern boundary of Twitchell Island) and sailed as far as the mouth of the Mokelumne River (approximately 2 miles further up the San Joaquin River than the Seven Mile Slough junction) to obtain fresh drinking water.

For comparison, we look at salinity monitoring data in that region for 1981 and 2002 to see the location of potable water.[11] The source document (Town of Antioch v. Williams Irrigation District, 188 Cal. 451) for the 1870's drought uses up to 100 mg/L chloride concentration as the threshold for a potable water supply. Monitoring data from 1981 shows similar salinity intrusion as described by the Twitchell Island resident; salinity along the San Joaquin River at Bradford Island (about 1.5 miles upstream of Three Mile Slough) exceeded 1,000 μS/cm EC (about 250 mg/L Cl) during August and September. During the same time period, salinity was around 400 μS/cm EC (about 64 mg/L Cl) approximately 5 miles upstream on the San Joaquin River between Seven Mile Slough and the Mokelumne River. This comparison indicates that the extent of salinity intrusion in 1981 is similar to that which occurred in 1870 and 1871.

Similarly, in September 2002, the salinity in the San Joaquin River at San Andreas landing (less than 2 miles downstream of the Mokelumne River mouth) peaked at 977 μS/cm EC, which corresponds to approximately 225 mg/L chloride concentration. Therefore, if the observer was to travel upriver for potable water in 2002, they would have likely traveled up to the mouth of the Mokelumne River as they did in 1870. Salinity intrusion in critically dry years is even farther into the Delta than was found in 2002.

In conclusion, salinity intrusion up the San Joaquin River during the dry years of 1870 and 1871 as described by a Twitchell Island resident is consistent with salinity intrusion in 1981 and 2002 under similar hydrological conditions. There is no evidence that salinity intrusion during the drought of 1870-71 was more extensive than salinity intrusion during similar water years in the current salinity regime.

[11] 1981 and 2002 were both dry water years in the Sacramento River basin as defined in D-1641 with similar annual unimpaired Sacramento River flow to the years 1870 and 1871. Annual unimpaired Sacramento River flow in 1870, 1871, 1981, and 2002 was 11 MAF, 10 MAF, 11 MAF, and 14 MAF, respectively.

February 16, 2010

Division of Water Rights
State Water Resources Control Board
Attn: Phillip Crader
P. O. Box 2000
Sacramento, CA 95812-2000

Re: Delta Flow Criteria Informational Proceeding

Dear Mr. Crader:

The City of Antioch has been diverting Sacramento River water for drinking water use from the western Delta since the 1860s, and as such, has information and data directly relevant to the SWRCB's current proceedings to establish Delta flow criteria. The City, because of its position in the western Delta, is also concerned with the ecological health of the Delta and the long-term viability of the City's historic freshwater fishing and recreational opportunities.

Please find attached the City of Antioch's exhibits and supporting documents describing the historical salinity conditions at Antioch. The City of Antioch believes that it is vitally important to consider historical salinity and flow conditions when establishing flow criteria and water quality standards that will affect the future biological and ecological integrity of the Delta, and we believe that the SWRCB should not allow flow to be reduced below, or salinity to be increased above, levels currently allowed by both D-1641 and X2 requirements. In fact, the City asks the SWRCB to establish flow and salinity standards in line with the Delta's historic fresh condition.

We appreciate your consideration in this matter. Please feel free to contact me with any questions.

Sincerely,

P. Harrington

Phil Harrington
Director of Capital Improvements and Water Rights
City of Antioch

Attachments:

- City of Antioch's Witness List
- City of Antioch's Exhibit Identification List
- City of Antioch's Response to Key Questions
- City of Antioch's Written Summary
- City of Antioch's supporting document – a powerpoint presentation on historical salinity conditions
- City of Antioch's supporting document – A report by Thomas Means (1928): "Salt Water Problem"
- City of Antioch's supporting document – Excerpts from the DWR (1931) Report: "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay"
- City of Antioch's supporting document – DWR (1960) Report: "Delta Water Facilities"

WITNESS IDENTIFICATION LIST (Revised January 29, 2010)
(Due 12 Noon, Tuesday, February 16, 2010)

Delta Flow Criteria Informational Proceeding

Scheduled to Commence
Monday, March 22, 2010

______________**The City of Antioch**________________ plans to call the following witnesses: (name of individual participant or group of participants)

NAME	PROPOSES PARTICIPATION ON THE FOLLOWING PANEL(S) note panel number)	WILL THE WITNESS SUBMIT TESTIMONY (no if only responding to questions)
Susan C. Paulsen, Ph.D., P.E., Vice President, Flow Science Incorporated	Hydrology (Panel 1) and Hydrodynamics (Panel 5)	Yes
E. John List, Ph.D., P.E., Principal Consultant, Flow Science Incorporated	Hydrology (Panel 1) and Hydrodynamics (Panel 5)	No
Phil Harrington, Director of Capital Improvements and Water Rights, City of Antioch	Hydrology (Panel 1) and Hydrodynamics (Panel 5)	No
Matthew L. Emrick, Special Water Counsel to the City of Antioch	Hydrology (Panel 1) and Hydrodynamics (Panel 5)	No

EXHIBIT IDENTIFICATION LIST
(Due 12 Noon, Tuesday, February 16, 2010)

Delta Flow Criteria Informational Proceeding

Scheduled to Commence
Monday, March 22, 2010

PARTICIPANT: **The City of Antioch**

Exhibit Identification Number	Exhibit Description
Antioch Doc #1	City of Antioch's Cover Letter
Antioch Doc #2	City of Antioch's Witness Identification List
Antioch Doc #3	City of Antioch's Exhibit Identification List
Antioch Doc #4	City of Antioch's Response to Key Questions
Antioch Doc #5	City of Antioch's Written Summary
Antioch Doc #6	City of Antioch's supporting document – a powerpoint presentation on historical salinity conditions
Antioch Doc #7	City of Antioch's supporting document – A report by Thomas Means (1928): "Salt Water Problem"
Antioch Doc #8	City of Antioch's supporting document – Excerpts from the DWR (1931) Report: "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay"
Antioch Doc #9	City of Antioch's supporting document – DWR (1960) Report: "Delta Water Facilities"

Response to Key Questions

Delta Flow Criteria Informational Proceeding
March 22, 2010

The following are brief "bullet-point style" responses to the five questions posed by the State Water Board in its original notice. The written testimony and the supporting documents submitted by the City of Antioch elaborate on these responses.

Key Question #1

What key information, in particular scientific information or portions of scientific information, should the State Water Board rely upon when determining the volume, quantity, and timing of water needed for the Delta ecosystem pursuant to the board's public trust obligations?

- The current Delta ecosystem is very different than the historical Delta – both flow and salinity are altered compared to historical conditions. For example:
  - since European settlement in the 1850s, dramatic changes to the Delta landscape have occurred, including removal of tidal marsh and building of permanent river channels
  - water management operations (reservoir storage and diversions) since the early 1900s have increased reservoir storage in the upstream watersheds to more than 30 million acre-feet (MAF)
  - water exports from the Delta have been steadily increasing since the 1950s to the present, from about 0.5 MAF/yr to about 5 MAF/yr
- Before 1918 (i.e., before large-scale diversions for upstream agricultural operations), freshwater conditions were pervasive in the western Delta as indicated by literature and technical reports (e.g., testimony from the Antioch lawsuit in 1920, DPW 1931 and DWR 1960)
- Salinity monitoring data indicate that salinity at Antioch has increased from 1965 to present; the increase in salinity continues in recent years.
- Salinity intrusion under current management conditions occurs earlier in the year (currently beginning in about March, as compared to June-July historically). Salinity intrusion also persists longer; currently, the period of high salinity persists for about 10 months on average, compared to about 5 months on average for unimpaired flow conditions (i.e., without any current management operations but with the current Delta channel configuration).

For large reports or documents, what pages or chapters should be considered?

- Specific page number references have been provided in the detailed exhibit and supporting documents.

What does this scientific information indicate regarding the minimum and maximum volume, quality, and timing of flows needed under the existing physical conditions, various hydrologic conditions, and biological conditions?

- Historic Delta was significantly fresher than the current Delta.
- Characterization of the Delta as "historically saline" is false and is not based on scientific evidence.
- Salinity intrusion under current management conditions occurs earlier (timing) and persists longer (duration) compared to unimpaired flow conditions (i.e., without any current management operations but with the current Delta channel configuration).
- Salinity has continued to increase in recent years at Antioch.
- The fraction of time that water at Antioch is suitable for use (when salinity is < 250 mg/L chlorides or 1000 µS/cm EC) has declined significantly.
- Historical fresh conditions must be considered in any effort to restore ecological conditions in the Delta.

With respect to biological conditions, what does the scientific information indicate regarding appropriateness of flow to control non native species?

- This question is not addressed in the City's submittal.

What is the level of scientific certainty regarding the foregoing information?

- Salinity and flow monitoring data were collected using scientific techniques which are universal and reliable.
- Testimony and historical evidence presented is consistent with historical literature reports, measurements made by the California & Hawaiian Sugar Refining Corporation (C&H) during the early 20th century, and also with paleo records constructed from tree rings and sediment cores (presented by others and in CCWD salinity report).

Key Question #2

What methodology should the State Water Board use to develop flow criteria for the Delta? What does that methodology indicate the needed minimum and maximum volume, quality, and timing of flows are for different hydrologic conditions under the current physical conditions of the Delta?

- The City suggests that, given historical conditions, salinity should not be allowed to rise (and flows should not be allowed to decline) beyond existing levels as required by D-1641 and X2 operations criteria.
- The City requests that compliance points should not be moved land-ward.
- The SWRCB should consider using the gauging station at Antioch as a point of interest for monitoring of both salinity and flow conditions in the western Delta.

Key Question #3

When determining Delta outflows necessary to protect public trust resources, how important is the source of those flows?

- Even though Antioch is on the San Joaquin River, the Sacramento River was historically and continues to be the main source of water at Antioch. Thus, the Sacramento River has historically been the main source of water in the western Delta, and the source of water to which Delta species have been historically exposed and to which they may have adapted.
- In the context of flushing of the South Delta, baseline residence times should be established based on current conditions, and to be used as a measure by which future actions (e.g., BDCP) can be assessed.

How should the State Water Board address this issue when developing Delta outflow criteria?

- This question is not addressed in the City's submittal.

Key Question #4

How should the State Water Board address scientific uncertainty when developing the Delta outflow criteria?

- The City of Antioch respectfully suggests, in light of the information provided, that the SWRCB should err on the side of not allowing greater salinity intrusion.

Specifically, what kind of adaptive management, monitoring, and special studies programs should the State Water Board consider as part of the Delta outflow criteria, if any?

- This question is not addressed in the City's submittal.

Key Question #5

What can the State Water Board reasonably be expected to accomplish with respect to flow criteria within the nine months following enactment of SB 1? What issues should the State Water Board focus on in order to develop meaningful criteria during this short period of time?

- This question is not addressed in the City's submittal.

State Water Resources Control Board
Delta Flow Criteria Informational Proceeding
March 22, 2010

Exhibit by City of Antioch
Summary of Historical Freshwater Availability at Antioch

Summary

The historic (pre-1918) Delta was significantly fresher than the current Delta. The characterization of the Delta as "historically saline" is false and is not based on scientific evidence. Historical salinity and flow conditions must be considered when: (i) establishing Delta outflows and inflows to protect public trust values which adapted to these conditions, (ii) establishing the criteria (volume, timing and quality) required by Senate Bill 7X 1, and (iii) establishing drinking water quality standards for the Delta.

1. Introduction

The City of Antioch (Antioch), located along the San Joaquin River in the western portion of the Sacramento and San Joaquin River Delta (Delta), is one of the oldest towns in California. Since the 1860s, Antioch has obtained all or part of its freshwater supply directly from the San Joaquin River.[1] The City, because of its position in the western Delta, is also concerned with the ecological health of the Delta and its long-term viability as a recreational destination.

As part of the informational proceeding on establishing flow criteria in the Delta, this document summarizes the historical salinity and flow conditions near Antioch and contrasts them with the largely saline conditions prevailing today. The supporting document to this summary is a "powerpoint style" document containing text and figures relevant to the material presented in this summary.

2. Systemic changes have reduced freshwater flows and increased salinity in the western Delta, including at Antioch

Salinity in the western Delta (including at Antioch) is influenced both by natural factors, including ocean tides and hydrology of the upstream watersheds, and by artificial factors, including channelization of the Delta, elimination of tidal marsh, reservoir storage and release operations, and water diversions.

Major anthropogenic modifications to the Delta that affect salinity intrusion began with the European settlement of the region around 1850. Tidal marsh acreage in the Delta decreased from over 250,000 acres in the 1870s to less than 30,000 acres in the 1920s and

[1] Much of the water in the western Delta (including the City's water supply) comes from the Sacramento River. Historically, significant amounts of Sacramento River water flowed into the San Joaquin River east of Antioch at Three Mile and Georgiana Sloughs. Sacramento River water also reaches Antioch where the river merges with the San Joaquin River just west of the City. <u>Town of Antioch v. Williams Irrigation District et al.</u> (1922) 188 Cal. 451, 455

has since continued to decrease (CCWD 2010), producing significant changes in the Delta landscape (Att. at pg. 7). For example, dredging of the Delta river channels to create the Stockton and Sacramento Deep Water Ship Channels affected the salt transport and distribution in the Delta (CCWD 2010). Construction of reservoirs for storage purposes started in the early 1900s and the largest reservoirs of the Central Valley Project (CVP, Lake Shasta) and the State Water Project (SWP, Lake Oroville) were completed in 1945 and 1968, respectively (CCWD 2010). Total upstream reservoir storage capacity increased from 1 million acre-feet (MAF) in 1920 to more than 30 MAF by 1979 (CCWD 2010). Water exports from the Delta have been steadily increasing since the 1950s, and the combined annual exports from CVP and SWP have increased, on average, from about 0.5 MAF/yr in the late 1950s to about 5 MAF/yr during the recent period (Att. at pg. 8).

3. Historical extent of freshwater

Testimony from the lawsuit filed by the Town of Antioch in 1920 and from various literature reports demonstrates that freshwater (low salinity conditions) prevailed in the western Delta in the late 1800s and early 1900s.

<u>3.1 Testimony from Antioch's lawsuit in 1920</u>

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 [plaintiff] v. Williams Irrigation District et al. [defendants] (1922, 188 Cal. 451)). The testimony from the Antioch lawsuit provides a perspective of the salinity conditions prevailing in the early 1900s.

3.1.1 Pre-1918: Freshwater was available at Antioch year-round

Testimony from the defendants in the Antioch lawsuit indicated that in the late 1800s, water at Antioch was known to be brackish at high tide during certain time periods, but Antioch was able to pump freshwater at low tide throughout the year, with the possible exception of the fall season during one or two dry years. Water at Antioch was fresh at low tide at least until around 1915 (when the pumping plants started pumping continuously, regardless of tidal stage) (Att. at pg. 11).

Testimony from the plaintiff in the Antioch lawsuit indicated that Antioch's freshwater supply was obtained directly from the San Joaquin River (see footnote 1 above) from about 1866 to 1918, first by private water companies and then by the municipality after 1903 (when the City acquired pre-existing water rights) (Att. at pg. 12). Plaintiff's testimony included salinity measurements taken at Antioch (1913-1917) that indicated that prior to 1918, freshwater was available at Antioch even during dry years and in the fall (Att. at pg. 12).

3.1.2 Post-1918: Increased upstream diversions drastically increased salinity intrusion

Testimony and measurements from the Delta (1918-1920) presented by the plaintiff in the Antioch lawsuit indicated that after 1918, salinity abruptly increased during the irrigation (rice cultivation) season, but returned to a potable level after irrigation ceased (Att. at pg. 13). The effect of upstream diversions was also confirmed by records in the plaintiff's testimony from California & Hawaiian Sugar Refining Corporation (C&H) (CCWD 2010). Plaintiff's testimony indicated that although Antioch is located along the San Joaquin River, the source of much of the water at Antioch was the Sacramento River, which flowed to Antioch via Georgiana and Three Mile Sloughs (Att. at pg. 14-15); this was confirmed by the California Supreme Court (Att. at p. 15).

Information from the Antioch lawsuit is consistent with literature reports (see the following discussion) and with paleo records of salinity and river flow obtained from tree rings and sediment cores (CCWD 2010).

3.2 Literature reports

Several literature reports confirm that freshwater was available year-round in the western Delta (including Antioch) and Suisun Bay during the late 1800s and early 1900s. For instance, DPW (1931), the precursor to the Department of Water Resources, indicated that the City of Antioch obtained all or most of its freshwater supplies directly from the San Joaquin River until 1917, and that salinity intrusion prevented domestic use of water at the Antioch intake in summer and fall after 1917 (Att. at pg. 9). DPW (1931) and Tolman and Poland (1935) indicated that prior to the 1920s, water near the City of Pittsburg was sufficiently fresh for that City to directly obtain all or most of its freshwater (Att. at pg. 10). Dillon (1980) and Cowell (1963) indicated that prior to the 1920s, freshwater was available in the Suisun Bay and Carquinez Straits for use by the City of Benicia (Att. at pg. 10). Means (1928) indicated that Carquinez Strait (near Martinez in the western Delta) is the approximate boundary between salt water and freshwater under natural conditions. Moreover, Means (1928) also indicated that during the wet season freshwater extended up to the Golden Gate (Att. at pg. 9).

The California Department of Water Resources (DWR, 1960) estimated that water with a chloride concentration of 350 mg/L or less would be available at San Joaquin at Antioch about 85% of the time under "natural" conditions (Att. at pg. 16). DWR (1960) also estimated that chloride concentrations at Antioch would be less than 350 mg/L about 80% of the time in 1900 and about 60% of the time by 1940, with decreasing freshwater availability due to upstream diversions; DWR also projected further deterioration of water quality in 1960 and later, but did not include the effects of reservoir releases for salinity control (Att. at pg. 16).

4. Current Salinity Conditions at Antioch

Salinity data compiled by the Interagency Ecological Program (IEP) and California Data Exchange Center (CDEC) were used to analyze the present availability of freshwater at Antioch. These quantitative measurements from the present were compared to the testimony from the Antioch lawsuit and to observation recorded by C&H to establish how salinity at Antioch and in the western Delta has increased over time compared to historical conditions.

4.1 Freshwater availability continues to decline

Availability of freshwater at Antioch continues to decline. Antioch may take water at its intake when salinity is less than 250 mg/L chlorides (equivalent to about 1000 µS/cm EC)[2]. The number of days per year, expressed as a percentage, when daily average salinity at Antioch was below 1000 µS/cm EC declined from about 70% in the late 1960s to about 40% during the recent period (Att. at pg. 19).

Even in years with above normal runoff in the Sacramento River watershed, freshwater at Antioch is less available than historically (Att. at pg. 20). For instance, during the above normal water year 2000, water at the City of Antioch's intake was below 1000 µS/cm EC for the entire 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-a-half months (mid-June through September). For the remaining four months (October-January), water at the City's intakes exceeded 1,000 µS/cm EC for the entire day, regardless of tidal stage. Testimony from the Antioch lawsuit indicates that prior to 1918, water at the City of Antioch's intake was below 1000 µS/cm EC for the entire day during above-normal years and in all but dry fall months.

Salinity at low tide at Antioch during the present is higher than historical conditions (Att. pg. 21). For instance, during the period 1985 to 2009, the tenth percentile low tide daily salinity was below 1,000 µS/cm EC for about one-and-a-half months, and the 25th percentile low tide daily salinity was below 1,000 µS/cm EC for about nine months. However, testimony from the Antioch lawsuit indicates that during the driest years prior to 1918, low tide salinity at the City of Antioch's intake was below 1000 µS/cm EC for about nine months; for all but the driest years, salinity at low tide was below 1,000 µS/cm EC throughout the year. These data establish that salinity is higher at Antioch for a wider range of hydrologic conditions and for a longer duration of the year than under historic conditions.

4.2 Salinity intrusion occurs earlier and extends farther

Since the early 1900s the California & Hawaiian Sugar Refining Corporation (C&H), located in Crockett near the western edge of Suisun Bay, obtained its freshwater supply in Crockett. When freshwater was not available at Crockett, C&H used barges that traveled upstream on the Sacramento and San Joaquin Rivers to procure freshwater. The measurements of distance to freshwater from Crockett, recorded during these barge operations, serve as a surrogate for the historical extent of freshwater in the western

[2] 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 µS/cm EC, based on the site-specific empirical relationships between chloride concentration and EC (K. Guivetchi, DWR Memorandum dated June 24, 1986).

Delta. A comparison of C&H data during 1908-1917 and estimates[3] of distance to freshwater from Crockett during the post-SWP construction period (1966-1975) indicates that salinity intrusion into the Delta occurs on average about 4 months earlier (in March instead of July) during the post-SWP construction period of 1966-1975 (Att. at pg. 17). Comparison of C&H data from 1908-1917 to estimates of distance to freshwater from Crockett during the period 1995-2004 indicates that salinity intrusion during the recent period not only occurs earlier (by 4 months) but also extends farther in to the Delta (by about 5 to 20 miles) (Att. at pg. 18).

5. Conclusions

- Prior to 1918, freshwater was almost always available at Antioch at least at low tide. Only during dry years and during high tide conditions did salinity at Antioch become brackish.
- Between 1918 and the late 1930s, drought conditions, upstream water diversions, and channelization increased the salinity of water at Antioch.
- By 1940 the drought receded, but salinity at Antioch remained elevated.
- Salinity has continued to increase in recent years at Antioch.
- The fraction of time that water at Antioch is suitable for use (when salinity is < 250 mg/L chlorides or 1000 µS/cm EC) has declined significantly.
- "Historic" Delta was significantly fresher than the current Delta.

6. Request

The City of Antioch requests that the State Water Resources Control Board review and incorporate historic salinity data into its analyses when considering Delta outflow requirements to protect public trust resources in the Western Delta and the flow requirements of SB X7 1 (e. g., volume, timing and quality), and that the Board use historic data to establish and to adjust its "baseline" of water quality for both fisheries health and drinking water quality standards. In fact, the City asks the SWRCB to establish flow and salinity standards in line with the Delta's historic fresh condition. The City also requests that the SWRCB consider using the gauging station at Antioch as a point of interest to ensure that flow criteria and salinity objectives are met.

References

[CCWD] Contra Costa Water District. 2010. Report titled "Historical Freshwater and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay".

Cowell, J. W. 1963. History of Benicia Arsenal: Benicia, California: January 1851 – December 1962. Berkeley, Howell-North Books.

[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.

[DWR] Department of Water Resources. 1960. *Delta Water Facilities*. Bulletin No. 76. State of California.

Dillon, R. 1980. Great Expectations: The Story of Benicia, California, Fresno, California. 241 pp.

Means, T. 1928. Salt Water Problem: San Francisco Bay and Delta of Sacramento and San Joaquin Rivers, San Francisco, California, April 1928. Report prepared for the Association of Industrial Water Users of Contra Costa and Solano Counties.

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).

[3] These estimates were made using IEP data in CCWD (2010), which will be presented by the Contra Costa Water District during this informational proceeding.

Testimony by City of Antioch

For SWRCB Delta Flow Criteria Informational Proceeding

Submitted February 16, 2010

For hearings beginning March 22, 2010

Overview

- Antioch has taken fresh drinking water from the Delta since the 1860s
- Infrastructure and flow diversions have changed distribution and timing of freshwater flows
- Historic conditions were far fresher than current conditions
- Quality of water at Antioch has declined markedly

Why Is This Important ?

- Characterizations of the Delta as "historically saline" are false
- Native species are adapted to historical conditions, so historic salinity and flow patterns must be considered in establishing appropriate flow and salinity standards

What Should Happen ?

- SWRCB should review and incorporate historic salinity data into its analyses
- SWRCB should use historic data to establish an historic baseline of water quality and flows for both fisheries and drinking water quality standards

What Should Happen ?

- SWRCB should ensure that flows are not reduced, nor salinity increased, beyond levels assured by D-1641 and current X2 requirements
- In fact, the City of Antioch asks the SWRCB to establish flow and salinity standards in line with the Delta's historic fresh condition
- SWRCB should state that characterizations of the Delta as "historically saline" are false
- SWRCB should consider using Antioch's gauging station as a 'point of interest' to gauge flow and salinity conditions

Systemic Changes Have Influenced Flows and Salinity

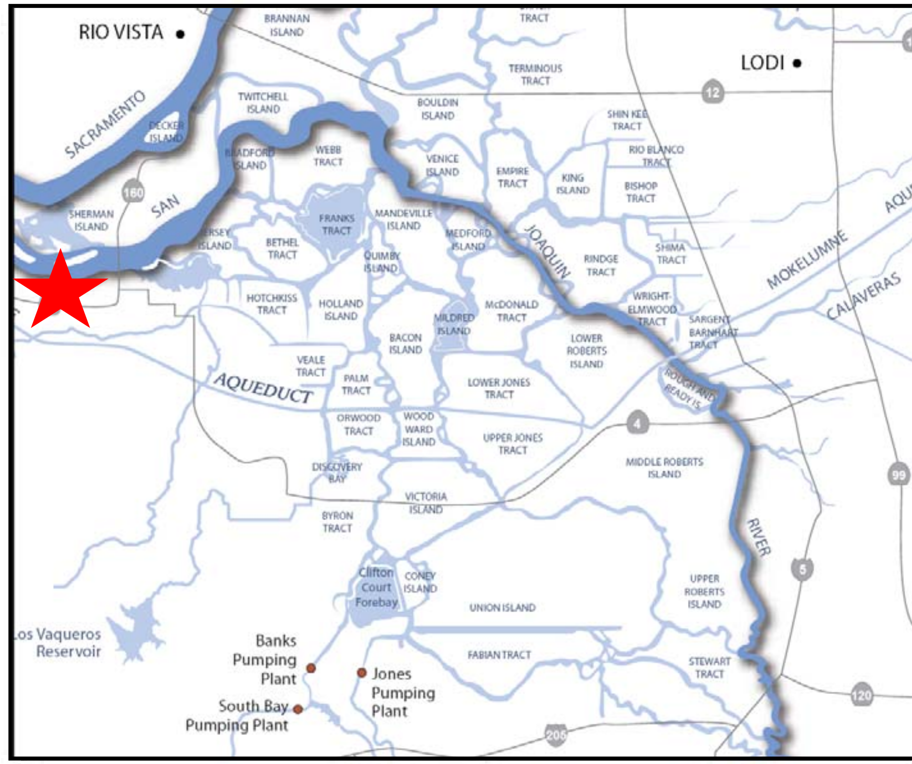
Factors Influencing Salinity

- Hydrology
- Changes to the Delta landscape
- Water Management
  - Exports
  - Diversions
  - Reservoir Storage

The Delta Landscape is Dramatically Different

1873

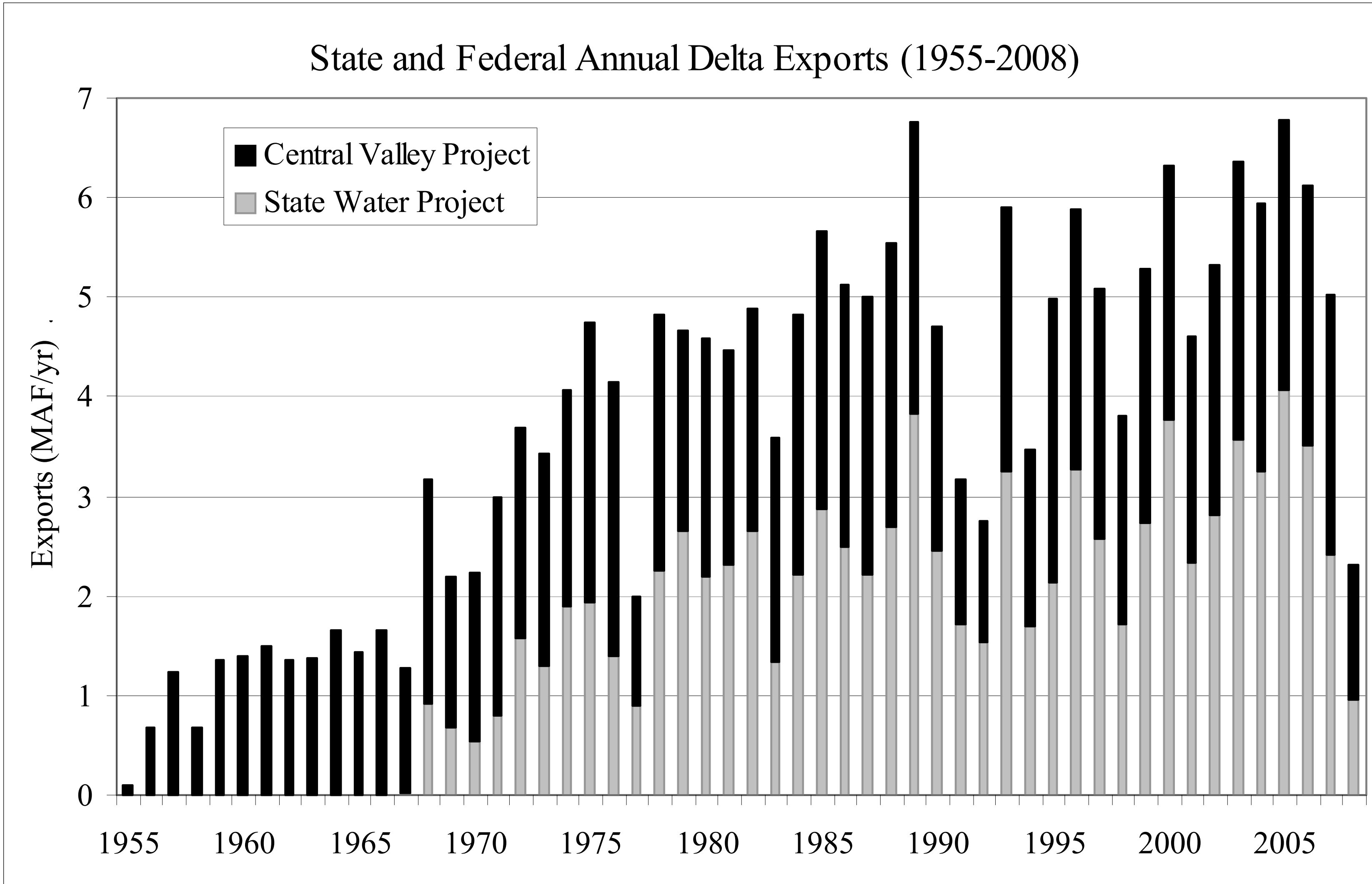
2010



★ Approximate location of City of Antioch's water intake

Source: left panel: DWR archives presented to Delta Vision (2008) final report; right panel: Delta Vision (2008)

Water Exports Have Increased and Remove Fresh Water from Delta



Data from IEP's DAYFLOW Program

Pre-1918, Fresh Water was Available in Western Delta Nearly Year-round

Location	Quotation
Antioch, CA	"*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… 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)
Western Delta	"*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) "*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)
Carquinez Strait (Western Delta)	"*Under natural conditions, Carquinez Straits marked, approximately, the boundary between salt and fresh water in the upper San Francisco Bay and delta region…*" (Means, 1928, pg. 9) "*For short intervals in late summer of years of minimum flow, salt water penetrated at lower river and delta region, and in wet seasons the upper bay was fresh, part of the time, to the Golden Gate.*" (Means, 1928, pg. 9 & pg. 57)

DPW (1931). Bulletin No. 27. State of California, Department of Public Works, See http://www.archive.org/details/variationcontrol27calirich
Means, T. (1928). Salt Water Problem: San Francisco Bay and Delta of Sacramento and San Joaquin Rivers, San Francisco, California, April 1928. A report prepared for the Association of Industrial Water Users of Contra Costa and Solano Counties.

Pre-1918, Fresh Water was Available in Western Delta Nearly Year-round

Location	Quotation
Benicia, CA (Suisun Bay)	"*In 1889, an artificial lake was constructed. This reservoir, filled with fresh water from Suisun Bay during the spring runoff of the Sierra snow melt water …*" (Dillon, 1980, pg. 131) "*…in 1889, construction began on an artificial lake for the* [Benicia] *arsenal which would serve throughout its remaining history as a reservoir, being filled with fresh water pumped from Suisun Bay during spring runoffs of the Sacramento and San Joaquin Rivers which emptied into the bay a short distance north of the installation.*" (Cowell, 1963, pg. 31)
Pittsburg, CA	"*From 1880 to 1920, Pittsburg (formerly Black Diamond) obtained all or most of its domestic and municipal water supply from New York Slough [near Pittsburg at the confluence of the Sacramento and San Joaquin Rivers] offshore.*" (DPW, 1931, pg. 60) "*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 in 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)

Cowell, J. W. 1963. History of Benicia Arsenal: Benicia, California: January 1851 – December 1962. Berkeley, Howell-North Books
Dillon, R. 1980. Great Expectations: The Story of Benicia, California, Fresno, California. 241 pp.
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

Testimony from Antioch Lawsuit: Pre-1918, Fresh Water was Available at Antioch Year-round

- Antioch lawsuit in 1920: Town of Antioch [plaintiff] v. Williams Irrigation District et al. [defendants] (1922, 188 Cal. 451)

- Plaintiff alleged that the upstream diversions were causing increased salinity intrusion at Antioch

- Testimony from defendants in the Antioch lawsuit (from the supporting Supreme Court record on file at the State Archives) (CCWD, 2010)
    - In the late 1800s, water at Antioch was known to be brackish at high tide during certain time periods.
    - Antioch was 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).

Testimony from Antioch Lawsuit: Pre-1918, Fresh Water was Available at Antioch in Fall

Testimony from plaintiff in the Antioch lawsuit (from the supporting Supreme Court record on file at the State Archives)

- Antioch's freshwater supply was obtained directly from the western Delta from about 1866 to 1918 (pg. 47-48).

- Prior to 1918, freshwater was available at Antioch even during dry years and in the fall (pg. 23-24).

Date	Location	Salinity (ppm)
1913 (Sept; a dry year)	Antioch	66
1916 (Aug. 5th; wet year)	Antioch	22.3
1916 (Aug. 9th; wet year)	Antioch	12.3
1916 (Sept. 19th; wet year)	Antioch	101.3
1917 (Sept. 14th; wet year)	Antioch	141.6

Testimony from Antioch Lawsuit: Post-1918, Upstream Diversions Drastically Increased Salinity Intrusion

Testimony from plaintiff in the Antioch lawsuit (continued)

•After 1918, salinity abruptly increased during irrigation (rice cultivation) season, and returned to a potable level after irrigation ceased (pg. 18-20)

Date	Location	Salinity (ppm)
1918 (Sept. 25th; dry year)	Antioch	1360
1920 (mid-July; critical year)	Pittsburg, CA	4500
1920 (end-July; critical year)	Pittsburg, CA	6000
1920 (mid-Aug.; critical year)	Pittsburg, CA	9500
1920 (end-Sept.; critical year)	Pittsburg, CA	2500
1920 (during rice irrigation; critical year)	Antioch	12,500
1920 (end-Oct, after irrigation; critical year)	Pittsburg, CA	fresh

Measurements at Pittsburg, CA, are from the Great Western Electro Chemical Co.

•Information on the effect of upstream diversions is also confirmed by records in the plaintiff's testimony from C&H Sugar (see CCWD 2010).

Testimony from Antioch Lawsuit: Water at Antioch is from Sacramento River

- Testimony from plaintiff in the Antioch lawsuit (continued)

  - Plaintiff testimony asserted that in 1920 "the amount of water which the San Joaquin carried was dependent entirely upon the amount of water in the Sacramento," and that "the San Joaquin itself carried practically no water at all. In other words, it was demonstrated that the amount of fresh water which came into the San Joaquin and down as far as the Town of Antioch was practically all Sacramento River water." (pg. 15)

  - Water was delivered to the San Joaquin River from the Sacramento River via two main conduits: Georgiana Slough and Three Mile Slough. 1920 flow rates in these sloughs were the basis of the assertion quoted above.

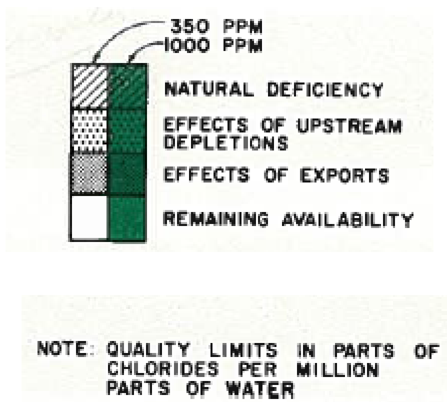
Testimony from Antioch Lawsuit: Water at Antioch is from Sacramento River

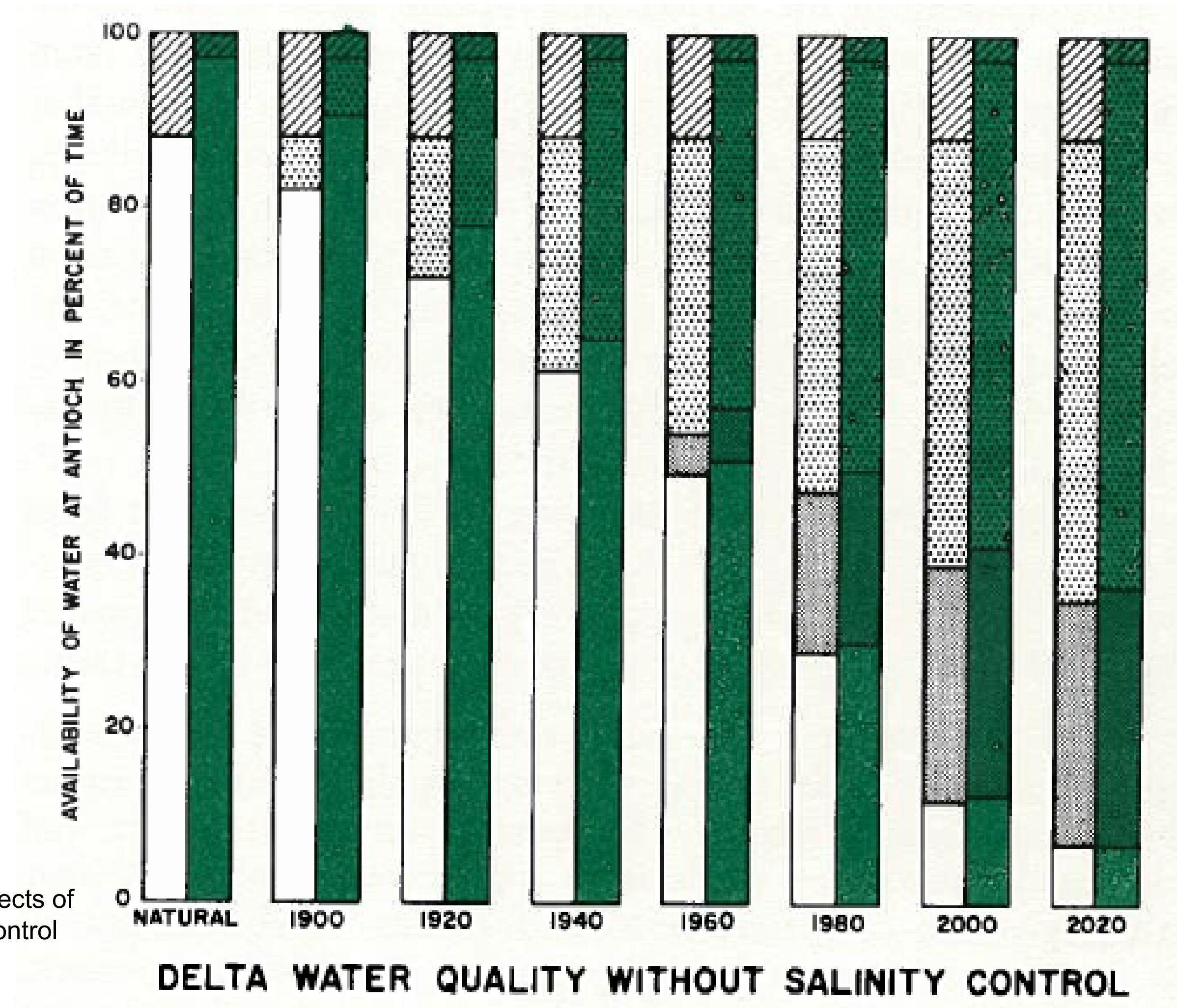
- "It is necessary here to state some additional facts to explain how this pollution comes about and why diversions from the Sacramento River may or do affect the volume and quality of the water flowing down the San Joaquin River . . . From the Sacramento River at two points, one about eight [Three Mile] and the other about twenty - three miles [Georgiana] above its mouth, sloughs diverge, into which parts of its waters escape and flow through the said sloughs and into the San Joaquin River at points several miles above the place of the diversion by the city of Antioch." Town of Antioch v. Williams Irrigation District et al. (1922) 188 Cal. 451, 455

Freshwater Availability has Declined

DWR (1960, pg. 13) found that freshwater was available at San Joaquin River at Antioch:

- •85% of the time under “natural” conditions
- •80% of the time in 1900
- •60% of the time by 1940
- •50% of the time by 1960

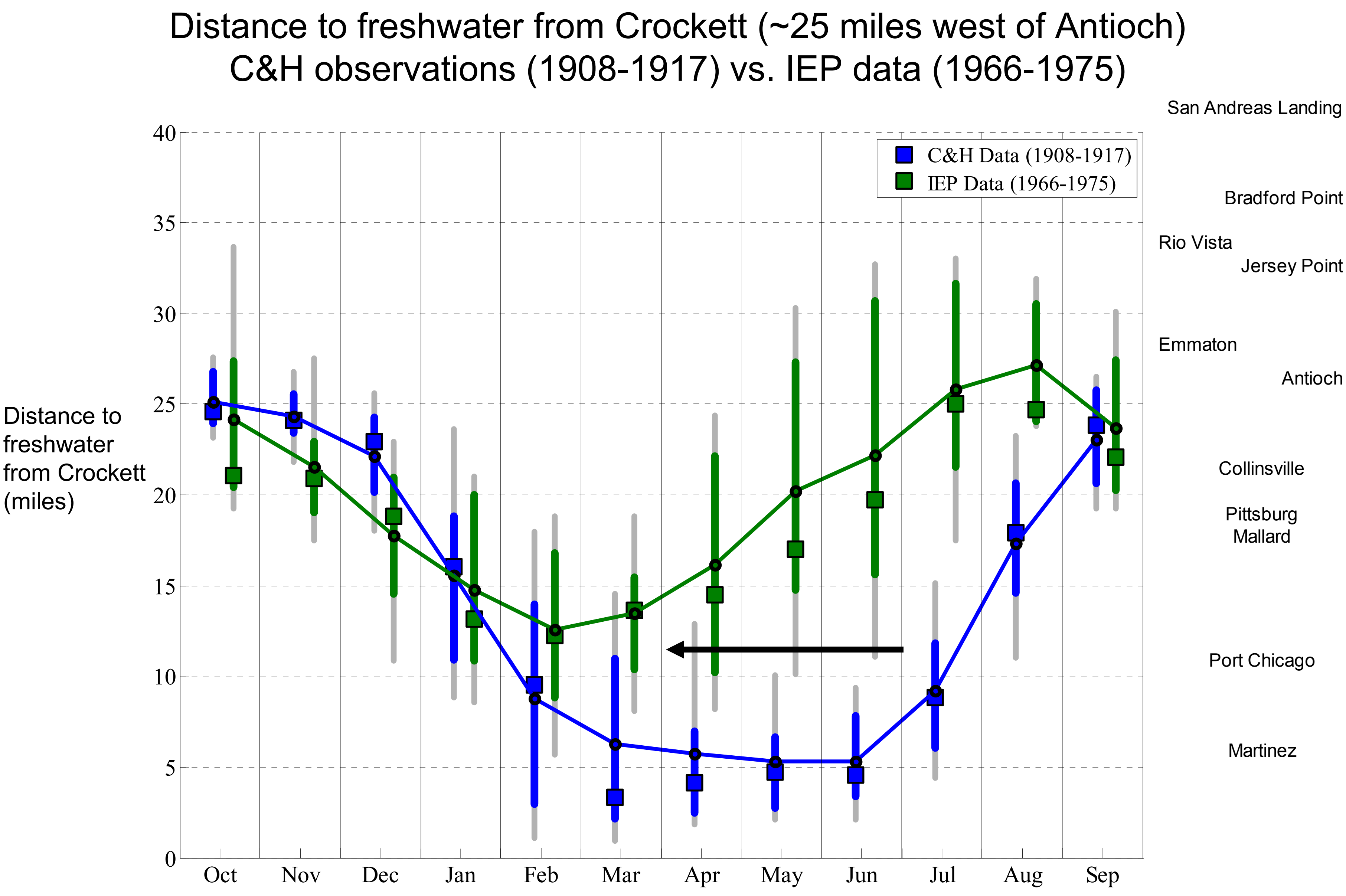




Note:- report did not include effects of reservoir releases for salinity control

DWR (1960). Bulletin No. 76. State of California. See http://www.deltacorridors.com/uploads/Bulletin_No._76_Delta_Water_Facilities-Color.pdf

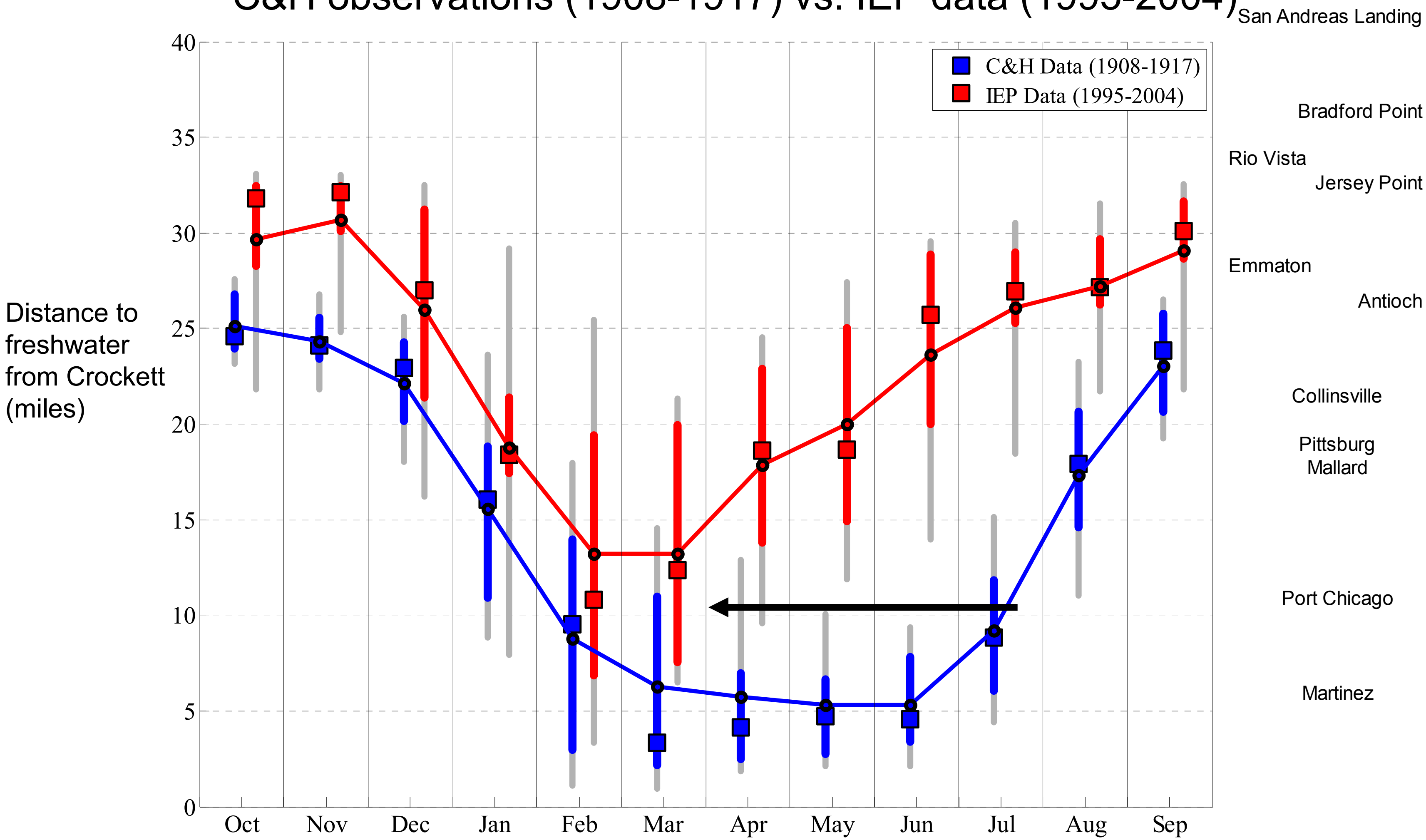
Salinity Intrusion Occurred Earlier by 1975



Source: CCWD Salinity Report (2010)

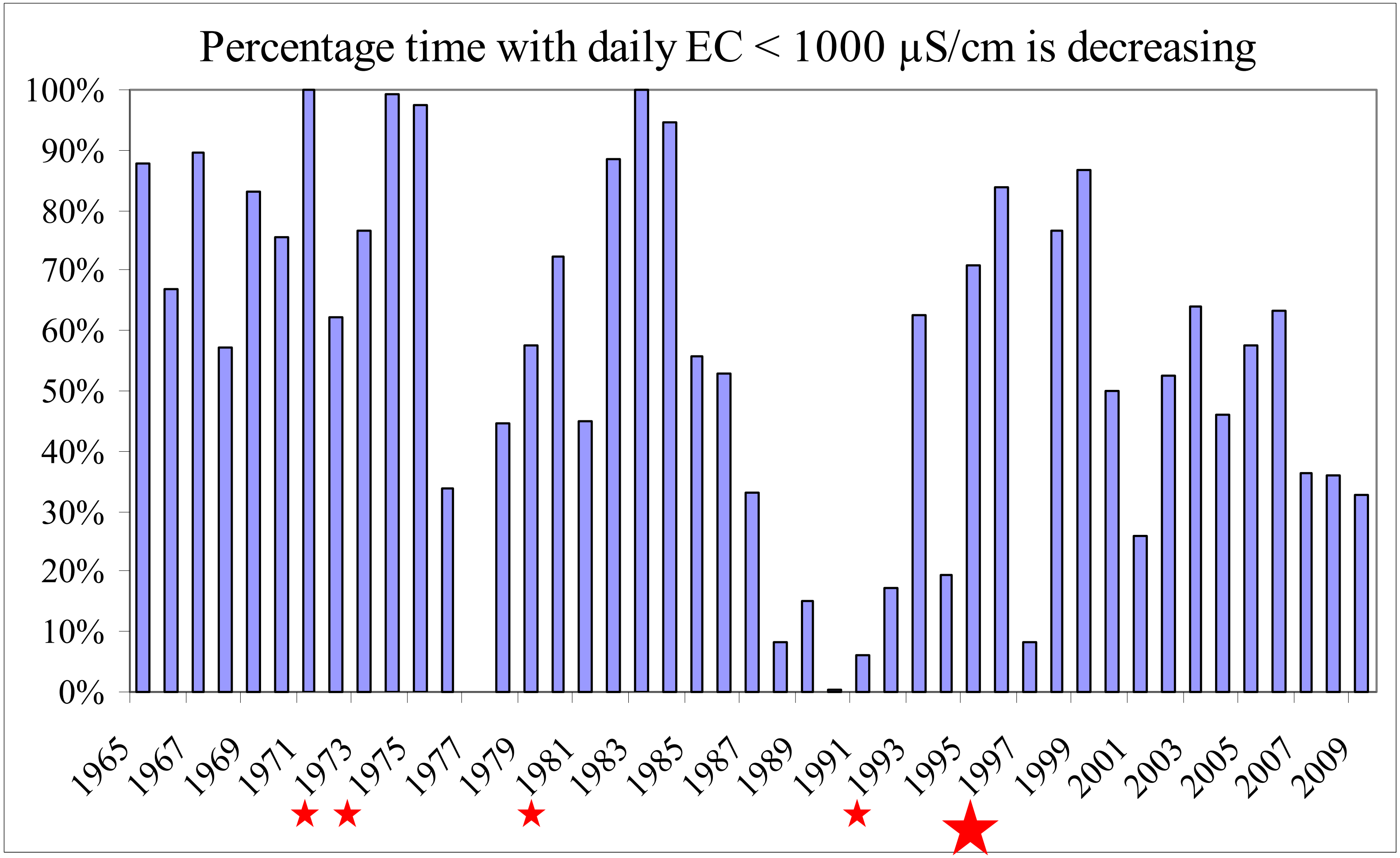
Salinity Intrusion Occurred Even Earlier and Extended Farther by 2004

Distance to freshwater from Crockett (~25 miles west of Antioch)
C&H observations (1908-1917) vs. IEP data (1995-2004)



Source: CCWD Salinity Report (2010)

Freshwater Availability at Antioch Continues to Decline

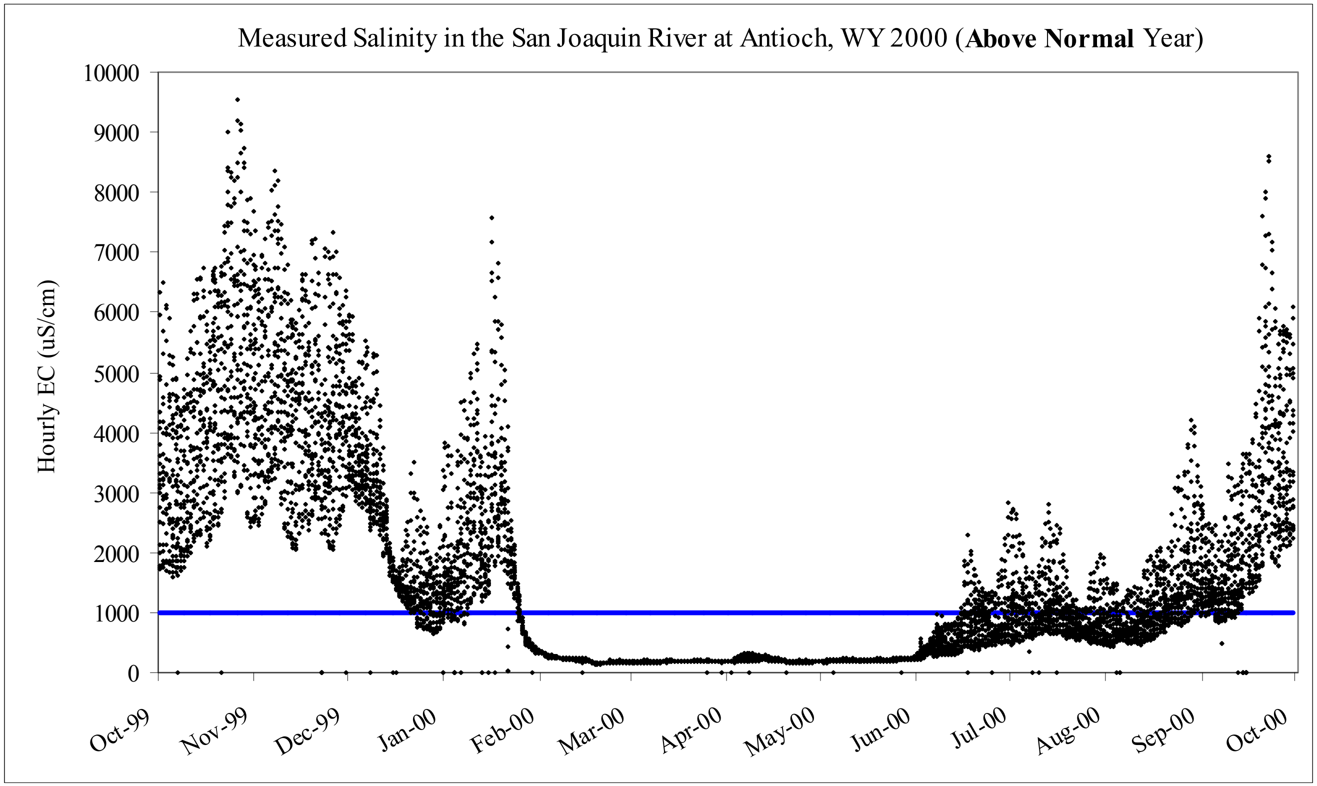


★ 10%-20% data missing

★ 80% data missing

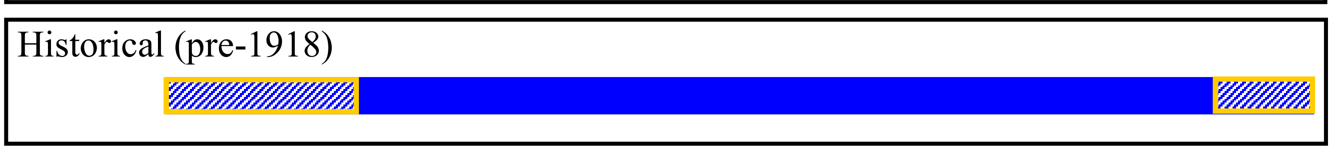
Data from IEP & CDEC

Even in Above Normal Years, Freshwater is Now Unavailable in Summer/Fall



Freshwater Criterion
< 1000 EC

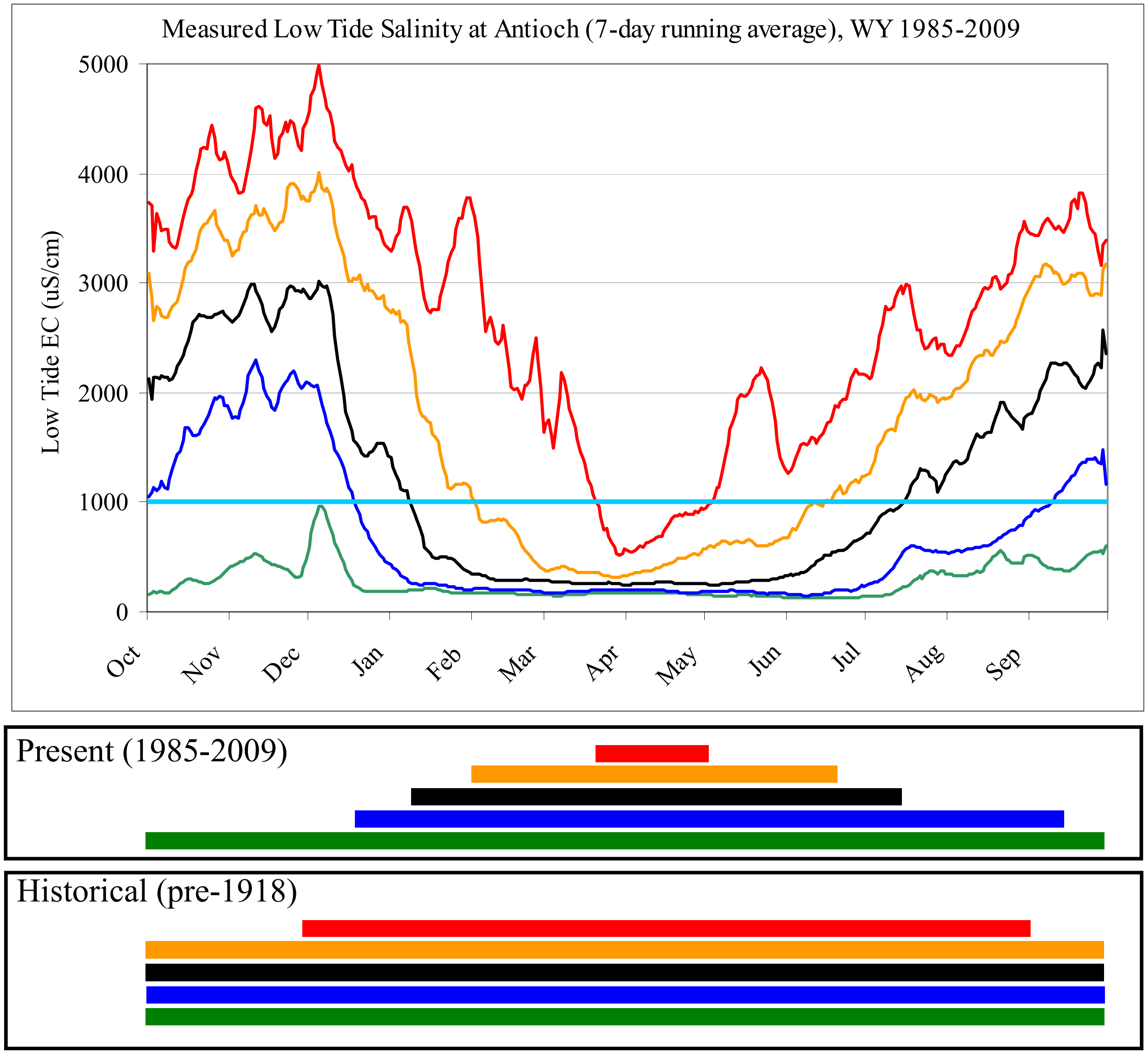
< 1000 EC all day
< 1000 EC low tide only
> 1000 EC all day



Pre-1918,
freshwater was
available year-round

Data from CDEC

Freshwater is Now Available at Antioch Far Less Often



Pre-1918, freshwater was available year-round at low tide in all but driest years

Data from CDEC

Summary: The Western Delta was Historically Fresher

- Pre-1918, freshwater was almost always available at least at low tide.
- Between 1918 and the late 1930s, drought conditions, upstream water diversions, and channelization increased the salinity of water at Antioch.
- By 1940 the drought receded, but salinity at Antioch remained elevated.
- Salinity continues to increase in recent years at Antioch.
- The fraction of time that water at Antioch is suitable for use (when salinity is < 250 mg/L chlorides or 1000 μS/cm EC) has declined significantly.
- “Historic” Delta was significantly fresher than the current Delta.

Conclusions

Consider historic fresh conditions to:

Establish Delta outflows and inflows to protect species adapted to these conditions.

Establish the criteria (volume, timing, quality) required by SB 7X 1.

Establish drinking water quality standards for the Delta.

Flow Science Incorporated
723 E. Green St., Pasadena, CA 91101
(626) 304-1134 • FAX (626) 304-9427

April 14, 2010

Division of Water Rights
State Water Resources Control Board
Attention: Phillip Crader
P.O. Box 2000
Sacramento, CA 95812-2000

Re: Delta Flow Criteria Closing Comments

Dear Mr. Crader:

Flow Science, on behalf of the City of Antioch, appreciates this opportunity to submit closing comments to the SWRCB regarding its development of Delta Flow criteria for the purpose of informing planning decisions for the Delta Plan and the Bay Delta Conservation Plan.

Our closing comments include key points and recommendations for SWRCB consideration, supported by our written testimony and exhibits and the oral testimony provided at the hearings on March 22-24, 2010. Because we do not have the biological expertise to recommend specific flow rates and flow volumes, we are not providing specific quantitative recommendations with this submittal.

At the March 2010 hearing, we suggested that it may be useful for the SWRCB to consider a process of simultaneously working from the "bottom up"—identifying the flow needs of fish—and working from the "top down"—analyzing flows that can be provided by the current system and systems operations, in the context of other beneficial uses, including upstream flow and temperature requirements, and water supply needs. On behalf of the City of Antioch, I would be happy to work with SWRCB Staff to explore the advantages of such a process and to participate in such a process.

Key Points for SWRCB consideration

As discussed in our February 16, 2010, written submittal, the City of Antioch has been diverting water for drinking water use from the western Delta since the 1860s. In its written testimony, the City of Antioch has provided the SWRCB with information and data on historical flows and salinity conditions in the western Delta (testimony submitted by the City of Antioch on February 16, 2010, and incorporated here by reference in its entirety; see http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/antioch.shtml). Key points in the City's oral and written testimony include the following:

1. Historical fresh conditions must be considered in any effort to restore ecological conditions in the Delta.

We believe that it is essential for the SWRCB and its Independent Science Team to consider the historical salinity and flow conditions within which the Delta fisheries thrived, to ensure that the Delta flow criteria and other standards will ensure the protection of public trust resources, i.e. the future biological and ecological integrity of the Delta.

Systemic changes in the Delta over the years have reduced freshwater flows and dramatically increased salinity (Antioch testimony, Document #5, p. 1). Infrastructure and flow diversions have changed distribution and timing of freshwater flows, and historic conditions were far fresher than current conditions (Antioch testimony, Document #5, p. 2-4 & Document #6, p. 16-21).

It has sometimes been contended that the Delta was historically saline. As mentioned in our oral testimony (and as documented in the City's written testimony at p. 4-5 of Document #5), while the system experienced variability in flows and salinity in the past, the variability existed in a significantly fresher Delta, especially in the fall, spring and early summer months. As shown in Contra Costa Water District's submittal "Historical Freshwater and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay" (at p. v and p. 47), while variability occurred historically, the levels of salinity were much lower than current conditions.

2. Native species are adapted to historical conditions, so historic salinity and flow patterns must be considered in establishing appropriate flow and salinity standards.

Our oral testimony during the March 2010 Informational Proceeding outlined the changes that have occurred to alter the flow and salinity environment in the Delta. This testimony on such changes was supported by other panelists. These changes include, in approximate chronological order:

- Alterations to Delta channels and loss of marshlands (Antioch testimony, Document #5, p. 1-2 & Document #6, p. 7)
- Alterations to sedimentation and transport patterns (Antioch testimony, Document #6, p. 7)
- Diversions of flows upstream of the Delta including the dewatering of significant portions of the San Joaquin River (Antioch testimony, Document #5, p. 2 & Document #6, p. 14-15)
- Diversions/exports of flows from the Delta and from Delta channels themselves (Antioch testimony, Document #6, p. 8 & p. 16)

3. Because of these changes to the Delta, flow now plays a more crucial role than in the past, in order to maintain or improve physical habitat and water quality in the Delta.

We encourage the SWRCB to explore and document the biological significance of the historical changes in flow and salinity regimes, and to consider this information in its recommendations. It is critical to keep in mind the significance of Sacramento River flows on the health of the public trust resources in the Delta.

Closing Recommendations

1. SWRCB should review, consider, and incorporate historic salinity data into its Flow Criteria analyses. The City of Antioch and Contra Costa Water District have provided valuable data regarding historic Delta flow and lower salinity conditions.
2. SWRCB should use historic flow and salinity data to establish a baseline of water quality and flows sufficient to restore public trust resources in the Delta.
3. SWRCB should ensure that flows are not reduced, nor salinity increased, beyond levels assured by D-1641 and current X2 requirements. Ideally, the SWRCB should increase flows to more proximate historic conditions of outflow and low salinity. The City is not recommending that historic flows be completely restored as this is not practical and could potentially impact other beneficial uses. However, historic flows and historic low salinity levels supported native species and must be considered in making any determinations on restoring Delta flows.
4. Compliance points for outflow and salinity should not be moved land-ward (easterly) and should likely be established more westerly than present as supported by the historical data.
5. Due to the loss of historic San Joaquin River flows, it is critical that Sacramento River flows be maintained in and through the Delta – and that the SWRCB recognizes that such Sacramento River flows included significant flows into the Central and Western Delta through Georgiana and Three Mile Sloughs.
6. SWRCB should consider using Antioch's gauging station as a 'point of interest' to gauge flow and salinity conditions, given Antioch's historical diversion of fresh drinking water dating back to the 1860s.

Please feel free to contact me or Phil Harrington with any questions.

Sincerely,

Susan C. Paulsen

Susan C. Paulsen, Ph.D., P.E.
Vice President and Senior Scientist

cc: Phil Harrington

Frank

SALT WATER PROBLEM

SAN FRANCISCO BAY *and* DELTA *of* SACRAMENTO *and* SAN JOAQUIN RIVERS

APRIL, 1928

THOMAS H. MEANS, *Consulting Engineer*
216 PINE STREET · SAN FRANCISCO, CALIFORNIA

THOS. H. MEANS
CONSULTING ENGINEER
216 PINE STREET
SAN FRANCISCO

TELEPHONE SUTTER 78

June 10, 1928.

Association of Industrial Water Users of Contra Costa and Solano Counties.

Dear Sirs:

Statements in this report on pages 39, 51, 56, 63 and 69 concerning the proposed Southern Pacific Railroad's Suisun Bay Bridge, located near Army Point, were published before the plans of that company were made public. The information now available shows that the site selected for the railroad bridge lies from 800 to 1800 feet above the location for the Salt Water Barrier selected by Mr. Young. The plans for the bridge provide for piers founded on rock over both the waterway and marsh areas. The experiences of the railroad do not favor the location of the tracks upon rock fill dikes, as proposed by Mr. Young, but would require piers to rock throughout the length of the structure. According to estimates by the railroad company's engineer, the saving in cost by combining the railroad bridge with the barrier under these conditions would be small and the disadvantage of having the lift span located close to locks, where the movement of vessels is slow, serves to offset any saving in cost

The railroad bridge as planned provides for a bridge giving a clearance of 70 feet (as compared with 50 feet in Young's plans), a height great enough to permit the free passage of river boats. The lift span will be used for ocean-going vessels. Piers are spaced 413 feet on centers and foundations in all cases will be carried to bedrock. The construction of the barrier as proposed by Young will not be interfered with if this site is selected.

The estimated cost of the bridge now proposed is about $6,400,000, exclusive of approaches, track, etc.

There is no advantage to be gained by a combined structure unless the result is in decreased cost to both barrier and railroad. Since there is apparently no such advantage to be gained and the bridge will not interfere with the barrier if the Army Point site is selected, I suggest that this letter be attached to my report in correction of the statements made therein.

Very truly yours,

THOS. H. MEANS.

SALT WATER PROBLEM

SAN FRANCISCO BAY *and* DELTA *of* SACRAMENTO *and* SAN JOAQUIN RIVERS

APRIL, 1928

THOMAS H. MEANS, *Consulting Engineer*
216 PINE STREET · SAN FRANCISCO, CALIFORNIA

MARTINEZ:
MARTINEZ DAILY STANDARD

TABLE OF CONTENTS

Preface

The following report by Engineer Thos. H. Means was financed by the Association of Industrial Water Users of Contra Costa and Solano Counties.

The only instructions given Mr. Means in preparing this report were to get the facts, and it is hoped that this document will be of benefit in establishing some of the facts relating to the proposed Salt Water Barrier as designed by Engineer Walker R. Young.

The following firms are members of the Association:

American Smelting & Refining Co.
Associated Oil Company
Atchison, Topeka & Santa Fe Railway Co.
F. E. Booth Company
California-Hawaiian Sugar Refinery
Columbia Steel Corp.
Coos Bay Lumber Co.
Fibreboard Products, Inc.
General Chemical Co.
Great Western Electro Chemical Co.
C. A. Hooper & Co.
Johns-Manville, Inc.
Kullman-Salz & Co.
Mountain Copper Co.
Pioneer Rubber Mills
Redwood Manufacturers Co.
San Francisco & Sacramento R. R.
Shell Company of California
Southern Pacific Company
Union Oil Company

ASSOCIATION OF INDUSTRIAL WATER USERS
OF CONTRA COSTA AND SOLANO COUNTIES
C. W. SCHEDLER, *Chairman.*

PENETRATION OF SALT WATER IN UPPER BAY AND LOWER RIVER REGION

Under natural conditions, Carquinez Straits marked, approximately, the boundary between salt and fresh water in the upper San Francisco Bay and delta region of the two tributary rivers—the Sacramento and San Joaquin. Ordinarily salt water was present below the straits and fresh water was present above. Native vegetation in the tide marshes was predominantly of salt water types around San Pablo Bay and of fresh water types around Suisun Bay.

In tidal waters, into which run fresh water streams of variable flow, there is an ebb and flow of salt water and the zone of mixing will move up and down stream as the fresh water flow increases and decreases. For short intervals in late summer of years of minimum flow, salt water penetrated the lower river and delta region, and in wet seasons the upper bay was fresh, part of the time, to the Golden Gate. This variation in quality of water was not, however, of sufficient duration to affect the characteristic vegetation growth of the regions on each side of the straits, nor to change the designation of Suisun Bay as ordinarily a fresh water body and San Francisco Bay as salt water.

The works of man have changed conditions in many ways. The most important changes have been brought about gradually,—so slowly as to be hardly noticeable. The dry season of 1918,—when large summer diversions for irrigation in the Sacramento Valley resulted in the sudden penetration of salt water farther upstream than ever known before, at such an early period in summer,—first brought the salt water problem to public notice. The slow effects of increasing diversions in previous years had escaped notice, but were brought prominently to the attention of the inhabitants of the upper bay and delta regions in this year. Since 1918, the dry years of 1920, 1924 and 1926 have more convincingly demonstrated the importance of the salt water problem.

An accurate picture of natural conditions is not possible, because no records have been collected on which such a picture can be based, but very close approximations can be made. The log of the distance traveled by the water barge of the California Hawaiian Sugar Company in going upstream to obtain fresh water has been kept since 1908. These figures give the means of determining approximately the conditions during that period. In 1908 irrigation had been extensively developed in both valleys and conditions then were not natural. For an estimate of earlier conditions we must go to the stream flow records of the tributary streams before important diversions are taken out.

It is the practice of the Sugar Company to send the barge upstream until water of approximately 50 to 70 parts per million chlorine is reached. The crew of the barge are equipped with apparatus by which water is analyzed until this degree of purity is reached. Since trips are made nearly every day during the summer months, the record is a very good indication of the point reached by salt water. A summary of the complete records shows the fluctuation of the line between fresh and salt water. Records of the Sugar Company are attached. (Table 1.)

The Sugar Company requires water of great purity. For irrigation, domestic or ordinary industrial uses, water of a lesser degree of purity may be used. A comparison of the point where the Sugar Company's barge is filled with the point where the remaining uses could be satisfied, indicates that from five to ten miles downstream from the place where the barge turns, water could be obtained satisfactory for domestic supply. Making an allowance of 7½ miles in the average records, we find that an average flow of 5,000 second feet in both streams will maintain fresh water at Collinsville; 7,000 second feet will maintain fresh water at the San Francisco-Sacramento ferry.

If we sum up the flow of the important tributaries of the Sacramento and San Joaquin rivers at the points where these streams leave the mountains and assume that this flow under natural conditions would have reached the head of the Suisun Bay, we will find that at no time in the past ten years would the average monthly flow have been less than 5,100 second feet. It is probable, should all streams be running in a natural way, that salt water would have penetrated no farther in this extremely dry period than Antioch, and then only for a few days at a time.

It is not possible to make a more detailed study of this condition without making a number of assumptions as to speed of flow from the gaging stations to the head of the bay, and there is little accurate information on which the assumptions may be made. The definite statement that salt water under natural conditions did not penetrate higher upstream than the mouth of the river, except in the driest years and then only for a few days at a time, is warranted. (See Table 2 for monthly flow of tributary streams.)

At present salt water reaches Antioch every year, in two-thirds of the years running further upstream. It is to be expected that it will continue to do so in future, even in years of greatest runoff. In other words, the penetration of salt water has become a permanent phenomenon in the lower river region.

CAUSE OF CHANGE IN SALT WATER CONDITIONS

The cause of this change in the salt water condition is due almost entirely to the works of man. If natural changes have had any effect, it is too small to be measured. The most important natural condition is the sequence of dry and wet periods. Since 1917 the State has experienced dry years with low runoff in nearly all streams. During this period two years have exceeded normal stream flow in some streams (1921 and 1927). In each of these years excessive salinity (over 100 parts chlorine per 100,000) was present at Antioch about two months.

Irrigation

Storage and diversion of water have been the principal causes of salinity increase in the upper bay country. The area irrigated varies from year to year; in 1926 the acreage of lands on the floor of the valley was approximately as follows:

Estimate of Diversions and Area Irrigated 1926—Sacramento and San Joaquin Valleys, Not Including Mountain Areas

	Acre Feet Diverted	Acres Irrigated
Sacramento and tributaries above Sacramento, including rice, 128,439 acres	1,644,973	235,995
Delta uplands	146,906	53,649
Delta area		264,479
San Joaquin Valley estimated	2,100,000	700,000
	3,891,879	1,254,123

In addition to this area on the valley floor, there is a large acreage in the mountains which uses water from the streams tributary to the rivers that drain through Suisun Bay. The acreage irrigated in the mountains is not so accurately known as the area on the valley floor, but it is large and, particularly in low flow season, very effectively uses up the water in the streams. The use of water in the mountains is usually more economical than in the valley and the return seepage is less. The net effect is to consume all of the water diverted. The effect upon the flow is pronounced.

The latest accurate determination of area irrigated is that made by the United States Census.

IRRIGATION IN CALIFORNIA

Census of 1920

	1902	1919	1920 Area in Enterprises	1920 Area Capable of Irrigation
Sacramento River and Tributaries	206,312	640,950	1,204,769	864,605
Sacramento River direct	10,942	194,397	439,169	296,748
Pit River	72,072	89,984	129,984	107,478
Cow Creek	2,321	6,068	12,488	7,446
Cottonwood Creek	1,858	2,972	21,016	4,112
Battle Creek	2,642	2,966	6,590	5,108
Stony Creek	4,110	23,559	45,143	36,191
Feather River	67,111	142,841	186,756	167,463
Yuba River	Not Rep.	19,473	69,074	23,492
Cache Creek	3,756	24,541	56,498	31,212
American River	10,112	47,156	82,695	52,842
Other Tributaries	31,388	86,993	155,356	132,513
San Joaquin River and Tributaries	220,651	1,069,161	2,072,739	1,497,661
San Joaquin River direct	129,647	642,261	1,083,862	873,300
Fresno River	10,729	12,412	30,004	14,016
Merced River	19,636	65,151	222,715	71,709
Tuolumne River	Not Rep.	165,533	298,418	250,425
Stanislaus River	13,840	75,359	155,453	111,192
Calaveras River	Not Rep.	13,323	21,598	16,489
Mokelumne River	5,558	36,848	155,480	72,144
Cosumnes River	Not Rep.	3,259	9,011	6,405
Other Tributaries	41,241	55,015	96,198	81,981

The above includes springs and wells.

Where area in watershed is not reported (not rep.) it is included in other watersheds.
Records for other census periods have not been tabulated so as to be comparable.

This table shows that in the 18 years between 1902 and 1920 the area irrigated in the Sacramento Valley trebled, while in the San Joaquin Valley the increase was nearly five times as great. The area included in irrigation enterprises was only half watered in 1920, while the area capable of being irrigated was only about two-thirds watered. The total area irrigated in both watersheds was 1,710,000 acres in 1920.

No accurate records have been collected since 1920. It is known, however, that the growth of irrigation has continued, though at a slower rate than prior to 1920. Since 1920 the growth in area has been proportionally larger in the San Joaquin than in the Sacramento Valley. In the latter valley grain production (seldom irrigated) is still profitable and much land within irrigation projects goes into grain. Other crops, such as rice, vary in area with the price of rice.

United States Department of Agriculture tabulation of area in rice in California is shown below:

ACRES IN RICE IN CALIFORNIA

1920	162,000
1921	135,000
1922	140,000
1923	106,000
1924	90,000
1925	103,000
1926	149,000

Storage reservoirs, both for irrigation and power, have been built on many streams in the past fifteen years. Many others are planned and their construction will be undertaken within a short time. The following list of reservoirs is as complete as it is possible to make it. Small reservoirs—less than 1,000 acre feet capacity—have been omitted.

STORAGE RESERVOIRS
GOLDEN GATE DRAINAGE WATERSHED

SACRAMENTO BASIN		Height of Dam	Reservoir Capacity Acre-Feet
Cottonwood Creek	Misselbeck Reservoir	105	5,460
Pit River	Darris Reservoir	------	12,500
Pit River	Big Sage Reservoir	------	--------------
Pit River	Mt. Shasta Power Co. No. 3	112	36,000
Stony Creek	East Park	139	51,000
	Stoney Gorge	120	50,000
Paradise Creek	Paradise Reservoir	------	--------------
Battle Creek	2 Reservoirs	------	3,000
Feather River	Lake Almanor	125	1,317,000
	Bucks Creek	128	103,000
	Butte Valley	115	106,000
Yuba River	Bullards Bar	183	11,000
	Lake Francis	70	2,400
	Spalding	------	74,000
	25 Reservoirs, small	------	54,000
	Bowman being enlarged	------	--------------
American	4 Reservoirs	------	12,800
Mokelumne	Pardee under construction	350	200,000
	Electra System, 7 Res.	------	24,800
Stanislaus	Salt Springs, under construction	300	130,000
	Relief	140	15,000
	Strawberry	135	18,000
	Utica, 3 Reservoirs	------	8,900
	Woodward	------	36,000
	Melones	191	112,500

Tuolumne	Hetch Hetchy	......	....
	O'Shaughnessy Dam	344	206,000
	Dom Pedro	284	290,000
	Lake Eleanor	......	25,300
	Dallas Warner	......	28,000
	Davis	......	48,000
Merced	Exchequer	330	278,000
San Joaquin	Florence Lake	......	64,500
	Huntington	165	88,700
	Shaver Lake	183	138,500
	Crane Valley	150	38,000
Cache Creek	Clear Lake	......	400,000
Suisun Creek	Gordon Valley	104	10,000
Total Constructed Reservoirs			3,998,360

Projected Reservoirs (Partial List)

Sacramento	Kennett	420	2,838,000
	Iron Canyon	......	709,000
American	Folsom	220	300,000
Mokelumne	Dry Creek	140	1,200,000
Tuolumne	O'Shaughnessy, increased to	430	350,000
Total Projected Reservoirs			5,397,000

In round numbers, reservoirs of a capacity of 4,000,000 acre feet are in use on streams tributary to San Francisco Bay above Carquinez Strait. Reservoirs of much larger capacity are being considered for future construction.

Mining Debris. Mining debris and sediment in the rivers and by-pass channels have probably changed the tidal flow to a small extent, and may have affected salt water movements. The effect has been too small to measure, but it has been generally in the direction of reducing tidal prism and tidal flow where the deposits are laid down in bay waters, and of increasing tidal flow through the Golden Gate where deposited in the rivers. The net change has probably been very small. Gilbert, in his report upon Hydraulic Mining Debris (U. S. G. S. Prof. Paper 105, page 87) estimates the reduction in tidal currents in Golden Gate caused by deposition of debris as 2.49 per cent.

Land Reclamation. Reclamation of land by building levees has affected tidal flow and movement of salt water in two ways: first, by decreasing the tidal prism in the delta and, second, by changing the time of arrival of floods and of low water.

First, Reduction of Tidal Prism: The reduction in tidal prism by the construction of levees in the delta region and around the upper end of San Pablo Bay and around Suisun Bay has probably had the effect of slightly reducing the tidal flow through Golden Gate. As has been shown by Gilbert in the publication above referred to, the effect of leveeing in the lower river has had the tendency of increasing Golden Gate flow, while the same work in Suisun and San Pablo Bays has had the opposite effect. The net effect, however, is small and results in decreased flow. Gilbert (U. S. Geologic Survey Professional Paper 105, page 79) estimates the average percentage of the flow through Golden Gate as follows, when all marshes are leveed:

MARSH LAND AREAS—AVERAGE VOLUME FLOWING THROUGH GOLDEN GATE EXPRESSED IN PERCENTAGE

	Per Cent
San Pablo Bay marshes and Napa River	*1.95
Suisun Bay	*1.18
Sacramento Delta	†1.04
San Joaquin Delta	†3.35
Net effect on Golden Gate flow	†1.26

* Means decrease in tidal flow through Golden Gate.
† Means increase in tidal flow through Golden Gate.

Second, Change in Time of Arrival of Floods: The effect of leveeing upstream from tide lands has been to decrease the storage in basins and to increase the rate of travel of floods toward tide water. Under natural conditions the basin areas filled with water in flood time and slowly released this water in late summer, maintaining the flow well into the period of low water.

Most of these up-river basins have been leveed and floods run through the river channel and by-passes to the ocean with very little retardation by storage. There is no stored water from these basins to maintain low flow, consequently the low flow reaches the tidal channels earlier in the year than under natural conditions.

The effect of this reclamation work upon salt water conditions has been very pronounced. In the period just prior to 1918, some of the largest reclamation districts were leveed, Sutter Basin being a notable example. Prior to this closing off from flood flows these basins retained large volumes of water, sometimes until the middle of summer, the water slowly draining back into the channel. Nowadays instead of delivering water to the channel, water is taken from the channels for irrigation during summer months. Drainage returns a small part of the irrigation water directly to the river.

Return seepage from irrigation has had the effect of increasing the low water flow in the Sacramento. Stafford, in publications of the Division of Water Rights (Biennial Report November, 1924, page 133; Sacramento-San Joaquin Water Supervisor's Report 1926, page 85) estimates the water returned to the Sacramento River as follows:

WATER RETURNED TO SACRAMENTO RIVER (INCLUDING ALL ACCRETIONS)

Flow in Second Feet

	1924	1925	1926
June	879	-------	2280
July	734	1624	1573
August	785	1320	1240
September	634	1310	1077
October	-----	460	-------
Mean	763	1179	1543

Dredging, particularly in the Sacramento River, near its mouth, has had the effect of increasing the water prism, but the probable effect upon tides through Golden Gate is to decrease them. The dredging work is so far upstream as to be on the tidal movement opposite to that in the Golden Gate.

The deepening of the channel has, further, the effect of permitting the deep flowing salt water to pass upstream with more ease through the deep channel. A like effect will probably result from deepening of Suisun Bay and the San Joaquin River to Stockton, a navigation project authorized by Congress.

It is not possible to measure these effects, but it is well established that salt water being heavier moves along the bottom of deep channels with greater ease than over shallow ones. Any deepening of channels or straightening of approach through dredger cuts has the tendency to facilitate the movement of the deeper waters.

Irrigation and Storage of Water in the San Joaquin Valley. Irrigation in the San Joaquin Valley has had an effect upon tidal conditions and the movement of salt water in two ways: first, by diverting and storing water during flood period, and second, by increasing the flow in late summer and fall months through return seepage.

A much larger utilization of water resources has taken place in the San Joaquin than in the Sacramento Valley. Rainfall is lighter on the floor of the valley, so dry farming has been less profitable and there is greater necessity of irrigation. All streams tributary to the bay are now completely diverted during the low flow period and no water enters the tidal channels except return flow. This condition has been true for over ten years.

The following brief description of the streams and the irrigated area will show the extent to which the water supply has been put to use.

Upper San Joaquin. The upper San Joaquin enters the valley floor at Friant. The mean annual flow of the stream at the valley's edge averages 2,050,000 acre feet. Storage above this point, built by the San Joaquin Light and Power Corporation and the Southern California Edison Power Company under contract with riparian owners and appropriative users of water, amounts to 330,000 acre feet. Other storage reservoirs have been planned. Lands irrigated from the stream lie on both sides of the river and aggregate 400,000 acres. The diversion capacity of the ditches, sloughs and canals in use is very large.

Above the Merced River, canals, ditches and sloughs with control gates have a capacity in excess of 7,000 second feet. Sloughs and channels used for wild flooding increase this diversion capacity to in excess of 10,000 second feet. Below the Merced, a number of pumps take water from the river to West Side slope. Down to Paradise Dam, about the head of tide water, these diversions total in excess of 500 second feet.

All water entering the valley is diverted in late summer. The San Joaquin is dried above the Merced for three or four months a year. Return seepage commences to "make" about the mouth of the Merced. Below that point there is always water in the channel, except for short periods of time, just below some of the larger pumping plants.

Fresno River. This stream has a small watershed area of low mountains with a mean annual flow of 68,000 acre feet. The entire low flow is utilized around Madera and toward the San Joaquin. No return seepage makes from this area, as pumping plants have lowered the ground water plane and probably intercept nearly the entire ground water flow.

Chowchilla River. This stream has about the same area and topographic conditions in its watershed as has the Fresno. Its mean flow approximates 68,000 acre feet. All low flow is utilized. Pumping has been heavy on its lower course. No return seepage makes from this area.

Merced River. The Merced Irrigation District and riparian lands lying above the junction with the San Joaquin utilize all low flow. The Exchequer Reservoir of the Merced District, with a storage capacity of 278,000 acre feet, controls the stream except in wet years. The power plant at the dam delivers water into the river, when water is plentiful, in excess of the district's diverting capacity. Water always passes the district's headgate for use of lands lower down on the Merced. The mean flow of the stream is 1,330,000 acre feet. Return seepage maintains a continuous flow at the mouth of the Merced, the water coming from both the Turlock and Merced sides of the river. This return flow now amounts to 80 to 100 second feet in summer months and there are indications that it is increasing. Pumps along the Merced utilize a part of this return flow.

Tuolumne River. The Tuolumne drains a high mountain area and has a mean annual flow of 2,055,000 acre feet. Three irrigation districts—the Waterford, Modesto and Turlock, with a total area of 276,783 acres—divert water at the LaGrange Dam. Three storage reservoirs with capacity of 366,000 acre feet are operated by these districts. The City of San Francisco has rights on the upper watershed for water for domestic uses and has built reservoirs of capacity of 231,000 acre feet. A conduit of capacity of 620 second feet is under construction. San Francisco has control of other reservoir sites and proposes, ultimately, to divert 400 million gallons daily (620 second feet) from the watershed. To do this, storage of about 850,000 acre feet will be required.

Return seepage in the Tuolumne, at its mouth, resulting from irrigation now amounts to from 250 to 350 second feet constant flow. Additional seepage from these irrigated areas appears in the Merced, the Stanislaus and San Joaquin rivers.

Stanislaus River. The Stanislaus River—mean annual flow 1,376,000 acre feet—is under storage control for both power and irrigation. Power reservoirs with capacity built or being built of 172,000 acre feet, high on the stream, increase the low flow, but this water is re-stored in reservoirs or diverted by the South San Joaquin and Oakdale irrigation districts. These districts, with an area of 145,348 acres, have in Melones and Woodward reservoirs a storage capacity of 148,000 acre feet. All low flow is diverted. Return seepage in the Stanislaus River at its mouth (coming in part from the Modesto District) now varies from 100 to 160 second feet constant flow. An additional amount enters the San Joaquin River.

Return Flow in the San Joaquin River. Return seepage in the San Joaquin River from the mouth of the Merced to Durham Ferry (just above tide water) now amounts to a continuous flow of from 600 to 1,000 second feet. About 300 second feet of this water is diverted above tide water by pumps irrigating West Side lands. Additional pumps recently installed or in process of installation and pumps diverting from the tidal portion of the stream have a combined capacity of between 750 and 800 second feet. In the peak of the irrigating season these West Side pumps divert practically all of the visible flow in the San Joaquin River. The delta lands and islands are dependent upon ground water flow and such water as flows down the Calaveras, Mokelumne and connecting sloughs from the Sacramento River.

NET RESULT OF IRRIGATION AND STORAGE ON SALT WATER PROBLEM

Summarizing former statements upon the effect of irrigation and storage upon the flow of salt water in the lower river and upper bay region, the following may be said:

1. Under natural conditions the boundary between salt and fresh water was Carquinez Straits. In late summer, Suisun Bay became brackish but salt water penetrated as far as Antioch only rarely and then for but a few days' time.

2. The combined effects of irrigation and diversion in the Sacramento Valley have been to reduce the flow entering tidal waters to a small fraction of the flow under natural conditions. In 1924 the flow at Sacramento was about 720 second feet and was below 1,000 second feet for in excess of a month. In 1925 the flow at Sacramento reached a minimum of 2750 second feet and was below 3,000 for nearly a month. In 1926 the flow of the Sacramento reached a minimum of 1200 second feet and was below 2,000 for over a month.

3. The late summer flow of the San Joaquin—all return seepage—has been below 1,000 second feet in all years except 1927. The capacity of pumping plants irrigating West Side lands exceeds the inflow nearly every summer, so that, so far as visible flow in the San Joaquin is concerned, all of the late summer inflow into tidal channels is used on West Side area. The delta lands now must obtain their supply from the water stored in channels or which flows underground, or from the Calaveras, Mokelumne, and sloughs connecting with the Sacramento River.

4. The use of water by the delta lands on both San Joaquin and Sacramento rivers has not been accurately determined. The area irrigated amounts to 360,000 acres. If this area consumes 1¾ acre feet of water per annum, of which 20 per cent is used in a month, the consumptive draft will be at the rate of 2100 second feet. This quantity exceeds the low flow in years of light rain.

PRESENT CONDITIONS OF SALT WATER IN UPPER BAY AND LOWER RIVER REGIONS

Salt water conditions have been under observation by the Division of Water Rights of the Department of Public Works since 1917. Results have been published in the annual reports of this Division. Earlier records of much value in the study of the problem are those of the California-Hawaiian Sugar Company, referred to earlier in this report, covering the period from 1908 to 1920. In 1920 the Sugar Company obtained a supply from the Marin Municipal Water District at San Quentin Point, approximately 15 miles from Crockett. Since then, when the distance traveled upstream to fresh water is less than 15 miles, the water is taken from the river; when the distance exceeds 15 miles, the Marin County water is used.

A number of other investigations of salt water conditions have been collected at various places and are of help in the determination of the changes which have taken place in recent years. Among these records are those collected by Mr. William Pierce north of Suisun Slough, on the north side of Suisun Bay; records for a short period by the Pacific Portland Cement Company at Suisun, showing salinity of Suisun Slough; records by the Great Western Electro Chemical Company at Pittsburg, extending from 1916 to date, giving total solids and chlorine in the river water; and information collected at various times in the investigation of water supplies by the City of San Francisco, the City of Richmond, and the East Bay Water Company. A large amount of information from these various sources has been obtained and is helpful in interpreting the changes which have taken place and in formulating a fairly accurate conception of conditions in the past and what may be expected in the future.

Attached to this report is a chart of the region, the base being photographed from the Annual Report of the Division of Water Rights. On this chart red lines have been placed showing the penetration of salt water during the months of June and September, 1924. Similar charts for other years show that in every year, salt water has penetrated to a point beyond Antioch on the San Joaquin River and Collinsville on the Sacramento, and that in years of low flow, such as 1918, 1920, 1924 and 1926, the extreme limit of salt water penetration has been well into the delta region.

The year 1927 is one of approximately 100 per cent runoff in the streams tributary to San Francisco Bay. In this year salt water reached the middle of Suisun Bay in June, was approximately at Collinsville and Antioch in July, and during August and September had reached approximately to Emmaton on the Sacramento and the lower end of Jersey Island on the San Joaquin River.

Stream flow records show that approximately one-third of the years are in excess of 100 per cent runoff and two-thirds of the years below that figure. This gives, roughly, an approximation of the period of time in which salt water conditions will be worse than in 1927 and the period in which better results can be expected.

For practical purposes, a period of thirty days or more would be detrimental to either irrigation, domestic use or supply for industrial purposes. An examination of records in more detail indicates that, under the conditions now existing, in practically all dry years salt water will reach the lower end of the delta for at least a month's time, and that in two-thirds of the years water will be in the lower delta region in excess of a month's time or as much as three to four months.

The areas of delta land within the salt water flow are shown in the following table:

	Approximate Stream Flow in Per Cent, Normal	Area of Delta Penetrated by Salt Water
1924	24	169,000
1926	53	58,000
1925	74	8,500
1927	100	5,000

PROSPECTIVE CHANGES IN THE FUTURE

Storage of water for power purposes and diversion for irrigation and domestic uses in the watersheds tributary to the bay are steadily increasing. The rate of increase of the irrigated area is not so rapid as during the decade 1910 to 1920, but there is a steady, continuous growth and plans are on foot for large increases in the use of water through new projects and through the extension of irrigation on old projects.

As illustrating the extent to which conditions are changing, reference may be made to the growth of the San Joaquin River basin since the year 1920, a period ordinarily regarded as one of stagnation in irrigation development in California. Since 1920, the Southern California Edison Power Company has constructed and placed in operation the Florence Lake and Shaver Lake Reservoirs on the San Joaquin River with a storage capacity of 203,000 acre feet. This stored water will be diverted and used as fast as it is released for power purposes by the agricultural lands above the mouth of the Merced.

On the next stream, the Merced Irrigation District has built a storage reservoir of 278,000 acre foot capacity and has approximately trebled the area in irrigation in 1920. The district is rapidly growing and the entire irrigable acreage in the total of 189,000 acres will be all in cultivation within a few years.

On the Tuolumne River, since 1920, the Modesto and Turlock Irrigation Districts have built the Dom Pedro Reservoir of 290,000 acre foot capacity, and both districts have extensively increased their irrigated area. The growth is steady.

The Waterford District has acquired rights to use the water of the Yosemite Power Company, which formerly delivered approximately 60 cubic feet per second into the Tuolumne River below LaGrange Dam, further reducing the stream flow.

Since 1920 the City of San Francisco has built Lake Eleanor and the O'Shaughnessy Dam, storing 231,000 acre feet. The water released from these reservoirs has not yet been diverted from the watershed but it has been picked up, at least during the summer period, by the irrigation districts, and no water except return seepage has flowed into the Tuolumne River during the summer and early fall months.

On the Stanislaus River, the Melones Dam has been built by two irrigation districts in cooperation with the Pacific Gas and Electric Company, and the late summer use of water has been very much increased.

In addition the Power Companies have now under construction Salt Springs Reservoir on the headwaters of the Stanislaus, with the intention of ultimately raising this to storage capacity of 130,000 acre feet. This water when released will be caught by the Melones and Woodward reservoirs lower on the stream and utilized during the late summer.

The East Bay Utility District has now under construction the Lancha Plana Reservoir site on the Mokelumne River, a reservoir of 200,000 acre foot capacity, and has completed a pipe line from the Mokelumne to the East Bay district of a capacity of 60 million gallons daily (90 second feet). The water to be diverted by this Utility District will be taken out of the watershed and there will be no return flow from it.

In addition to the reservoirs and increased irrigated area on the east side of the San Joaquin, several pumping plants have been built lifting water up the West Side slope for the irrigation of high lands. Important among these are the Banta-Carbona Irrigation District, approximately at the head of tide water, which commenced irrigating in 1925 and now has a pumping capacity of 220 cubic feet per second.

The Burkhart Ranch further south has installed a pumping capacity of about 50 cubic feet per second since 1920, and a number of other districts and appropriators of water have increased either the size of their pumping equipment or the extent of their use, so that at the present time the capacity of the pumping plants irrigating West Side lands exceeds the flow in the San Joaquin River at the place where tide water is reached.

Further extension of this irrigated area is in progress and one new district is now engaged in preparation of plans which will result in the pumping of approximately 300 second feet from the river.

Extension of area supplied by pumping from wells has been going on at the same time. In Fresno, Madera, Merced, Stanislaus and San Joaquin counties, hundreds of pumping plants have been installed since 1920, all drawing from water which, under natural conditions, would have its outlet to the sea through the San Joaquin River. It is impossible to accurately estimate the effect of this withdrawal of water upon the stream flow or the underflow to delta areas, but, if it has not already done so, it will at some time affect the flow by reducing the quantity of water which reaches the stream from underground sources and affecting to that extent the late summer discharge into tidal waters.

Irrigation development has not been so pronounced in the Sacramento watershed since 1920. There are a large number of irrigation and reclamation enterprises in the Sacramento Valley which have irrigation systems of a capacity larger than the irrigated area. There is, in addition, a large area of land still devoted to grain, rice, sugar beets and other general farm crops, which goes in and out of cultivation as economic conditions vary. The years when grain prices are high, large areas of grain go into cultivation, a portion of which is irrigated. With prospects of low prices for grain other crops are planted, some of which use more water than does grain. The most noticeable effect on the water supply, however, is the increase and decrease in the rice crop. The area irrigated in rice since the industry became stabilized varies from 130,000 to in excess of 200,000 acres a year, and in years of large crop the effect upon the water supply is very noticeable.

Although no large new enterprises have been built in the Sacramento Valley in recent years, the increase in irrigation in the older districts has been steady. The area devoted to orchards, to alfalfa, and to general farm crops requiring irrigation, steadily increases. The result has been continued drafts upon the supply from the river and to gradual reduction in the total flow downstream from the main cultivated section. The reduction in flow, to some extent, has been controlled by the operations of the Division of Water Rights through the Commissioner appointed to superintend the diversions from the Sacramento and San Joaquin rivers. The principal effect of the work of the Commissioner has been to reduce the waste of water, to encourage economy and to endeavor to keep the flow at Sacramento as high as possible, both for purposes of navigation and the use of delta lands.

Return seepage and waste from the lower ends of the rice irrigation canals have to some extent ameliorated the extreme low flow conditions experienced in 1920 and 1924, but the steady increase in irrigated area goes on each year. The total quantity of water which passes out of the valley in late summer is slowly but surely decreasing.

There is nothing to indicate any change of conditions in the immediate future. Irrigation has reached nearly stable conditions on the upland areas of the San Joaquin Valley, largely because the streams are nearly developed to their full capacities. On the Sacramento River, however, large areas of fertile land under irrigation systems built to supply them with water are certain to be placed in crop and increase the use of water. The result will be a steady depletion of the stream and an increase of the salt water menace.

Salt water conditions such as have occurred in the lower delta since 1918 have become permanent and will not be improved until some additional water supply is turned into the river during the low flow period, or unless a barrier is built to prevent the approach of salt water from the ocean. It is difficult to conceive a set of natural conditions that would change this situation. We have reason to expect years of heavy runoff to follow the long period of dry years since 1917, but a review of the past does not lead to the belief that summer water supply can be increased to such a point that any appreciable effect will be experienced by the delta region and industrial area.

EFFECT OF SALT WATER ON DEVELOPMENT

The industrial and agricultural areas along the upper bay and lower river region came into being before there was any serious thought of the salt water problem, in other words prior to 1918, for that was the first year in which the encroachment of salt water was serious and over a long period of the year. Since 1918 there has been no large increase of cultivated land in the delta region and few new industries of importance have been established in the industrial area. There has been, however, a steady growth in the industries already established.

The effect of salt water upon the various users of water will be discussed in the following paragraphs.

Agriculture. Water to be supplied for agricultural purposes must be free from large quantities of soluble matter. The upper limit of concentration safe for use depends upon the soil, crop, rate at which it has been used, drainage facilities, and to some extent upon whether fresh water is available at other times in the year for leaching purposes. The determination of the safe limit is, therefore, a matter of considerable difficulty, as it will vary as these factors differ.

For the purposes of this report, however, it is fair to assume that water containing 100 parts of chlorine per 100,000, equivalent to 160 parts of sodium chloride or common salt per 100,000, is the upper limit of safety; since the water contains other salts the total salinity of water containing 100 parts of chlorine will vary from 175 to 200 parts per 100,000. Water of this degree of salinity is not safe for use, except where precautions are taken to provide good drainage and to continue leaching the water through the soil so that there is no accumulation of salty matter. Such water may be used with safety on light soils where drainage is good and the use excessive, and is not harmful where used occasionally during late summer. One-half of this quantity, or 50 parts per 100,000, is much safer for use and waters of this degree of salinity could be used with comparative safety.

The records quoted above show that in years of extreme low flow, waters of 100 parts of chlorine per 100,000 will penetrate into the delta region to points beyond Rio Vista on the Sacramento, and to Stockton and beyond the mouth of Middle River on the San Joaquin. During some part of the summer approximately one-half of the delta area will be surrounded by salt water.

This condition has several results: First, it renders questionable the irrigation of permanent crops, particularly such crops as are sensitive to salt; second, it has a tendency through the percolation beneath the levees of sub-irrigating the adjoining land with saline water; third, it reduces the value of lands through the fear of salinity; and fourth, it adds expense and uncertainty to the question of domestic supply, for on most of the delta the river is a source of domestic water.

The net effect of this condition is to render agriculture uncertain in the delta, to reduce the value of land, and to create a menace which will result in the destruction of the land by the accumulation of salts.

AREA OF AGRICULTURAL LAND AFFECTED BY SALT WATER BARRIER

The area of agricultural land affected by the salt water barrier is taken as:

1st—The area of marsh land lying practically at sea level.

2nd—The area of land up to elevation 150 above sea level; an elevation to which pumping has been carried with success.

These areas may be subdivided into geographic regions as follows:

1st—The area around San Pablo Bay, between Carquinez Strait and the site of the San Pablo barrier.

2nd—The area around Suisun Bay, that is, from the mouth of the river at Collinsville to Benicia.

3rd—The delta area or region upstream from the mouth of the river.

4th—Irrigated or irrigable lands above the delta.

San Pablo Bay Area. A large area of marsh land lies along the west and north shores of San Pablo Bay. At present a large part of this area is in process of reclamation. Much of it is growing grain crops or pasture, but little of it is irrigated. The surrounding waters are salty at nearly all times of the year. Fresh water fills the sloughs and bay during flood time, a period becoming shorter each year. Ground water of good quality has not been found and there is little likelihood of its ever being obtained, as deep wells have been drilled in many places.

Much of the land is yet salt and all of it is influenced to some extent by the salt in the bay, and the reclamation by using rainfall alone to wash out the salt is slow. The presence of fresh water surrounding the area would permit much more rapid reclamation and would make it possible to bring into profitable agriculture nearly this entire area.

Surrounding the marsh area is an area of high ground nearly as large, all of which is now unirrigated. This marginal area could be all watered and made available for many different crops by fresh water from San Pablo Bay and tributaries if this bay were kept full of fresh water. Novato, Petaluma and Sonoma Creeks and Napa River all penetrate the marsh lands and extend to high land; they would make fresh water available for the adjoining high ground and enable pumps to supply small units or large, depending upon the physical conditions.

It is to be expected that at some future time all agricultural lands in California will make use to some extent of irrigation water where such is available. Irrigation in the coastal belt has not advanced as rapidly as in the interior valleys, because owners of such land can grow profitable crops without artificial watering. Maximum results can be obtained only by irrigation and it is but natural to expect water to be in demand at some future time.

The San Pablo Bay areas which may at some time become interested in irrigation are all areas where climate and soil are acceptable to agricultural pursuits. The region is close to centers of population; transportation facilities are usually good or easily improved; it is one where increased population is certain. The availability of fresh water in the bay and tidal sloughs will serve to stimulate this growth.

Lands so situated, close to tidal waters and centers of population, are likewise attractive to industries. As the San Francisco Bay region grows, more and more of the territory adjoining the bay will change from agriculture to industrial or residential property. With a water supply attached to it, the change in use becomes easier, for the amount of water required for agriculture supplies the needs of residential or industrial occupation.

Carquinez Strait. Carquinez Strait—7½ miles long—extends from Suisun Bay to San Pablo Bay. High hills with only small areas of flat land bound the strait. The opportunities for extensive developments for use of water in this territory are limited by the topographic conditions. Industries already occupy much of the available territory and the small valleys, particularly in Contra Costa County, are now filled by towns, the population resulting from industrial, transportation and commercial enterprises along the waterfront.

If the strait is filled with fresh water and tidal fluctuations and currents are decreased, the more complete occupation of all available ground will be possible. At the present time growth is restricted by water supply. Martinez, Port Costa and adjoining territory obtain a part of their water from wells at Concord, 12 miles away. The supply from ground water is limited. Large additions to this supply are impractical. The Sugar Refinery at Crockett has barged water from the river or the Marin County shore at great cost for many years.

On the north side of the strait, the town of Benicia has a small water supply but cannot increase this supply very much without great expense.

Suisun Bay Area. Marsh lands adjoining Suisun Bay total 70,000 acres. Immediately adjacent to these marshes is an area of 93,000 acres of higher land suitable for agriculture but not now irrigated. Fresh water in Suisun Bay would make it possible to convert this area of dry land to irrigated areas of high value.

The marsh area of Suisun Bay is all practically at sea level. Much of it is salt marsh or at least contains enough salt to interfere with some kinds of agriculture. A large part has been leveed and utilized for pasture, but with unsatisfactory drainage, and salt has accumulated.

Fresh water in the surrounding tidal channels and freedom from daily tidal fluctuations will permit the leaching of this land and make the reclamation of it practical. The land is inherently fertile and will become very productive when leached of salt. The works to accomplish this are simple in character and the operation is simple and certain of success.

If fresh water is made available, there is little question but that these marsh lands can eventually be made as productive as the delta lands of the Sacramento and San Joaquin rivers further upstream.

The high ground above these marsh areas and which may be watered by practical lifts out of tidal channels includes the lower parts of Green Valley around Cordelia, the lower part of Suisun Valley, now highly developed to deciduous fruits, and the region from Suisun to Denverton.

South of the bay the lower parts of Walnut Creek and Ignacio and Seal Creek valleys may be reached with low pumping lifts. These valley lands are now in part planted to fruits and the agricultural possibilities of the region have been demonstrated. Irrigation water cannot be obtained for these areas from any other source known at this time. Wells are of small yield and uncertain life. Storage reservoirs on these streams may be possible but none is known except small ones, and these will serve only small local areas.

The most important difficulty is the extremely erratic nature of the runoff from this area. In wet years floods are heavy, but in years below normal precipitation the runoff may be very limited, often negligible. Storage to be dependable must hold water over two or three dry years, an impracticable condition for agriculture except in very limited areas. The greater part of the area will remain unirrigated unless some cheaper, more dependable supply of water is made available. A salt water barrier will place fresh water at points where it can be readily obtained by practical developments.

The Delta Region. The delta region, affected by tide levels, extends as far up the San Joaquin River as Duncans Ferry (6 miles below the mouth of the Stanislaus River) and up the Sacramento a short distance above the City of Sacramento. The distance from the mouth of the San Joaquin to the head of tide water by river is 77 miles; to the head of tide water on the Sacramento is 56 miles. Between these extremes are many miles of tidal channels and sloughs affording access by boat to nearly all parts of the region, and by relatively short dredger cuts, making it possible to deliver tidal water at the edge of high ground.

This region includes 367,000 acres of land, either marsh or swamp and overflow, and 91,000 acres of high ground immediately adjacent to the marsh on the west side of the valleys. These total 458,000 acres.

The entire area is irrigated or irrigable from waters at tide level. The most recent information indicates that of this area 360,000 acres are now irrigated in both deltas. In both deltas an area of 98,000 acres remain to be irrigated, parts of which are irrigated and farmed irregularly. The economic status of the farmer has much to do with the area under cultivation.

The Up River Country. The entire irrigated area tributary to Suisun Bay is to some extent interested in the salt water problem. At the present time a suit is before the Superior Court of San Joaquin Valley, between riparian users and appropriators in the delta region and 443 defendants on the streams above the delta. This suit involves nearly all of the large users of water, both for irrigation and power, on the stream. Much other litigation is in prospect. The outcome of this controversy cannot be foreseen but it is impossible to predict anything but serious complications and nearly endless difficulties no matter which turn the courts may take.

Should the outcome of the present suit be that tide water lands have no riparian rights upon waters of the streams, in excess of one-half of the present delta area will be periodically surrounded by salt water. The agricultural industry will be affected and the salt water menace to these lands will become permanent. The final result will be disastrous to a very large area of land which has been the most uniformly productive land in the state. The continued storage and use of water above tide level and the increase in pumping to high lands around the tidal area will cause salt water to enter the rivers in all years, and at times the greater part of the tidal waters will be contaminated with salt from the ocean.

Should the courts take the view that owners on tidal waters have riparian rights to the flow of the stream, a great deal of very valuable land now using water must release the water which has heretofore been used and a tremendous damage to higher areas will result. The release of waters may affect salt water conditions to some extent but it is impossible to conceive a condition in which enough water will be released to push back salt in years of light runoff.

As is shown later in this report in the chapter on "Storage and Release for Control of Salinity," the plan under which this proposal has been made does not look practical as a means of taking care of the irrigation problem of the delta. Furthermore, it leaves out of consideration the entire industrial area that lies just below the delta.

Power Companies. Two power companies supply the industrial region—the Great Western Power Company and the Pacific Gas and Electric Company. Both companies have an interest in the salt problem in two ways: The market for power is the first and most apparent interest the power companies have in this problem in that the maintenance of the present industries and their growth in the future affect the income of the distributing companies.

In a later chapter a statement of the approximate use of power for industrial and domestic purposes is included. The rate of growth of power sales indicates a steady increase in industrial activities. The more rapidly these factories grow and the more new factories there are installed, the better will be the power companies' incomes. A potential industrial territory offers opportunity for a very large increase in use of power and the encouragement of these industries is a legitimate function of power companies.

The second way in which these companies are interested is the question of litigation mentioned above. The Great Western Power Company and the Pacific Gas and Electric Company and subsidiary companies, such as the Sierra and San Francisco Power Company and Mount Shasta Power Corporation, are parties to the suit previously mentioned. In addition to them the San Joaquin Light and Power Company and Southern California Edison Company, both developers of power on the San Joaquin River, are included, and the Modesto and Turlock, South San Joaquin and Merced irrigation districts are included on account of their storage and use of water on tributary streams. The interests of these concerns, therefore, are created by the direct attack upon their storage and use of water in the higher watersheds.

Should the outcome of this suit establish the riparian right of the delta land owners, the power companies will suffer very seriously in consequence, by the necessity of either releasing water now stored or condemning the right to continue the practice of controlling the flows.

Fishing Industry. Under present conditions, with the Sacramento and San Joaquin rivers open to the flow of tides, fish have free access from the ocean to the fresh water streams draining the Sierra Nevada Mountains. Several types of commercial fish are caught in these waters and other fish are important as food for the commercial varieties. There has developed a considerable fishing and fish-canning industry along the bay and lower river shore. The catch in river and upper bay approximates 5,000,000 to 6,000,000 pounds a year—largely salmon, shad and striped bass. (See table.)

The Fish and Game Commission has in charge the maintenance of fishing and the preservation and control of natural fish life, together with the propagation of existing species and the introduction of new forms suitable to these conditions.

Plans for the salt water barrier provide for fishways so that fish may travel upstream. Fish will have free travel at such times as gates are opened and will no doubt pass through the ship locks at all times.

THE FUTURE OF THIS REGION

The future of the industrial region on Carquinez Straits and Suisun Bay depends upon the growth of population. California and other Pacific Coast states are growing more rapidly than any other section of the United States. There has been for many years a constant inflow of people from the East and an increase in population along the whole Pacific shore. The cities of Los Angeles, Oakland, San Francisco, Seattle and Portland have grown much more rapidly than is the average growth of American cities.

There is no such rapid development anywhere in the country except the industrial growth in the cities around the Great Lakes, where large manufacturing interests have centered. Aside from the City of Los Angeles, the rapid-growing cities of the country have been the industrial centers. In the case of Los Angeles, the industrial growth has been large but the great increase in population arises, to a large extent, from the attractive climate of this southern city.

Estimates of future population of the San Francisco Bay region have been made by several organizations in studies concerning public utility matters. The results of three such studies are shown in the table following. The first, Column I, is the estimate of the population of San Francisco and East Bay cities made in connection with studies of Trans-bay bridge; Column II is an estimate of the metropolitan district, taken as San Francisco, Alameda, Contra Costa and San Mateo counties, by the Telephone Company; and Column III the estimate of population of the East Bay Municipal Utility District by that organization. Each of these estimates indicates that the population will double in about 25 years.

ESTIMATES OF GROWTH OF POPULATION

YEAR	I. San Francisco and Trans-bay Cities	II. San Francisco Metropolitan District	III. East Bay Municipal Utility District
1910		686,873	229,404
1915	760,000		
1920	850,850	891,477	330,348
1925	976,000		
1930	1,100,000	1,329,200	501,000
1935	1,250,000		
1940	1,400,000	1,856,700	702,000
1945	1,577,000	2,172,000	
1950	1,750,000		948,000
1960			1,230,000

I. Estimate of population San Francisco and East Bay cities by Board of Engineers Trans-Bay Bridge, San Francisco, May, 1927.

II. Pacific Telephone & Telegraph Company—estimate by Robert W. Bachelor, includes San Francisco, Alameda, Contra Costa and San Mateo counties, April, 1925. Published in "San Francisco Business" April 17, 1925.

III. East Bay Municipal Utility District, Annual Report 1925, page 7.

Contra Costa County has grown at a more rapid rate than the Bay region as a whole. Census figures for the counties around the bay are shown in Table 4. Contra Costa's growth as compared with other bay counties is shown below:

Subdivision of State	Population 1920	Increase 1910 to 1920 Per Cent	Increase 1900 to 1920 Per Cent
State	3,426,861	44	130
Alameda County	344,171	40	164
Contra Costa	53,889	70	198
Marin	27,342	9	74
Napa	20,678	4	26
Sacramento	91,029	34	98
San Francisco	506,676	22	48
San Joaquin	79,905	58	125
San Mateo	36,781	38	204
Solano	40,602	47	69

Recent figures to show increase in population are shown in Table 5, in which are given the school enrollments for years 1915, 1921 and 1927. These are summarized below:

SCHOOL ENROLLMENT
BAY SHORE DISTRICTS—CONTRA COSTA COUNTY

	1915	1921	1927	Per Cent Increase 1915-21	Per Cent Increase 1915-27
Elementary Schools	5020	7262	9118	45	82
High Schools	510	1037	1586	103	210
Totals	5530	8299	10,704	50	94
Increase		50%	30%		

Population Growth and Its Cycles. California, in common with other states, is going through a readjustment of population distribution and kind of occupation. A comparatively few years ago the greater part of our population was engaged in agriculture; today manufacturing and mechanical industries occupy more people than agriculture. In 1920 agricultural pursuits (including forestry) occupied 18 per cent of the wage earners of the state as compared with 28½ per cent engaged in manufacturing and mechanical industries. Today the percentage engaged in manufacturing is higher and increasing all the time.

Students of population growth recognize cycles of growth which, for certain reasons, start slowly, grow rapidly and decline slowly. California has gone through two cycles of growth—mining and agricultural—and is now entering upon a third cycle—industrial.

The gold rush commencing in 1848 caused the first rapid increase of population after California became a part of the United States. As mining gradually declined in importance, agriculture attracted many people and a great increase in population occurred. Agriculture ceased to make rapid growth in 1912 and since that period manufacturing and mechanical trades have been the principal source of increase in population.

There are several reasons for present conditions:

1. Agriculture has been depressed since the deflation period of 1921. Costs are still high and the sale price of products has not entirely recovered. Profits have been low.

2. Land values in California are high. There is no more chance for cheap land. The incentive which caused many to enter agricultural pursuits in the great period of agricultural growth does not now exist.

3. Farming is more and more becoming purely mechanical; the same area of land can be farmed now with fewer men. This releases men for other occupations and reduces the number of men trained in farming operations—the potential buyers of farms.

4. Freight rates increased during the war and added greatly to cost of placing agricultural products in eastern market centers. At the same time the increase in freight has made it practical and necessary for many manufacturers to establish branches on the Pacific Coast.

5. Since 1900, hydroelectric power and long distance transmission of energy to manufacturing centers have been made practical and cheap, and dependable power for manufacturing has resulted.

6. California, since 1900, has become a large producer of oil. The cheap oil has encouraged manufacturing in many ways.

7. The Panama Canal and better shipping facilities have made raw materials

for manufacturing more easily available, and have made it easier to ship products of manufacture to other markets.

8. The climate of the coast region of California has become recognized as being well adapted to manufacturing. The cool weather, uniformity of seasons, freedom from freezing or destructive storms, have attracted workmen and capitalists.

The result of all this is that at present the growth of California lies around industrial centers. We are now living in an industrial age. The future of the state depends largely upon the rate and quality of this manufacturing and industrial growth.

This does not mean that there is to be expected a decline in agricultural activity. On the contrary the growth of cities and centers of industrial enterprises will stimulate the growth in agriculture. Markets for more farm produce will result from increases in industrial population, there will be a better market for the raw products of manufacture which originate on the farm and the improvements in transportation that will result from manufacturing will benefit agriculture. We may expect the growth in agriculture to continue, but at a rate lower than during the years prior to 1912.

Agricultural Extension Possible and to Be Expected. In the chapter in which the region lying tributary to the upper end of the bay and lower river is described, the statement is made as to the area of land which could be irrigated from fresh water basin above the proposed salt water barrier. These areas are as follows:

AREAS IRRIGABLE FROM FRESH WATER BASIN
ABOVE BARRIER

	Marsh	Upland	Total
San Pablo Barrier			
San Pablo Bay	51,000	48,000	99,000
Army Point Barrier			
Suisun Bay	70,000	93,000	163,000
Totals above San Pablo	121,000	141,000	262,000
Delta Region above mouth of river:			
San Joaquin	257,000	58,000	315,000
Sacramento	110,000	33,000	143,000
Grand Total	488,000	232,000	720,000
Of this area, that above Army Point is	437,000	184,000	621,000

Of this area, approximately 360,000 acres are irrigated in the delta region. The areas around Suisun Bay and on San Pablo Bay are surrounded by salt water for so much of the summer that pasture crops alone are grown to a considerable extent.

Following the history of growth of the country, it is reasonable to expect that all of the areas which can be irrigated from this fresh water basin will be irrigated and cultivated as rapidly as the population and increase in markets warrant. The region is close to markets, well supplied with transportation facilities, which will be both by rail and water, has a climate suitable to a great variety of crops, and it would be only natural that such areas would be put to use.

Industrial Growth to be Expected. There is no possible way of predicting what increase there will be in the industrial development except that it will be large and substantial in character. There are many basic industrial activities not represented in this part of the Pacific Coast—industries that will unquestionably settle in this region when a fresh water supply is assured—and there will be a continued and more rapid growth of the ones already on the ground.

Every large industrial region of the world has developed at points where fresh water is abundant and cheap, and where facilities for handling of raw products to factories and carrying the finished products to markets are well established, and the rates to markets are reasonable. San Francisco Bay, being in the geographical center of the Pacific Coast, is the natural point where large factories will locate. The fact that large cities are close at hand, that transportation facilities are established, that power is abundant and cheap where oil pipe lines bring oil from the fields further south, and that the climate is an unusually good one for a manufacturing business, are all important. If there is added to these essential conditions a large fresh water reservoir, there will be no more favorable location for manufacturing. It can be expected that the growth here will be as rapid as in any other part of the country and more rapid than has been true at any time in the past history of the state or Pacific Coast.

WATER REQUIREMENTS OF THE REGION

The present water requirements of the region are supplied from many sources. Richmond, on the upper end of San Pablo Bay, is within the East Bay Municipal Utility District, a public organization engaged in the construction of a water supply system from the Mokelumne River. It is to be expected that this district will purchase the distribution system of the East Bay Water Company now serving the territory, and that it will construct such additional facilities as may be required to supply industrial and domestic requirements of the territory. Water from this system will be costly. The charges of the East Bay Water Company average nearly 30 cents per 1,000 gallons. Little if any reduction in cost can be expected from the Utility District unless a part of the expense is raised as taxes.

The smaller towns, such as Martinez, Port Costa, Benicia, Bay Point, Antioch and Pittsburg, obtain water either from wells or by pumping from the river at fresh water times, or by small storage reservoirs filled during flood or fresh water season. In all of these towns water is high-priced (the average price of water from the Port Costa Water Company is about 27 cents per 1,000 gallons), usually of inferior quality at least some time of the year, and there is no great supply in sight to take care of rapid increase in growth of population. In fact the growth of the territory outside of the Utility District mentioned is to a large extent restricted by its water supply. The Utility District cannot serve the industrial plants on account of the high cost of water.

The construction of a salt water barrier will effectively remove this deterrent to growth, for it will place fresh water of good chemical quality alongside of all of these towns, and with the modern methods of filtration and purification the water will be suitable for domestic or any industrial use. The cost of pumping will be a small part of the cost of water from any other known source.

The industries now established between Oleum and Antioch, on both sides of the straits, use 10 million gallons daily and the use is increasing at the rate of a million gallons daily per year. Enlargements and extensions to these plants will probably increase this rate of growth.

Prediction as to the future is hazardous, as much depends upon whether or not a salt water barrier is built. This structure will greatly stimulate growth of present industries and will encourage the establishment of new ones. It is within the bounds of reason to expect 100 million gallons daily to be used by industries within the next 25 years.

Domestic Supply for Cities and Towns. Water for domestic purposes is higher priced in San Francisco and the East Bay cities than in any other large cities of America. This high price results from the difficulty of securing water in quantities sufficient to take care of the rapid growth of these communities. The same thing may be said of smaller cities along Carquinez Straits. Water for domestic use has been difficult to secure, the price is high, the quality is not good at all times. There is no known way by which small communities can satisfactorily grow unless the water supply is ample for the needs of their growing population.

As an example of this condition, the history of the Benicia Water Company may be cited. This company has made a careful investigation of the possibilities of securing water, has drilled wells for underground investigation, has considered storage possibilities in the hills back of the town, and has finally been required to use river water at such times as this water is available, and to supplement this supply with pumps. During much of the year the community is unable to supply water of a good quality without great difficulty.

On the south side of the straits the water supply for towns of Crockett, Martinez and surrounding territory is provided by the Port Costa Water Company, largely from wells in the neighborhood of Concord. Litigation has restricted the extent to which these wells can be utilized and this community will be faced with the very large expense of going to distant points for a water supply if the growth of the towns continues.

The town of Pittsburg is supplied from wells and, at seasons of the year when the water is fresh, from the San Joaquin River. The limit to the availability of underground waters is in sight and Pittsburg will be placed to great expense to secure a water supply if the growth continues to be as rapid as it has been in the past. Similar conditions prevail at Antioch, where protracted litigation called the attention of the state to the difficulties of this community carrying out its plan of pumping water from the river. Since 1920 Antioch has built a storage reservoir on the slopes to the south of the city, into which fresh water is pumped during the early summer, and stored and used in late summer. The result is that water is more costly and of poor quality for domestic purposes, largely on account of the taste of stored water in open reservoirs in bright sunlight.

The entire industrial areas along Suisun Bay and Carquinez Straits may be said to be restricted in growth on account of the fact that there is no easily obtainable supply of fresh water. The result has been a restricted rate of growth of population and an increase in cost of water to those who are already in the community.

The salt water barrier, to a large extent, will remove these difficulties. If the barrier is located at the San Pablo site, the entire area will be cared for. If it is placed at the Army Point site, the entire region upstream will be on a fresh water lake. The industrial area below the upper end of the straits can then be supplied from a relatively short pipe line heading above the barrier.

The reversal of flow, caused by tides at Sacramento, has endangered the cities' water supply by causing sewage to back upstream. The barrier will prevent this from occurring, as it will raise low water at Sacramento and prevent upstream flow.

SURVEY OF REGION AFFECTED BY SALT WATER

The region affected by salt water includes the area from the lower end of Carquinez Straits upstream to Isleton on the Sacramento River, Wakefield Landing on the San Joaquin, and Mansion House on Old River. It includes Carquinez Straits, Suisun Bay, and approximately one-half of the delta on the San Joaquin and Sacramento rivers. San Pablo Bay is of course affected but salt water is more nearly a natural condition in that body of water. Indirect effects are experienced in all parts of the watershed draining through Carquinez Straits and the Bay region and cities which have commerce with these industrial and agricultural areas. The problem, in fact, is one which interests all of California, for the prosperity of this industrial region and the prospective growth of this country in some measure affect the entire area engaged in agriculture or trade in this part of the Pacific Coast.

The region directly affected by the recent invasion of salt water includes the cities and towns of Oleum, Crockett, Port Costa, Martinez, Bay Point, Pittsburg and Antioch on the south side of the straits and Suisun Bay, and Vallejo and Benicia on the north side. Salt water extends as far upstream as Rio Vista.

The estimated population of these towns and outlying territory is in excess of 30,000.

Industries. The important industries located along the Straits af Carquinez and Suisun Bay are as follows:

INDUSTRIES

CARQUINEZ STRAITS

Left Bank:	*Town*
1—Union Oil Company Refining, casing and shipping petroleum products.	Oleum
2—Selby Smelting & Lead Company Branch of American Smelting & Refining Co. Smelting and refining non-ferrous metals.	Selby
3—California-Hawaiian Sugar Company Sugar refineries, largest in world, 5,000,000 lbs. a day.	Crockett
4—Port Costa Brick Company Makers of brick, etc.	Port Costa
5—Grain Warehouses Storing, cleaning, shipping—principally barley.	Port Costa
6—Petroleum Products Company Petroleum products.	Martinez
7—Mountain Copper Company Copper smelting and refining, fertilizers.	Martinez
8—Shell Oil Company Refining and shipping petroleum products.	Martinez
9—Southern Pacific Company Operating railroad and ferries.	——
Right Bank:	
10—Mare Island Navy Yard Repairs and construction of naval ships.	Vallejo
11—Sperry Flour Company Milling of wheat and other grains.	Vallejo
12—Benicia Barracks and Arsenal U. S. Army stores.	Benicia
13—Kullman-Salz Tannery Leather.	Benicia

SUISUN BAY

Left Bank: *Town*

1—Associated Oil Company............Avon
Refining and packing for shipment petroleum products.

2—Coos Bay Lumber Company............Bay Point
Manufacturing and wholesale lumber; large storage 75,000,000 F. B. M.

3—Pacific Coast Shipbuilding Company............Bay Point
Ship building—steel and iron products.

4—General Chemical Company............Nichols
Large manufacturers of heavy chemicals.

5—San Francisco & Sacramento Railroad Company............——

Most Important From Pittsburg to Antioch:

6—Booth Cannery Company............Pittsburg
Canners of fish, fruit and vegetables.

7—Hickmott Cannery Company............Pittsburg
Fish, fruit and vegetables.

8—Paraffine Company............Pittsburg
Paper board.

9—Great Western Electro Chemical Company............Pittsburg
Diversified heavy chemicals.

10—Redwood Manufacturing Company............Pittsburg
Redwood pipes and tanks and other products of redwood.

11—Columbia Steel Company............Pittsburg
Steel products.

12—Pioneer Rubber Company............Pittsburg
General rubber products.

13—H. W. Johns-Manville Company............Pittsburg
Magnesium and asbestos building specialties.

14—Santa Fe Railroad Company............——

Industries in Richmond and along the shores of San Pablo Bay are as follows:

Left Bank—Below Carquinez Straits: *Town*

1—California Cap Company............Stege
Caps for detonating high explosives.

2—Stauffer Chemical Company............Stege
Bulk chemicals from crude ores.

3—Metropolitan Match Company............Stege
Matches.

4—Pullman Manufacturing Company............Richmond
General shops, repairs and construction of cars.

5—Santa Fe Railroad Company............Richmond
General shops, repairs and construction of cars.

6—Standard Sanitary Mfg. Company............Richmond
Porcelain and enamel plumbing fixtures.
Distribution of other porcelain and enamel ware.

7—Certainteed Products Company............Richmond
Roofing and paints.

8—Republic Steel Package Company............Richmond
Metal containers, principally drums for oil and gasoline.

9—Standard Oil Company..........Richmond Point
Refining and shipping of petroleum products.
10—Philippine Refining Corporation..........Richmond Point
Refining copra and other vegetable oils.
11—California Wine Association..........Winehaven, Richmond Point
Formerly largest winery in world; industrial alcohol.
12—Giant Powder Company..........Giant
Dynamite and other explosives.
13—Hercules Powder Company..........Hercules
Dynamite, T.N.T. and other explosives.

The majority of these establishments along the Straits and Suisun Bay produce large outputs of material and are in the class ordinarily called "heavy" industries. They produce products essential to modern life both in peace and war times. Steel, iron, petroleum products of all kinds, chemicals, fertilizers, powder and fuse, leather, brick and tile, flour and feed, lumber and lumber products, ships and boats, sugar, fish and canned goods are produced in very large quantities.

A survey of the plants between Oleum and Antioch shows an annual production in 1927 of products valued at $250,000,000. The increase in annual output is large and the growth has been regular. The first large factory to establish in this territory was the Sugar Company in 1907. The period up to 1920 was an active one in growth, but since salt water troubles became so prominent only one new plant of large size has located here.

Freight in and out of this district by rail and water, directly attributable to these plants, approximated 14,000,000 tons in 1927. Three railroad systems serve the territory. Vessels, both river and ocean-going, handle much freight. Oil pipe lines from the fields in the San Joaquin Valley deliver oil to the refineries, to large tank farms for storage, and to vessels.

Expenditure for electric power by these industries was $800,000 in 1927. Electric power is furnished by the Pacific Gas and Electric Company and the Great Western Power Company. The use of power increases every year. Power rates are the same as in the Bay cities.

In 1927 these plants employed on an average of 8500 persons, the annual payroll amounting to $15,000,000. Comparatively little seasonal employment is found—most of the factories run fairly constantly through the year. The population dependent upon the factories, using a ratio of 4 to 1, is 34,000.

The industrial territory on San Pablo Bay below Oleum, in Contra Costa County, is nearly as large as the district described above. If the entire waterfront area in Contra Costa County is considered, we find the annual products to be $515,000,000; the number of employees to be 17,000; the annual payroll $29,000,000.

The industries between Oleum and Antioch now use 10,000,000 gallons of water a day. The annual increase is 10 per cent or a million gallons a day. All of this water is pumped from tide water level when there is fresh water in the stream, but some of the factories use wells during the salt water period. Draft upon the ground water is causing a change in the quality of many wells by drawing in salt water. There is a definite limit to the amount of water which may be drawn from underground sources, and it is apparent that this limit has been reached.

Factories engaged in the production of large quantities of "heavy" products ordinarily locate where fresh water is abundant and can be had at the cost of pumping. New plants seldom locate under any other conditions and when there is a choice between localities, the one where water is abundant and cheap is selected, providing the other factors which control locations are the same. There is only one place on the coast of California where such conditions existed in the past—the upper bay and lower river country. Industries now located there expected to obtain water by pumping direct from tide levels, and the change brought about by the invasion of salt water has added to expense of operation and has discouraged increase in plants which involve increased use of water.

There is great need of restoration of the favorable conditions of fresh water which formerly existed in this region. New industrial establishments will be attracted by abundant fresh water. If California does not provide such facilities, northern cities will offer greater inducements and many industries will locate Pacific Coast branches in these northern cities. There are in these other states large areas of land where pure, fresh water is abundant and may be had for the cost of pumping from permanent lakes or streams.

Rates for water in California cities are higher than in the north, as is shown in the following table:

COST OF 500,000 GALLONS OF WATER PER MONTH

San Francisco	$157.56
Oakland	161.71
Los Angeles	72.16
Stockton	54.50
Portland	44.11
Seattle	32.94

The recent disaster to Los Angeles' St. Francis Dam will probably result in an increase in water rates in that city. Proposals have been made to increase the base rate from 5 cents per 100 cubic feet to 18 cents. If this proposal is carried into effect, the rate for 500,000 gallons in the above table will be nearly $120.

Hardness of water is another factor in which northern cities have an advantage over the public supplies in California cities. Hardness is undesirable in water for either domestic or industrial uses—in some classes of industries hard water must be treated before use.

The comparison below will show the relative hardness of public water supplies of Pacific Coast cities:

HARDNESS IN CITY WATER SUPPLIES

Hardness as Calcium Carbonate, Parts Per Million.

(From Water Supply Paper 496)

	Maximum	Minimum	Average	
San Francisco	166	83		
Oakland			181	Reservoir and wells
Stockton			560	Wells.
Sacramento			60	River.
Los Angeles			163	Owens River.
			251	Los Angeles River.
Portland, Oregon	22	6	9	
Seattle, Washington	33	14	23	

The supply of Sacramento approximates the hardness of water that will be retained above a salt water barrier. The quality of water reservoired above the barrier will be better than any other city supply in California shown.

Hardness may be partly removed from water in modern purification plants. At Columbus, Ohio, water with average hardness of 272 parts per million was reduced to 97 parts at a cost of treatment of 2.45 cents per 1,000 gallons. (Proceedings of American Society of Civil Engineers, February, 1928.)

One of the needs of California today is a fresh water reservoir around which factories can be located with assurance of a permanent supply of pure water. Probably no single accomplishment in the construction program now under discussion will do more toward the general progress of the state. More factories mean greater population and more local markets for agricultural produce and amelioration of the general level of prosperity of the state.

A salt water barrier at San Pablo or Army Point will remove the obstacle now deterring the location of new industries in this region. It will remove the cause of added expense to the present plants and will encourage their more rapid growth.

Besides great quantities of water, large industries require cheap power, efficient transportation facilities, both by rail and water, and a good climate attractive to labor. The lower river and upper bay region lack only water. The salt water barrier will supply this single deficiency. If the barrier is not built, California, without doubt, will lose many important factories.

Shipping Interests. San Francisco Bay and the rivers drained through Carquinez Strait are used by boats engaged in river and bay traffic as well as ocean-going vessels. At the present time there is a large amount of river and bay traffic between Stockton, Sacramento and numerous delta landings and the cities around the bay. During parts of the year the river traffic extends beyond Sacramento and upstream from Stockton. Ocean-going vessels land at Carquinez Straits' points, Bay Point, Pittsburg and intermediate ports. Traffic by water is on the increase.

Tables 6, 7 and 8, in this report, give the tonnage and value of freight carried by water.

Projects for the improvement of navigation above Carquinez Strait have been approved by Congress and the work of acquiring rights-of-way in preparation for dredging is nearly completed. Two projects have been approved: First, the dredging of the channel through Suisun Bay to provide 26 feet of water for navigation purposes through this bay, and second, the Stockton deep channel which will provide 26 feet of water to Stockton.

Projects for deepening and regulating water depths for Sacramento River navigation are under consideration. A system of dams for controlling levels at low flow has been proposed, though not yet adopted by act of Congress. The present project provides 7 feet of water to Sacramento, 4 feet to Colusa, and with provision for 3 feet as far upstream as Chico Landing. Practical navigation upon the upper San Joaquin is now limited to the head of tide water, though if the project of the state for canalization of the San Joaquin under the "Coordinated Plan for Development of Water Resources" is carried out, navigation will be practical to points far above any places recently reached by boats.

Water transportation is available to all of the islands and reclaimed lands in the delta region, and nearly all of the agricultural produce grown in this country is shipped to market by boat.

Tides, currents and salt water phenomena in the upper bay and lower river region are important to shipping interests for several reasons: First and foremost is the fact that the presence of salt water has retarded growth and, if continued, will decrease the agricultural productivity of this region. Second, and no less important to shipping interests, is the fact that the industrial region along Suisun Bay and Carquinez Strait is held back in its natural growth by the menace of salt water. The water-carried tonnage in and out of this industrial area is large and is on the increase. The completion of the deep water channel will give a stimulus to commerce by water.

The natural result of a salt water barrier would be to increase very rapidly the industrial territory and there would be, in consequence, much more freight to be moved, a larger population to be served, and a tremendous increase in shipping. The effect will be noticeable on both bay and river boats and upon ocean-going traffic.

The plans for a salt water barrier provide for locks so that vessels may have uninterrupted access to the fresh water basin above the barrier. As discussed later, the Young report considers thoroughly the shipping business and the plans provide for locks of at least two sizes—one for small vessels and the second for large vessels. Locks are designed to provide for future increase in traffic, both in size and amount of traffic and depth of drafts.

Tides and currents now cause a loss of time to the shipping interests and necessitate special provisions and greater care in the handling of vessels, particularly in the rapid currents in the Carquinez Strait region. A barrier will provide for a constant water level above the structure except during periods of flood, which will reduce the currents to one direction only, and that downstream, and will facilitate the movement of vessels by reducing the time now consumed by bucking adverse currents. The ability to dock without currents is an additional value to ships.

It is generally agreed by navigation interests that there is some benefit in sea-going vessels docking in fresh water, in the destruction of growths of salt water which cling to the bottoms of the vessels and reduce their speed. Ocean-going shipping entering the fresh water basin above the barrier will have the benefit of this condition.

Sediment carried by the river waters into Suisun and San Pablo Bays adds to the difficulties of navigation and causes annual expenses in its removal. Debris from hydraulic mining is one of the principal sources of such hindrances to navigation. The rivers which enter Suisun Bay bring to salt water each year a portion of the debris deposited in stream channels in years of unrestricted mining. From the best information available, it is probable that the peak of movement of debris has passed out of the rivers and is moving through Suisun and San Pablo bays en route to the ocean.

What effect the salt water barrier will have on the movement is important from the standpoint of navigation interests. Studies which furnish information on the problem have been made several times in the past twenty-five years. The brief statement below discusses these investigations.

In 1906 the writer, then in the employ of the United States Reclamation Service, made a study of the sediment carried by many important streams in the West. The results are in part published in Water Supply Papers Nos. 274 and 237. The investigation had in part the determination of the amount of sediment carried in streams that might be lodged in storage reservoirs. At the time this study was undertaken, experimental work was carried on to determine methods of field and laboratory work. Sampling apparatus was designed and tested to permit the collection of samples at any depth. The use of this apparatus indicated that the problem resolved itself into two phases—suspended silt and sand rolled along the bottom. The suspended silt was found to be very fine and to remain in suspension a long time. It is moved as the water moves and in the tidal portions of the stream remains in suspension during the tidal movements.

Samples collected daily during 1906, a 125 per cent runoff year with heavy floods, gave an average silt content (weighted for flow) of 64.5 parts per million by weight or, for silt weighing 80 pounds per cubic foot, 0.081 cubic yards per acre foot. In 1908, a 67 per cent runoff year, the average silt content was 85 parts per million by weight or 0.106 cubic yards per acre foot. The total suspended silt in 1906 was 2,300,000 cubic yards; in 1908 it was 1,550,000 cubic yards.

The greater part of this material continues in suspension until the bay is reached, where slow currents permit a part of it to drop to the bottom. Flocculation from salt water to some extent encourages the deposition.

A salt water barrier will have the effect of improving conditions as affected by the deposition of the suspended silt. Fresh water above the barrier will remove the effect of salt water flocculation above the structure and there will be a greater tendency for the silt to be carried lower than under present conditions. As it is now, the flocculation commences in Suisun Bay or at the first point where fresh water and salt water mix. Eighty per cent of the sediment is carried in the flood months, at times when the barrier gates will be opened and the current above the barrier is highest. In these periods the tendency will be for sediment to be carried through the barrier with less deposition in Suisun Bay than under natural conditions.

Below the barrier, where fresh and salt water mix, there will be the same tendency for deposition and flocculation that now exists, the only important difference being the decreased tidal movements due to the barrier. There is no reason to expect any great change in conditions from those now found. Sediment moves to a large extent in flood periods, so that any accumulations which are deposited in low flow periods or in years of light runoff are swept away in flood years. Fine sediment which enters the streams probably will not greatly change in amount in future years, as the fine materials originating in former hydraulic mining operations are on the decrease. Storage reservoirs on the headwaters will tend to trap sediment and further reduce the load that will arrive at tide waters. On the whole, the barrier will probably benefit rather than harm the navigation interests so far as it affects suspended silt.

Sand and coarse debris rolled along the stream bottom make up an important but unknown part of the total stream load of sediment. Estimates by the writer, made in 1905, indicated that the equivalent of from 10 to 20 per cent of the suspended load was carried along the bottom. In a recent study of silt in the Colorado River (U. S. Dept. of Agriculture Technical Bulletin No. 67), the estimate is made that in that stream 80 per cent of the silt is in suspension and 20 per cent carried as bed load. Though the actual quantity may be in doubt, there is no question but that the stream bed at Sacramento and below has been lowering in recent years—an indication that the burden of debris from the old hydraulic mines is decreasing.

Sand and gravel along the stream bed do not move at ordinary flows but only when the stream is in flood. The barrier, therefore, will have little or no retarding effect upon the movement of sediment carried along the bed, for in times of flood the flow in all practical consideration will be unobstructed and the downstream velocity will be practically the same as without the barrier. The bed load will move as it now does, or at least will move as it would do if the barrier were not present.

Structures in Water. The teredo and other varieties of marine life which destroy wood have been noticeably active in San Francisco Bay and adjoining waters since about 1914. Prior to that time all wharves, docks and other structures in water in the upper bay country were built of untreated piles and the lives of the structures were very long. About 1914 the teredo became active and in the dry years which followed 1917 practically all wood structures in water below Antioch were destroyed. The Marine Piling Committee estimates that $25,000,000 damage was done in this period. Of this sum several million dollars represent damages in the territory upstream from Richmond. Here the invasion of the teredo is encouraged on account of the encroachment of salt water. In earlier periods fresh water was present each year long enough to prevent wood-destroying animals establishing themselves.

Many of these structures have not yet been replaced. Those which have been replaced have been largely of creosote or other treated piling at an additional cost over untreated timber. No form of treatment gives permanent protection but reduces the activities of boring animals and lengthens the life of timber.

The cost of structures built of timber is, therefore, greatly increased over what it was prior to the invasion of salt water in the upper bay. Where concrete is used an additional increase in cost also occurs, for concrete to be placed in sea water has to be of much better quality than concrete suitable for fresh water conditions. The ordinary mix of concrete for sea water contains approximately two-thirds of a barrel of cement per cubic yard in excess of that considered good quality for fresh water conditions. On this account alone concrete work costs at least $2.00 a yard more, due to the salt water invasion.

Under the present conditions, all future structures to be erected in this region must be built to resist teredo and other boring animals and salt water. The increased cost of wharves, docks, bulkheads, and all similar structures in water, will approximate 20 to 25 per cent more than if fresh water were present. The construction of a barrier to prevent the encroachment of salt water will greatly simplify such construction work and will reduce the cost under present conditions.

Corrosion of Pumps, Piping and Equipment from Salt Water. Steel and iron are corroded more rapidly in brackish or salt water than in fresh water. Experiments indicate that unpainted steel or iron lasts from two to ten times as long in fresh water as in brackish or salt water. This means that all gates, pipes, pumps and other parts of structures in water, or in industrial establishments where water is used, must be painted frequently or they will corrode more rapidly, require more frequent replacement, and cost more to operate than where fresh water is present. In the large industries, such as oil refineries, steel mills and plants where large amounts of cooling water are used, this becomes a very important factor.

Accurate estimates of the cost of salt water due to corrosion alone are difficult to make. Mr. C. W. Schedler, of the Great Western Electro Chemical Company of Pittsburg, California, estimates that there is a minimum of three million dollars' worth of equipment located in the plants between Crockett and Antioch being seriously depreciated by the presence of salt water. The normal life of this equipment is twenty years, or a depreciation of $150,000 a year. Mr. Schedler estimates that the salt water conditions of 1924 caused a depreciation twice as fast as ordinarily. The loss between Crockett and Antioch in that year is a cash loss of $150,000.

Conditions nearly as bad as 1924, so far as these industries are concerned, occurred in 1920 and again in 1926, and in each of the years between there is some increase in corrosion from salt water. Conditions in the future offer little promise of improvement, and the probability is that unless a barrier is constructed the present industrial plants alone, without consideration of future extensions or new plants, will suffer an annual loss from salt water in excess of that experienced in the past.

Estimates by the writer in the territory from Oleum to Antioch, on both sides of the channel, indicate a loss from salt water corrosion in excess of that made by Mr. Schedler. The writer is of the opinion that the average annual loss approximates $300,000 a year in the plants now operating.

Railroads. The natural and most feasible direction of travel north to south is across Carquinez Strait for both vehicular and rail traffic. At the present time all railroad transportation is handled by boats. Four lines of boats carry freight and passengers across this waterway. A year ago the first bridge was built—that across Carquinez Strait—for vehicular traffic only.

The Southern Pacific Company, the greatest railroad system in California, has studied a plan of bridging Carquinez Strait for many years. It is understood that a more active study of this problem is now going on than in any time in the past, and that prospects are good for the railroad to carry out such a development.

The San Francisco-Sacramento Railroad, which crosses the channel near the upper end of Suisun Bay, at one time acquired a permit to build a bridge at this point. The traffic carried by the company did not warrant such a heavy expenditure at that time, but recently the control of this road has been acquired by the Western Pacific Railroad Company, and it is likely that a large development of this transportation company will take place in the near future.

Any barrier built to hold back tide water can be easily arranged to act as a bridge for rail and vehicular traffic. In the Young report, a part of which is quoted later, estimates of the cost of providing such a barrier with a bridge are given.

Two applications have been recently filed with the County Board of Supervisors of Contra Costa County for a bridge permit across the bay region in the neighborhood of Richmond, the estimated costs being from $9,000,000 to nearly $20,000,000.

Should the barrier be built at San Pablo Point, it can serve there all present and probably future transportation needs. A barrier in Carquinez Straits, either at Army Point or Dillon Point, will be available for rail transportation and when the present bridge facilities are outgrown it may be used for vehicular traffic.

Mr. Herbert Benjamin, of the Southern Pacific Company, stated before the Joint Legislative Committee on April 16, 1928, that his company had made plans for a bridge between Bulls Head and Army Point, and that the cost, including approaches, was estimated to be less than $10,000,000. The bridge was designed to give clearance of 70 feet. Application for permit had not been formally made to the War Department.

The site selected for this bridge is one of the sites investigated by Young, and any bridge built for the railroad would prevent its use as a site for a salt water barrier. It is highly advisable that full consideration be given of the barrier problem before any bridge permit is let for this location. The barrier can be made to serve as a bridge and the advantages of the double use are apparent. If the barrier is built to accommodate both rail and vehicular traffic and a proper allowance made for this service, the net cost to other interests can be lowered. This phase of the question is discussed later in this report.

Ferries. The ferry from Benicia to Port Costa, now operated to care for vehicles, could be replaced by a barrier at Army Point or Dillon Point. The ferry now operating from Richmond to Point San Quentin could readily be replaced by a barrier at San Pablo Point. This slow method of crossing the water barrier can be replaced by a modern bridge, with little delay in traffic and with cost not greater than the present ferry charges. The automobile registration in California is on the increase and travel across the straits will be greatly stimulated by a bridge. There is no certain method of determining this quantity.

Local Shipping. The tonnage and value of local shipping on the Sacramento and San Joaquin rivers are given in attached tables. It will be seen that there has been a nearly constant increase in freight, except during the period of, and following, the World War. At present 2,100,000 tons of a value of $140,000,000 are carried yearly.

The increase in shipping which will follow the construction of a barrier against salt water will benefit local shipping. As shown elsewhere, the advantages of the barrier will offset the disadvantages, and on the whole greatly benefit shipping.

Ocean-borne Traffic. Ocean-borne traffic is varied, though lumber and petroleum products make up the greater part of the business. The tables attached show the volume of business in Suisun Bay to be about 2½ million tons, valued at over $40,000,000; for Carquinez Straits 4 to 5 million tons valued at $100,000,000 to $150,000,000; San Pablo Bay 4 million tons valued at over $60,000,000.

Increases in ocean-borne traffic will follow the building of a barrier and completion of a deep water channel to Stockton. The stimulation to industrial production will greatly increase traffic for all classes of vessels. Ocean shipping will benefit by the ability to dock in fresh water without the menace now caused by tidal currents. Fresh water tends to cleanse ocean vessels of growths which retard movement.

The menace to shipping in passing through locks is so small that no additional insurance is charged to vessels which use locks. The safeguards to navigation, now provided around locks, greatly reduce the danger in using them. Periods of fog are the times of greatest difficulty. The removal of ferry traffic across the straits at Benicia will probably offset the dangers due to navigating through locks in foggy weather.

SOLUTIONS OF THE SALT WATER PROBLEM

Several solutions of the salt water problems may be suggested:

1. Salt water barrier.
2. Storage and release.
3. Fresh water brought in by conduits or pipes.

The first is the only complete and the most satisfactory method of solving the problem. The Young report best describes the barrier and its effects upon the territory.

The Young Report. Mr. Walker R. Young, Construction Engineer, U. S. Bureau of Reclamation, has written a "Report on Salt Water Barrier—California, Below the Confluence of Sacramento and San Joaquin Rivers." This report is dated August 27, 1927, and was made by the U. S. Bureau of Reclamation in cooperation with the California State Department of Public Works, Division of Engineering and Irrigation, and Sacramento Development Association.

The report consists of a volume of 405 pages of discussion and descriptive matter, a volume of 592 pages of exhibits and tabulations, a portfolio volume of drawings and diagrams, and three volumes giving records of borings at various sites. The work described in these volumes extended over a period in excess of three years, or from January, 1924, to the date of completion.

A large amount of field work was done as a basis for office studies. The investigations include all problems that affect the construction or operation of the structure.

In his report Mr. Young describes in detail the various investigations he has made concerning the salt water problem. He presents sixteen preliminary designs and estimates with three alternatives "in order that they may be readily available in the economic study which is considered necessary in the final determination of the feasibility of the barrier." He made "no attempt to study the economic aspect of the problem other than to enumerate the advantages and disadvantages, as such a study was not considered within the scope of this (his) report." The report, therefore, is an engineering study of the barrier so far as concerns its physical feasibility.

The report determines what kind of a barrier should be built to accomplish its purpose, and presents a large amount of data to show its bearing upon various activities which will be affected by it. Four sites were investigated and the merits and objections to each are set forth in detail, but no final recommendation as to a site is made.

The following quotation from this report gives in condensed form the essentials included therein:

"SUMMARY OF RESULTS

"*General.* The studies made lead to the conclusion that it is physically feasible to construct a salt water barrier at any one of the sites investigated, but at great expense; and that it will be effective in controlling the salinity of the reservoir impounded above it. Not only will it protect the delta and industrial plants along the shores of the bays, but its construction will result in the conservation of a large part of the fresh water required to act as a natural barrier against invasion of water under present conditions.

"Without the barrier, salinity conditions will become more acute unless mountain storage is provided to be released during periods of low river discharge to act as a natural barrier against invasion of salt water. The amount estimated as necessary to act as a natural barrier was in excess of the flow in the Sacramento River above Red Bluff in 1924, and Red Bluff is located above the points of diversion of water used in irrigating the Sacramento Valley.

"The sites selected for development by drilling are considered geologically satisfactory for the type of structure proposed. Although preliminary designs and estimates are presented for four sites, there are only two general plans involved. A barrier, if constructed at the Army Point, Benicia, or Dillon Point site, would create a body of fresh water in Suisun Bay and in the delta channels, while a barrier at the Point San Pablo site would include San Pablo Bay as well.

"*Type of Dam Proposed.* The type of structure to which principal consideration is given is one in which the ship locks and flood gates are located at one side upon rock foundations, the closure of the present waterway being effected by means of an earth and rock fill dam to be brought up to its designed height after completion of the ship locks and flood gate structure. In another type studied the flood gates form the closure between concrete piers sunk to bed rock foundations in the present waterway by the open caisson method. Both types have been designed with and without provision for carrying a railroad and highway.

"The passage of floods is probably the most important problem since it involves the safety of the delta levee system. It would be desirable, if practicable, to provide gate area equivalent to, or slightly in excess of, the present waterway area in order that conditions of flow might remain unchanged, but the accomplishment of this plan would be very costly, if not altogether infeasible.

"In the design of the structure, advantage is taken of the difference in the elevation of water surface which it is possible to create above and below the barrier to discharge flood water. On account of the fluctuating head, resulting from tides on the downstream side, the discharge through the flood gates will vary from a maximum at low tide to a minimum at high tide. The reservoir above the barrier, therefore, will function as a basin in which the river discharge in excess of the flow through the flood gates at high tide is stored to be discharged at a rate in excess of the river discharge during low tide.

"The flood gates are of the Stoney roller type with sills depressed to 50 or 70 feet below sea level in order better to control the salinity of the water behind the barrier as explained in Chapter IX. In operation, the gates would be raised clear of the water surface as required to allow free passage of the floods. As the flood receded the gates would be lowered, one at a time, as necessary to maintain the water surface above the barrier at any predetermined elevation.

"The requirements for passing vessels through the barrier is an important consideration irrespective of where it might be located, but particularly, if located below Mare Island Navy Yard. In the designs proposed, ship locks have been provided in number to care for considerable growth in water-borne commerce, and in size to pass the largest ships likely to navigate the waters above the barrier.

"In some of the designs for the Army Point site, the ship locks would be constructed away from the flood gates, which, of course, would be advantageous for shipping during the passage of great floods from the rivers, but these are rare and considerable study would be required before it could be determined whether the advantage thus gained would offset the advantage of having the large salt water sump adjacent to the ship locks where the salt water entering the fresh water reservoir through the locks could be caught and returned to the salt water side. It is possible that the design with the ship locks and flood gates separated would be even more efficient in controlling salinity, but this is doubtful. The plan at the Army Point site in which the structures are separated interferes least with the plant of the Mountain Copper Company and results in economy otherwise.

"In the designs including a railroad and highway bridge across the locks these have been placed at an elevation to permit a large proportion of vessels using the locks to pass underneath without opening or lifting the bridges. In one design at the Dillon Point site, the clearance is made sufficient to pass