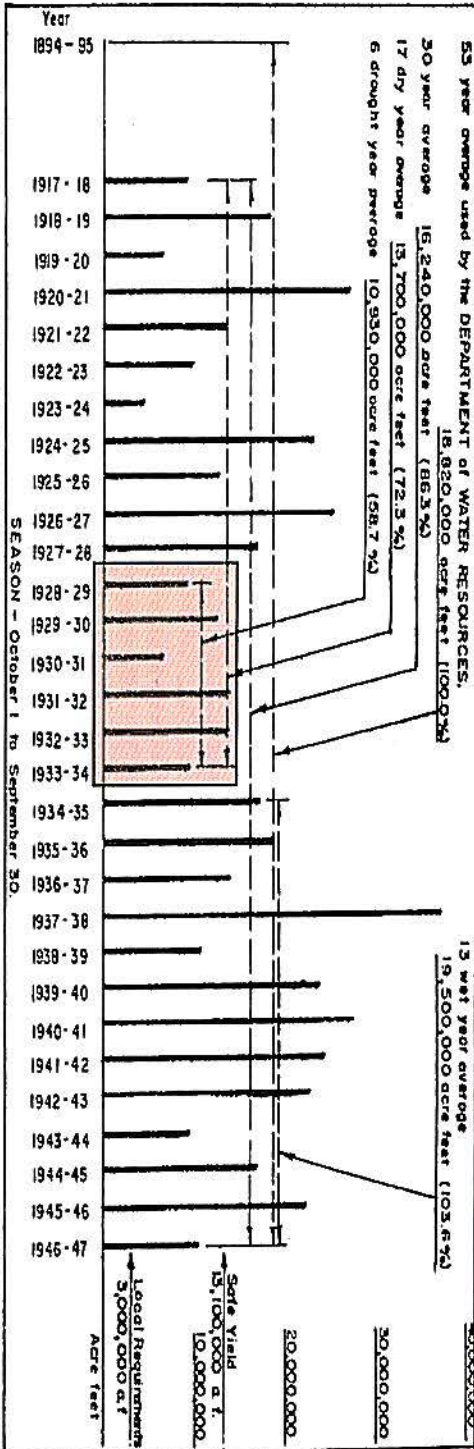


WEBER FOUNDATION STUDIES

ESTIMATED SEASONAL NATURAL RUNOFF
Klamath, Eel, Van Duzen, Mad, and Russian Rivers

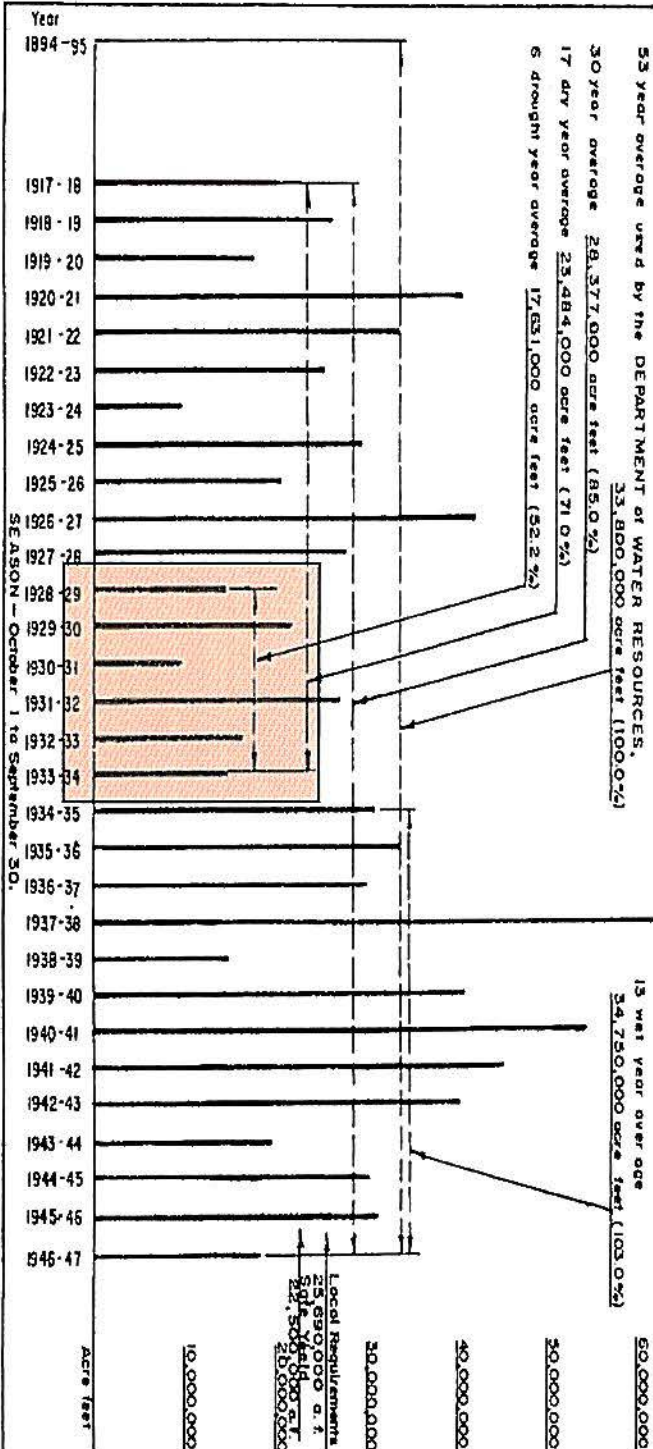
NORTH COAST AREA
1917-18 to 1946-47



Surplus
 7,930,000 AF/YR

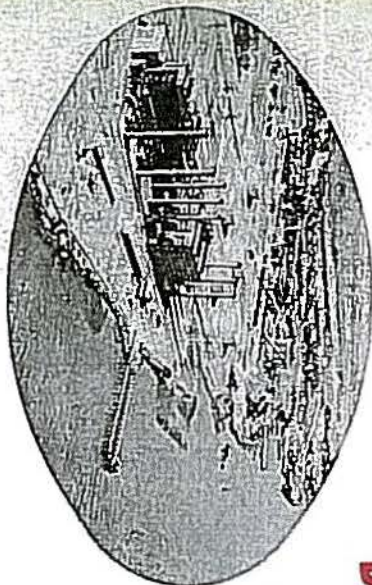
ESTIMATED SEASONAL NATURAL RUNOFF

CENTRAL VALLEY
1917-18 to 1946-47



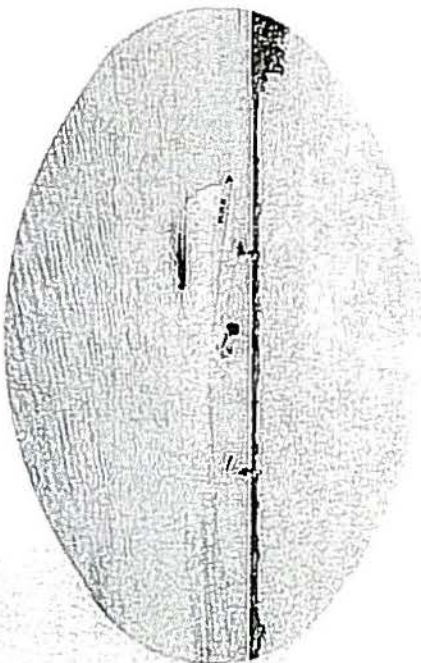
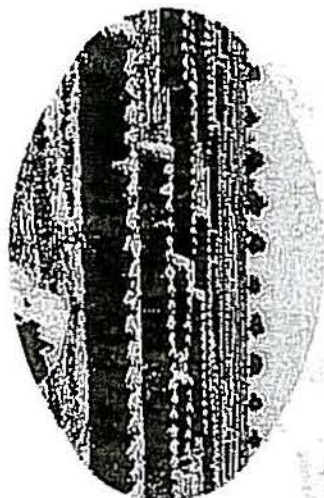
SHORTAGE
 8,049,000 AF/YR

Preliminary Edition



Bulletin No. 76

DELTA WATER FACILITIES



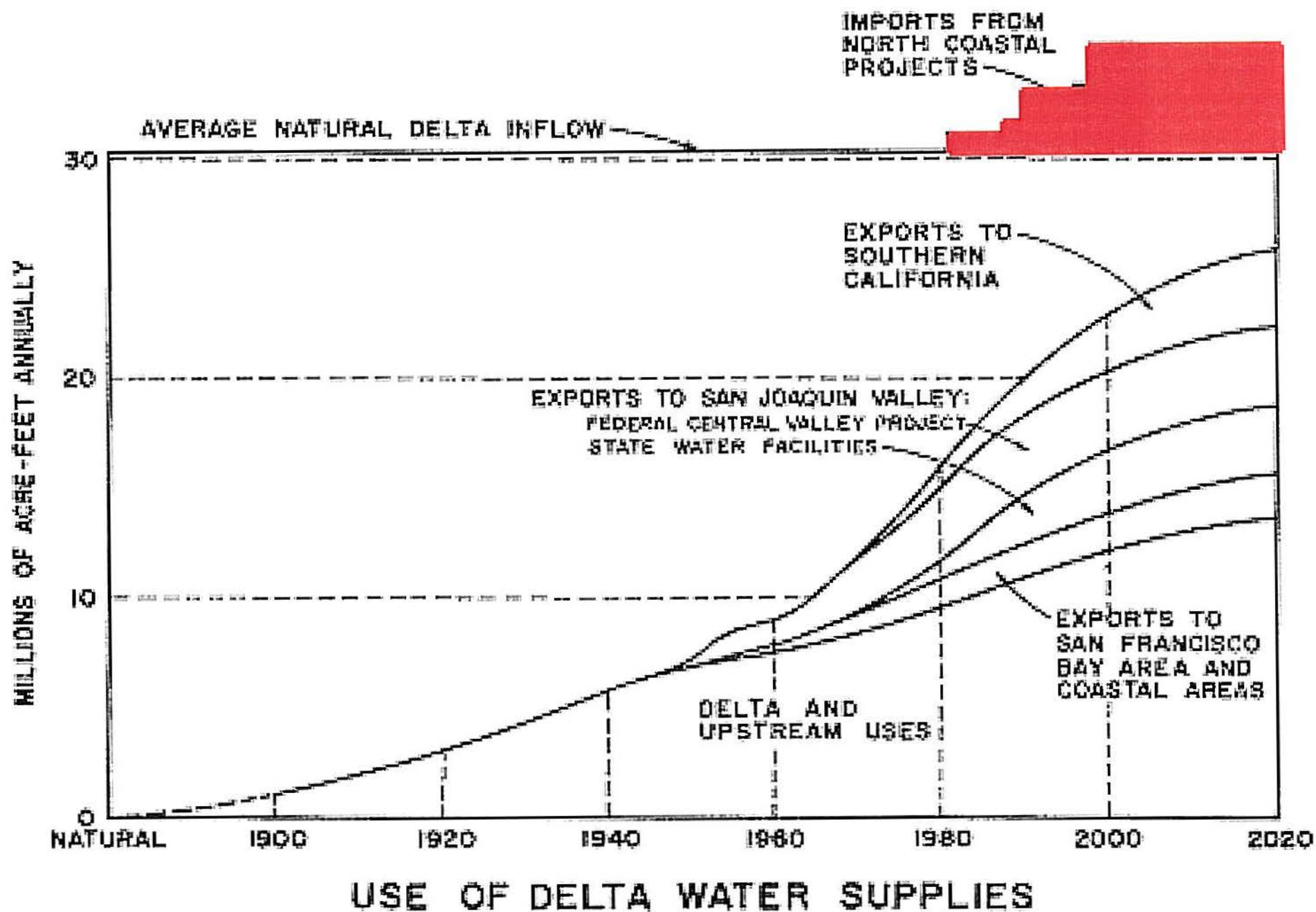
John

EDMUND G. BROWN
Governor
State of California



December, 1960

HARVEY O. BANKS
Director
Department of Water Resources



Historical Freshwater & Salinity Conditions

in the Western Sacramento - San Joaquin Delta & Suisun Bay

REPORT HIGHLIGHTS

**Sacramento -
San Joaquin Delta**

Suisun Bay

San Pablo Bay

**San
Francisco**

Pacific Ocean



0 2 4 8 12 Miles



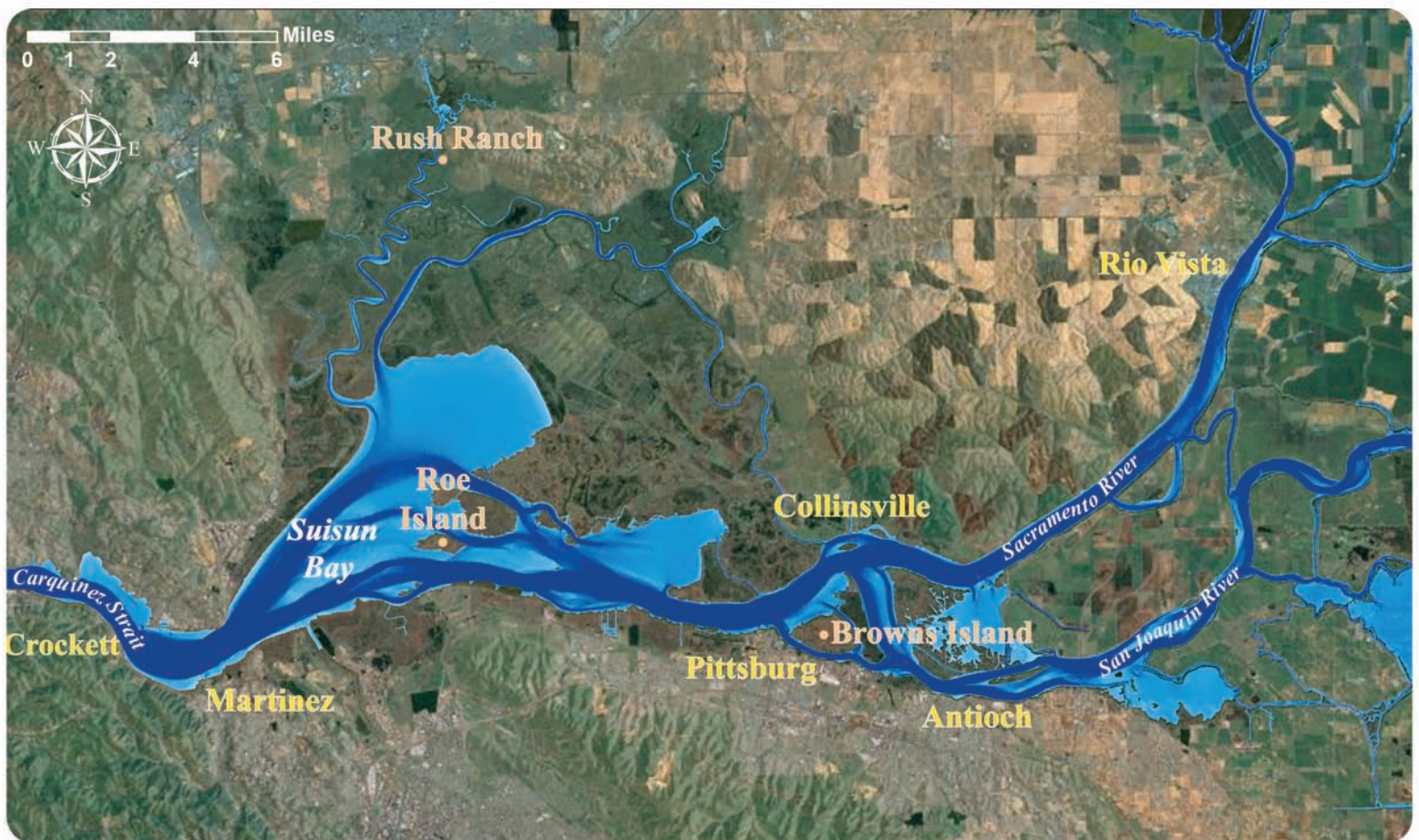
**CONTRA COSTA
WATER DISTRICT
WATER RESOURCES**

DECEMBER 2009

This document contains the highlights of Contra Costa Water District's technical review "Historical Freshwater and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay".

For references and data sources, please review the full report available on CCWD's website at www.ccwater.com/salt.asp

The map on this page shows key locations mentioned in this document.



Acknowledgments

CCWD would like to thank the City of Antioch for their contribution towards funding a technical review of CCWD's draft report "Trends in Hydrology and Salinity in Suisun Bay and the Western Delta" (June 2007); their review substantially improved the work and led to the final report "Historical Freshwater and Salinity Conditions in the Western Sacramento San-Joaquin Delta and Suisun Bay". CCWD is grateful to the many reviewers, including Richard Denton, Matthew Emrick, Gopi Goteti, Phil Harrington, Susan Paulsen, David Pene, Mat Rogers, and Peter Vorster. We also thank the following for sharing their data and analysis: Roger Byrne, Chris Enright, Spreck Rosekrans, and Scott Starratt.

Establishing the Historical Baseline

The watershed of the Sacramento – San Joaquin Delta (Delta) provides drinking water to more than 23 million Californians as well as irrigation water to millions of acres of agriculture in the Central Valley. The Delta itself is a complex estuarine ecosystem, with populations of many native species now in serious decline. The Delta estuary as we know it began to form only 6,000 years ago, following the end of the last ice age. Because the estuary is connected to the Pacific Ocean through San Francisco Bay, seawater intrusion causes the salinity of Suisun Bay and the Delta to vary depending on hydrological conditions. Seawater intrusion into the Delta affects estuarine species as well as drinking water and irrigation water supplies.

Successful ecological restoration of the Delta will depend upon knowledge of the conditions under which native species evolved. Contra Costa Water District’s report “Historical Freshwater and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay” provides a review of more than 100 years of studies, monitoring data, scientific reports, and modeling analyses that establish the historical salinity conditions in the Western Delta and Suisun Bay. This document presents the highlights of that report.

Is the Delta “artificially” fresh?

Some have suggested that the Delta is now kept artificially fresh, and that historically the Delta was saltier. This report addresses the question of whether the Delta is, in fact, artificially fresh through comparison of recent Delta salinity levels to the estimates and measurements of historical salinity going back 2,500 years.

Key findings:

- Measurements of ancient plant pollen show that the Delta was predominately a freshwater marsh for the past 2,500 years, and that the Delta has become far more saline in the past 100 years because of human activity.
- Salinity intrusion today is typically 3 to 15 miles farther into the Delta compared to the early 20th century, when much less fresh water was diverted.
- Before freshwater diversions increased in the 1940’s, the Delta and Suisun Bay would freshen every winter, even during the extreme drought of the 1930’s. However, that pattern has changed – during recent droughts (1976-1977, 1987-1994, and 2007-2009), the Delta did not freshen. Without seasonal freshening, contaminants and toxics can accumulate in the system.
- While half of the past 25 years have been relatively wet, the autumn salinity levels in 21 of those 25 years have resembled dry year conditions: *in terms of salinity, the Delta is now in a state of drought almost every autumn because of human activity including water diversions.*

➔ The Delta is not artificially fresh

The historical record and published studies demonstrate that the Delta is far saltier now than it would have been without human interference.

Historical reports chronicle unprecedented salinity intrusion, starting around 1917, due to upstream water use

The geography and freshwater characteristics of Suisun Bay and the Delta are recorded in writings of explorers and early settlers. In maps and journals from the 19th century, Suisun Bay was called “Freshwater Bay”.

By the early part of the 20th century, it was recognized that human activities, including the diversion of fresh water from the system, were causing increased salinity intrusion into Delta. Starting in 1917, local industries and residents observed unprecedented salinity levels, leading a local sugar refinery to seek a new water supply, the Town of Antioch to file a lawsuit against upstream water users, and the State of California to launch a salinity monitoring program and investigation.

The misconception that the Delta is now artificially fresh and does not experience the full range of natural salinity intrusion may be due to superficial comparison of the maximum salinity intrusion diagrams in the Delta Atlas (DWR, 1993), which show greater salinity intrusion during six years in the 1920's and 1930's than occurred from 1945-1990. However, maximum salinity intrusion in the early 20th century was strongly influenced by upstream diversions and channelization of the Delta. The quotations below from early 20th century reports show that salinity intrusion in the 1920's should not be considered natural.

1928 - Thomas H. Means. Salt Water Problem, San Francisco Bay and Delta of Sacramento and San Joaquin Rivers

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 predominately of salt water types around San Pablo Bay and of fresh water types around Suisun Bay...

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...

At present [1928] 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 the future, even in the years of greatest runoff. In other words, the penetration of salt water has become a permanent phenomenon in the lower river region.

The cause of this change in salt water condition is due almost entirely to the works of man.

1931 - Department of Public Works, State of California. Bulletin No. 27. Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay.

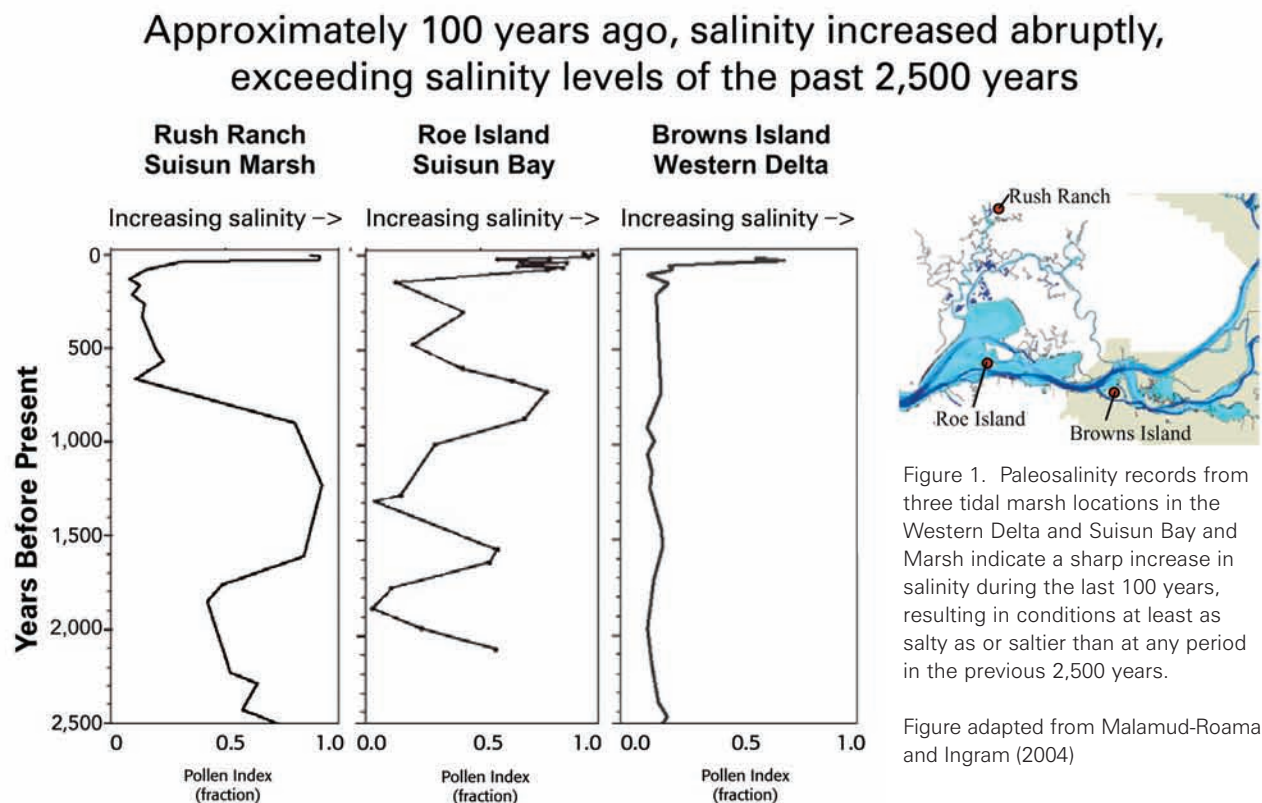
The dry years of 1917 to 1919, combined with increased upstream irrigation diversions, especially for rice culture in the Sacramento Valley, had already given rise to invasions of salinity into the upper bay and lower delta channels of greater extent and magnitude than had ever been known before.

Consistent with historical reports, paleosalinity records reveal a sustained period of freshwater conditions in the Delta, followed by a sharp, sustained increase in salinity starting about 100 years ago

In paleoclimatology, information from natural sources, such as atmospheric temperature (from ice cores) and precipitation cycles (from tree rings), is used to reconstruct past climate, providing a history of conditions before modern instruments. Salinity in the Bay and Delta tidal marshes has been reconstructed from sediment cores, providing evidence of salinity intrusion over the last 2,500 years.

The Delta was predominately a freshwater system for 2,500 years, even during century long droughts, until the early 1900's, as shown below at the Browns Island tidal marsh near the confluence of the Sacramento and San Joaquin Rivers (Figure 1). Although Suisun Bay experienced salinity intrusion during long drought periods (the last period ended approximately 700 years before present), salinity did not affect the western Delta to the same degree, likely due to the vast tidal marshes that existed until the early 20th century.

Furthermore, salinity levels in Suisun Bay during the past century exceed even the long drought periods of previous centuries, even though the watershed has received above average rainfall for the last 70 years. The abrupt increase in salinity during the last 100 years has been attributed to human activities, including reclamation of tidal marsh and diversion of fresh water.



Earliest salinity measurements reveal a fresher Suisun Bay in the winter/spring and less salinity intrusion into the Delta in the fall

The earliest salinity measurements in the Delta were recorded by the California & Hawaiian Sugar Refining Corporation (C&H) from 1908 to 1929. C&H obtained fresh water by sending barges that traveled upstream along Suisun Bay and into the Delta until they reached water with a chloride concentration of less than 50 milligrams per liter (mg/L). The distance the barges traveled is a measure of salinity intrusion; increasing distance indicates increasing salinity.

Salinity started increasing in 1917 and by 1920 the salinity had increased to the point that C&H abandoned the Sacramento and San Joaquin Rivers during the summer and fall, replacing the water supply with an agreement with Marin County. The increase in salinity recorded by C&H is consistent with the paleosalinity archives, reports from early settlers, and the conclusions of the State of California salinity investigation of the 1920's.

Comparison of the C&H observations for 1908 through 1917 (prior to significant upstream diversions) with recent salinity levels from two time periods of similar hydrology (Figure 2) indicates that fresh water was present further downstream in Suisun Bay and the western Delta more often and for a longer portion of the year from 1908 to 1917 compared to recent years. The colored (lower) parts of the graphs below show the progressive loss of fresh water from the system and the upper lines show the increasing salinity intrusion into the Delta.

Fresh water was available further downstream for a longer portion of the year in the early 1900's than in recent decades with similar hydrological conditions

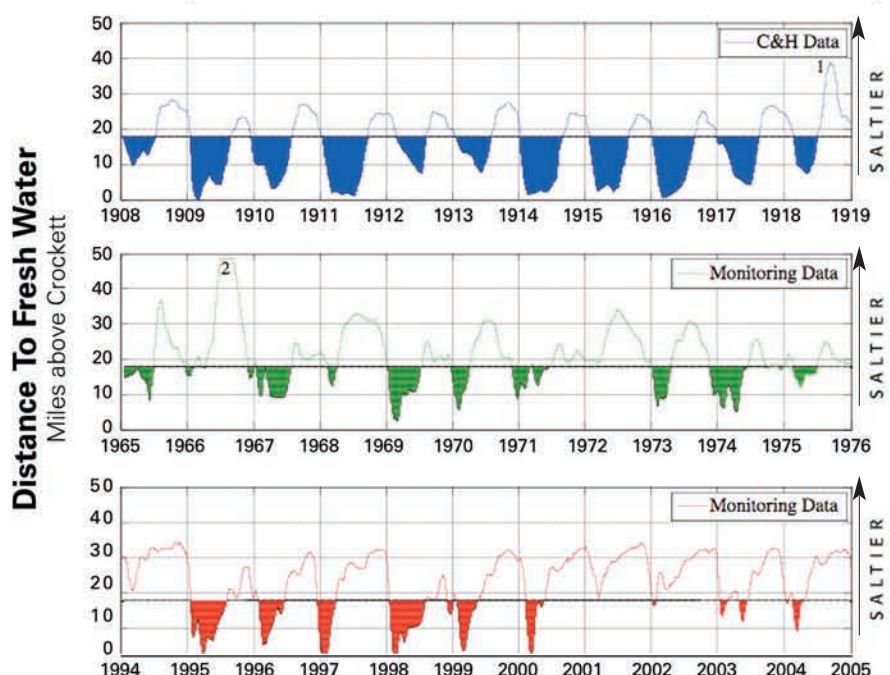


Figure 2. Fresh water was available within Suisun Bay for a longer time period each year during the early 1900's.

The colored portion on each chart represents the amount of fresh water (with less than 50 mg/L chloride or approximately 0.2 ppt salinity), that is available within Suisun Bay, downstream of the Delta boundary (approximately 18 miles above Crockett).

From 2001 to 2005, fresh water was seldom available below the Delta boundary, indicating that the Delta did not "flush". Without the seasonal freshening of the Delta, contaminants and toxics can accumulate in the system. Investigations found toxics to be a factor in the decline of the Delta ecosystem.

Note: While hydrological conditions were similar in the three time periods shown to the left, the sequence of wet and dry periods differs.

1 During August and September 1918, average water quality obtained by C&H exceeded 110 mg/L chloride

2 Salinity intrusion is likely an overestimate due to inadequate spatial coverage of monitoring stations in 1965 and 1966

The Delta no longer freshens during droughts and fall salinity is so high that drought-like conditions in the fall occur almost every year

Salinity at the confluence of the Sacramento and San Joaquin Rivers near Collinsville reveals the evolution of two factors identified as contributors to the decline of the Delta ecosystem: the accumulation of toxics (Figure 3) and the increase in fall salinity (Figure 4).

The Delta no longer freshens during droughts, creating the potential for toxic accumulation

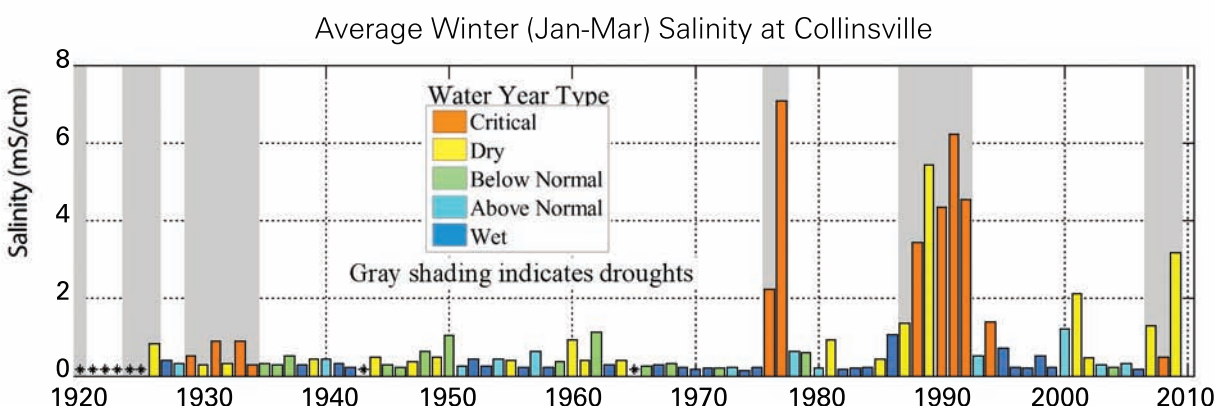


Figure 3. Even in the six-year drought from 1928 to 1934, the Delta still freshened every winter. However, the Delta has not freshened during more recent droughts (1976-1977, 1987-1994, and 2007-2009). This indicates that the Delta is not being “flushed” with fresh water as it was historically. The lack of flushing may allow waste from urban and agricultural developments upstream of and within the Delta to accumulate. Contaminants and toxics have been identified as a factor in the decline of the Delta ecosystem.

* Indicates no data are available

Historically, fall salinity was only high in relatively dry years. Recently, fall salinity is high almost every year

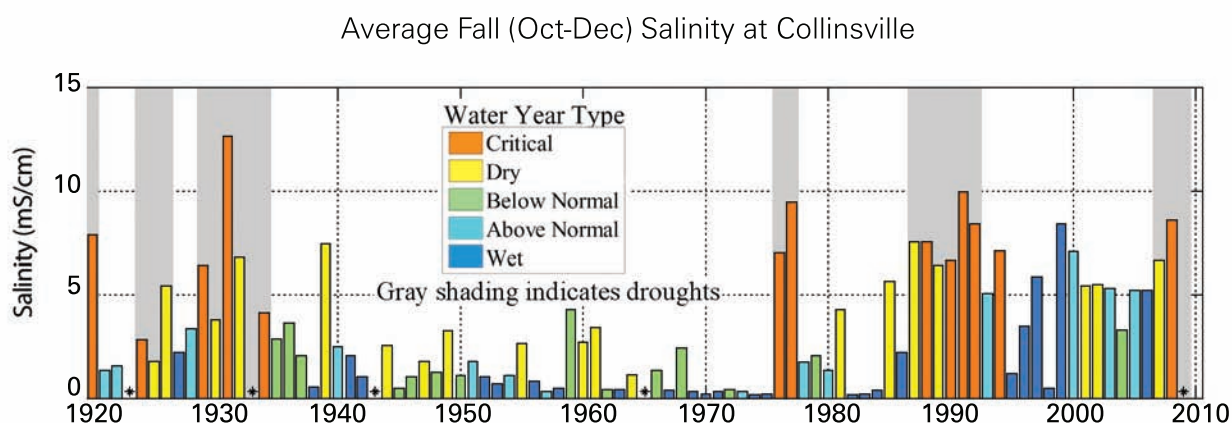
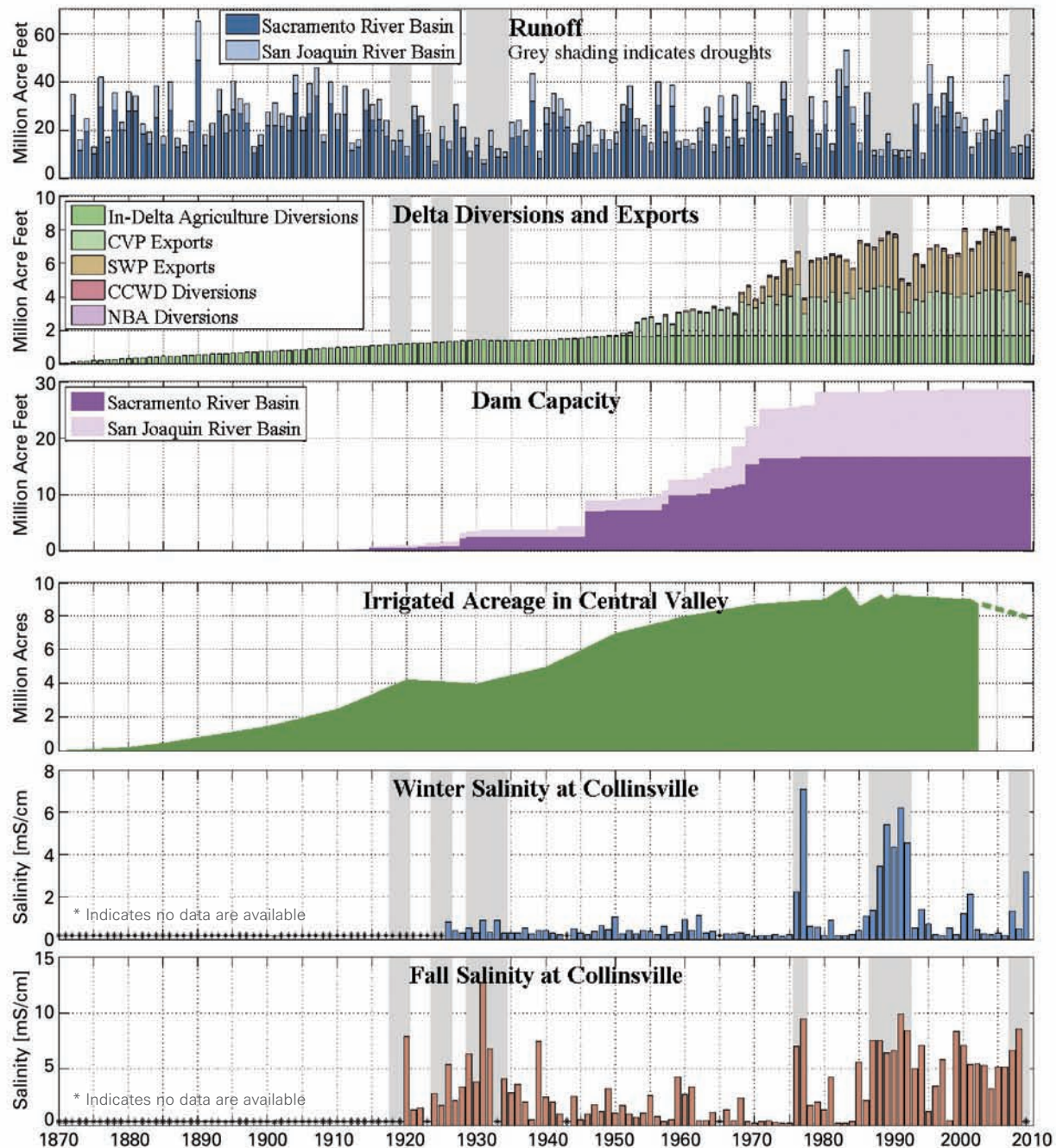


Figure 4. Fall salinity is now high almost every year, while historically, fall salinity was only high in dry and critical years. High salinity in the fall has been identified as a factor in the decline of the Delta ecosystem.

* Indicates no data are available

Salinity in the Bay and Delta responds to upstream runoff, diversion of fresh water, operation of upstream reservoirs, and the geometry of the Bay and Delta. From the mid-1800's until approximately 1920, the most significant impact on salinity was likely due to changes to the landscape of the Central Valley and Delta. Since 1920, reservoir operations and diversion of fresh water significantly increased salinity in the estuary.





CENTRAL VALLEY REGIONAL
WATER QUALITY CONTROL BOARD

Salinity in the Central Valley
An Overview

May 2006



CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

Table 3. Annual salt load from mass emissions and Delta exports through the Sacramento-San Joaquin Delta system

	Min	Max	Mean	1985 to 1994 Mean	2001 to 2004 Mean	Period of Record / Notes
<u>Mass Emissions</u>	Annual Salt Load (thousand tons/year)					
Sacramento River	730	3,049	1,945	1,521	1,748	1959 to 2004 ¹
Yolo Bypass	0	2,392	405	169	179	1959 to 2004 ¹ , assume EC=100
San Joaquin River	263	2,557	922	749	742	1959 to 2004 ²
Delta Outflow						
<u>Delta Exports</u>	Annual Salt Load (thousand tons/year)					
California Aqueduct (SWP)	983	1,022	1,004		1,004	2001 to 2004 ³
Delta Mendota Canal (CVP)	631	1,003	900		884	2001 to 2004 ³
North Bay Aqueduct	2	6	4	3	6	1959 to 2004 ¹ , assume EC=Sac River
Contra Costa Canal	37	46	41		41	1959 to 2004 ¹ , assume EC=SWP

¹Source: DayFlow; ²Source: USGS, 2006; ³Source: DWR, 2006c

Note: Blanks in the above table represent data that must be compiled by future efforts, if possible

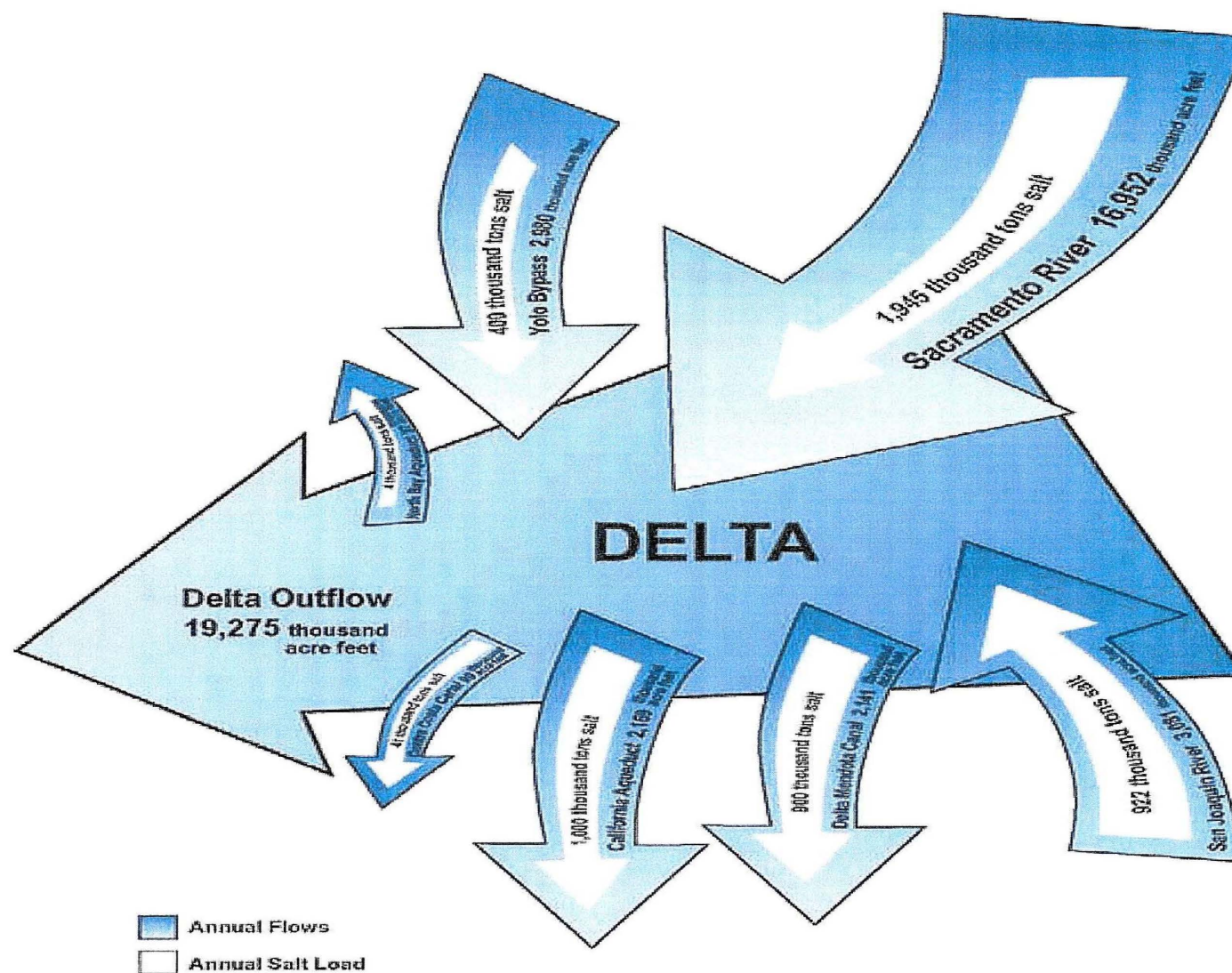


Figure 3. Mass emissions and Delta exports in the Sacramento-San Joaquin Delta system