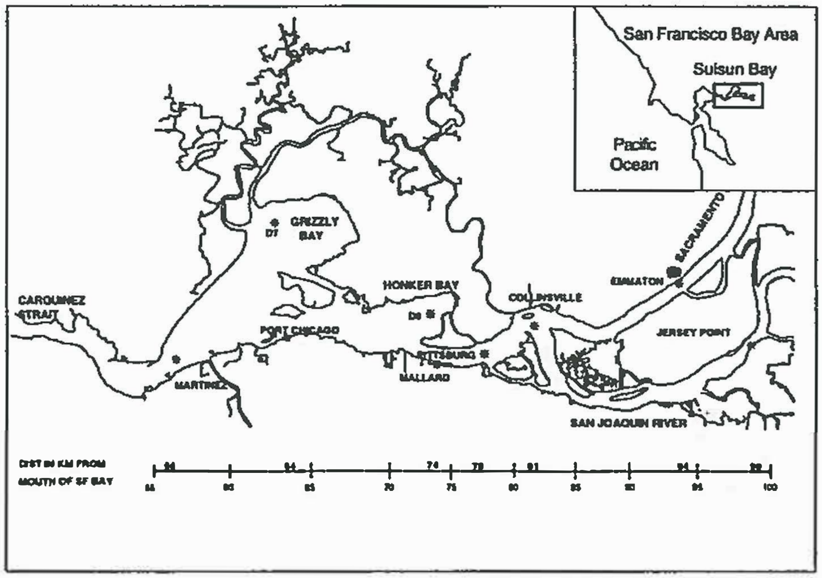
Salinity Characterization of Suisun Bay, California



Strategic Environmental Assessments Division
Office of Ocean Resources Conservation and Assessment
National Ocean Service
National Oceanic and Atmospheric Administration
Silver Spring, MD

July 1995

NOAA

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

U.S. DEPARTMENT OF COMMERCE

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This report should be cited as: Dennis, K.C. and C.J. Klein. 1995. Salinity Characterization of Suisun Bay, California. Silver Spring, MD: National Oceanic and Atmospheric Administration, Office of Ocean Resources Conservation and Assessment. 10 pp.

Acknowledgments

The work of many individuals was integral to the development and successful completion of this report. Within NOAA's Strategic Environmental Assessments (SEA) Division, Daniel J. Basta provided clear guidance on content and design. Naomi Wender-Milliner served as the senior editor, designed the layout, and worked on several graphics. Mitchell J. Katz also provided an editorial review of the final draft, and Douglas Pirhalla provided graphics support.

The authors would like to thank Michael Vasey, of San Francisco State University, for reviewing the report and organizing a meeting to review the technical material included. We would also like to thank the members of that technical review meeting: Richard Denton (Contra Costa Water Management District), James Arthur (United States Department of the Interior Bureau of Reclaimation), Hank Gebhard and Steve Hayes (California Department of Water Resources), Larry Smith (United States Geological Survey), and Steve Monosmith (Stanford University).

Several principal sources of data also deserve recognition, including: Ralph Finch and Steve Hayes (California Department of Water Resources), Sheryl Baughman (United States Department of the Interior Bureau of Reclaimation), John Burau (United States Geological Survey, Sacramento), and Jane Caffrey (United States Geological Survey, Menlo Park, CA).

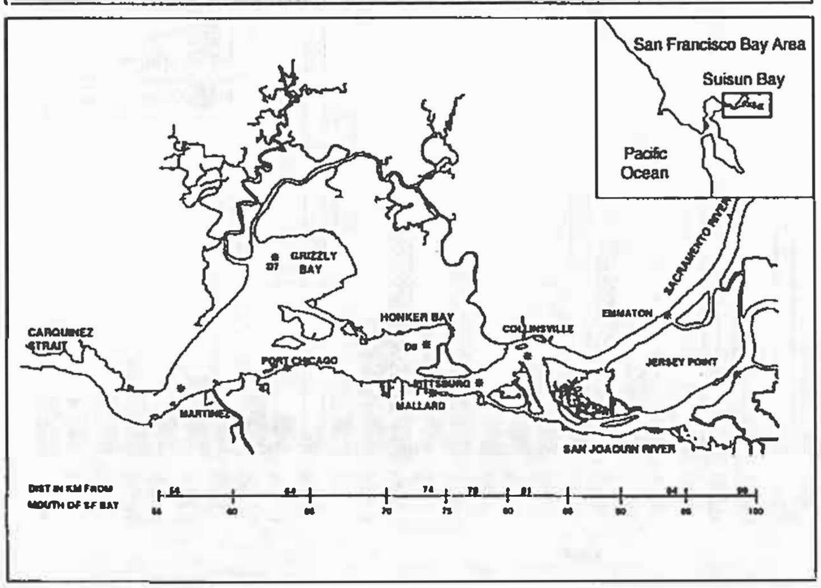
Background

The San Francisco Bay/Sacramento-San Joaquin River Delta estuary consists of South Bay, south of the Golden Gate Bridge; Central Bay; San Pablo Bay; and Suisun Bay, north of the Golden Gate Bridge. Occupying 1170 km^2, it is the largest estuary on the Pacific coast of the United States (NOAA, 1990). The Sacramento-San Joaquin drainage basin encompasses approximately 114,000 km^2 (NOAA, 1990), representing about 40 percent of the State of California (Conomos et al., 1985).

The San Francisco Bay system is a broad, shallow estuary with an average depth of 6.4 m (NOAA, 1990), comprised of broad shallows cut by narrow channels that are generally 10 to 20 m deep (Conomos et al., 1985). The deepest channels, at Golden Gate (110 m) and Carquinez Strait (27 m), are maintained by strong tidal currents that scour these natural topographic constrictions (Conomos et al., 1985). San Francisco Bay is composed of two types of estuaries: the southern portion (South Bay, south of the Golden Gate Bridge), a tidally oscillating lagoon-type estuary; and the northern portion (the three bays north of the Golden Gate Bridge), a partially mixed estuary, affected by varying seasonal freshwater inflow (Conomos et al., 1985).

Suisun Bay, defined as reaching from Carquinez Strait to the confluence of the Sacramento-San Joaquin rivers at Collinsville, is composed of Suisun Bay proper, Grizzly Bay, and Honker Bay (Figure 1).

Figure 1. *Location map of Suisun Bay with station location*



The largest volume of freshwater enters the bay from the Suisun Delta in winter (January to April); the smallest in summer (June to September). The San Francisco Bay and delta system is one of the largest areas for fish production in the country, with habitat supporting over 120 species. It is also one of the largest areas of waterfowl habitat, with over half the waterfowl and shorebirds migrating along the Pacific Flyway stopping in the bay area (U.S. EPA, 1994). Aquatic resources in the delta and Suisun Bay, however, have declined significantly since 1970 (San Francisco Estuary Project, 1993). Though the exact cause of these declines is unknown, prolonged drought and increased diversions of freshwater by State and Federal water projects have increased salinities in Suisun Bay over the last two decades.

Large increases of nonindigenous species in the area have also put stresses on the indigenous populations (San Francisco Estuary Project, 1993). Reduced flow between February and June has had the most significant impact on the aquatic habitat, as this is the period with the largest freshwater flow into Suisun Bay--when most native fish species migrate and spawn. These species recruit more successfully when large areas of the bay have salinities of 2 ppt or lower during this period (U.S. EPA, 1994).

The National Ocean Service (NOS) partnership began in April 1994, and includes NOS's Office of Ocean and Earth Sciences (OES) and Office of Ocean Resources Conservation and Assessment (ORCA), and San Francisco State University (SFSU). As part of the partnership agreement, NOS/OES has designed, installed, and is currently maintaining a real-time system to monitor conductivity and currents in the Suisun Bay and Delta region. The system was deployed in January 1995 and will remain in place at least until the fall of 1995. It is designed to help monitor the changes in habitat due to freshwater withdrawal, provide timely data for local estuarine research and management, and use this information to improve navigational safety and hazardous materials spill response. The purpose of this study is to understand salinity variability in the bay over a variety of time scales. The results of this study were used to determine the best locations for two new conductivity-temperature (CT) sensors in Suisun Bay.

Historic Changes in Freshwater Input

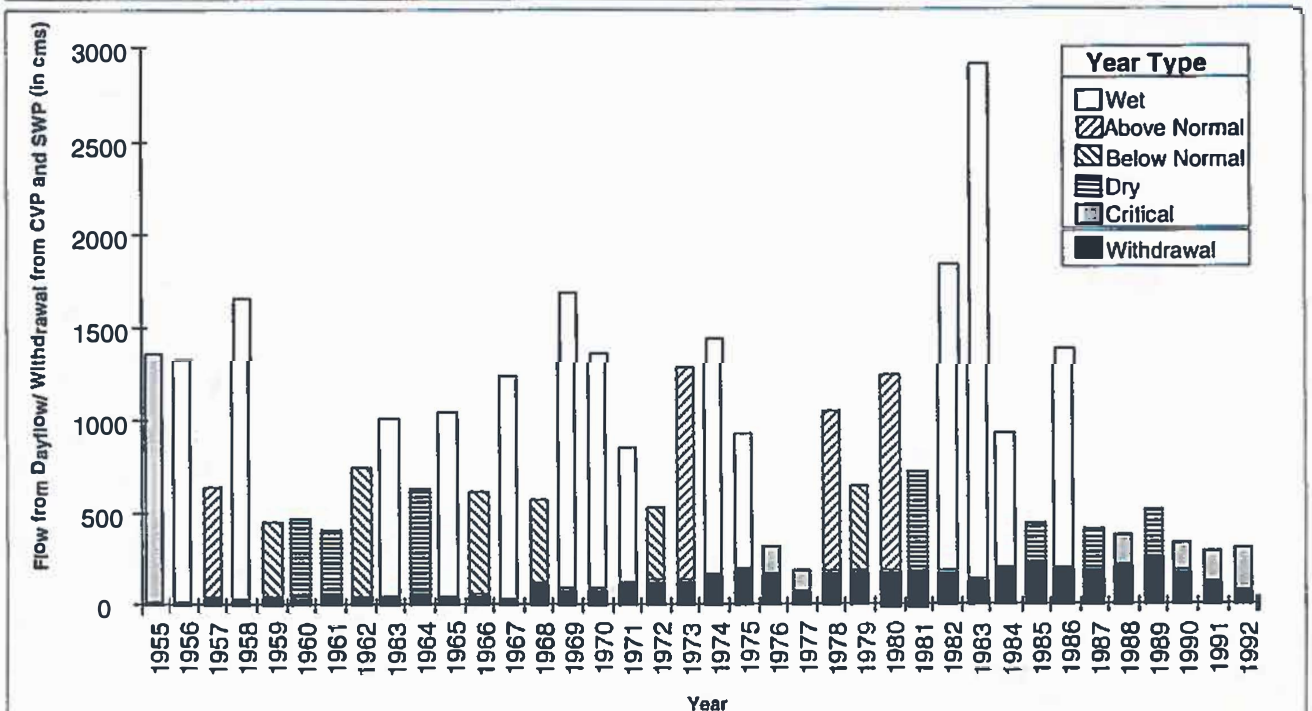
Directly measuring freshwater input into Suisun Bay is difficult because tidal currents are large relative to freshwater inflow. However, it is affected by the amount of water entering the system (i.e., wet versus dry year), withdrawals from both the Central Valley Project (CVP; Federal; on-line 1951) and the State Water Project (SWP; State; on-line 1967), and consumptive losses in the delta due to unregulated, unmonitored withdrawals by farmers.

In 1978 the California Department of Water Resources (DWR) developed a computer model called DAYFLOW that estimates the amount of freshwater that has historically entered Suisun Bay at Chipps Island. This program is basically an accounting procedure that sums the surface water inflows (rivers and streams flowing into the delta) with the delta precipitation runoff estimate, and subtracts the deltawide gross channel depletion (estimate of consumptive use in the delta) and total delta exports and diversions. It has been determined that the amount of flow into Suisun Bay varies greatly depending on the type of water year, the amount of water exported by the two water projects, and consumptive use in the delta.

The type of water year greatly influences the amount of water entering the bay. Water year type is divided into five categories: Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C), based on the Sacramento Basin Index. This index is the sum of the following: 40 percent times the April through July Four River Unimpaired Flow in Million Acre Feet (MAF); 30 percent times the October through March Four River Unimpaired Flow in MAF; and 30 percent times the previous year's Sacramento Basin Index in MAF, not to exceed 10 MAF (U.S. EPA, 1994).

Figure 2 depicts the average yearly flow (in cms) that has entered Suisun Bay between 1955 and 1992, along with the amount of freshwater withdrawn via the CVP and the SWP during this time. The drought conditions that affected the bay between 1987 and 1992 can be seen. These six years have all been classified as either dry or critically dry, based on the Sacramento Basin Water Year Type. Figure 2 also shows that average yearly water withdrawal has increased steadily since the 1950s, reaching a peak in 1989 with a mean withdrawal of 263 cms. Since that time, withdrawal has been reduced to 92 cms (1993), which approaches the level of withdrawal in the mid-1960s.

Figure 2. *Suisun Bay: Yearly averaged flow and withdrawal, by year type*



Historic Salinity Analysis

The purpose of conducting a historic salinity analysis is to better understand salinity variability in Suisun Bay at different time scales. Using the available historic salinity record, the salinity variability has been investigated in two ways: variability of salinity at each station has been examined, as has variability of the location of the 2 psu bottom isohaline. The 2 psu isohaline location, measured in kilometers from the mouth of San Francisco Bay, is significant because it correlates with several biological resources (San Francisco Estuary Project, 1993).

Data Availability. The historic salinity data used in this study includes electrical conductivity (EC) measurements obtained from the California Department of Water Resources (DWR), Division of Planning. The Division collects EC data from several sources, both within and outside DWR. The data received from the Division included data from DWR and from United States Department of the Interior's Bureau of Reclamation (USBR). The EC data were converted to salinity values using the UNESCO equations for practical salinity (UNESCO, 1981). Table 1 shows the following information about the stations to which the data were applied: station; averaging period; agency that collected the data; surface or bottom samples; period of record; and for which analysis it was used.

Until 1986, only daily averages, maximums, and minimums were retained from the continuous data collected by USBR. The DWR hourly data was collected continuously, then averaged to hourly readings, while the USBR data was collected once an hour.

Table 1. *Primary sources of salinity data*

AGENCY	STATION	AVE PERIOD	SUR/BOT	PERIOD	ANALYSIS
USBR					
	CHICAGO	1DAY	SUR	66-92	SAL, X2
	CHICAGO	MAX/MIN	SUR	66-88	SAL
	COLLINS	1DAY	SUR	66-92	SAL,X2
	COLLINS	MAX/MIN	SUR	66-88	SAL
	COLLINS	1HOUR	SUR	86-93	SAL,X2
	EMMATON	1DAY	SUR	64-93	X2
	EMMATON	1HOUR	SUR	86-93	X2
	JERSEYPT	1DAY	SUR	64-93	X2
	JERSEYPT	1HOUR	SUR	86-93	X2
	MTZ	1DAY	SUR	65-92	SAL, X2
	MTZ	MAX/MIN	SUR	65-88	SAL
	PITTSBURG	1DAY	SUR	65-93	SAL, X2
	PITTSBURG	MAX/MIN	SUR	65-88	SAL
	PITTSBURG	1HOUR	SUR	86-93	SAL, X2
DWR					
	MALLARD	15MIN	BOT	92-93	B/S
	MALLARD	1DAY	SUR	81-87	SAL, X2
	MALLARD	1HOUR	SUR	84-93	SAL, X2, B/S
	MTZ	15MIN	BOT	91-93	B/S
	MTZ	1HOUR	SUR	83-93	SAL, X2,BS

Discrete surface conductivity measurements collected biweekly at two stations, from 1975 to present, were obtained from DWR and used to examine salinity variability. Discrete salinity profile data collected monthly, over the period 1987 to 1991, were also obtained from USGS, Menlo Park (Wienke et al., 1990a; Wienke et al., 1990b; Wienke et al., 1991; Wienke et al., 1992; Wienke et at., 1993; Caffrey et al., 1994). The USGS data were used to compare surface and bottom salinities at various stations throughout Suisun Bay.

Conversion of Electrical Conductivity to Salinity. Most of the continuous data collected in Suisun Bay are EC measurements made at the surface. Since regulations require salinity standards be made at the bottom, two conversions are necessary: EC to salinity, and surface to bottom measurements.

Several methods have been implemented to convert EC to salinity. Both DWR and USBR use regression equations that have been determined for each of their sites. DWR has calculated regression equations based on a series of grab sample data collected for various sites throughout Suisun Bay and the delta. These data, collected at the surface in slack water following daylight high tides, were then grouped according to water year types, and regression equations were calculated. USBR developed an entirely different series of regression equations.

Because of the disparities in the methods used to convert EC to salinity values, UNESCO (1981) standard equations were applied in this study. One problem with this method, however, is that these equations are intended for salinities between 2 and 42 psu, while many of the historic salinities in Suisun Bay are below 2 psu.

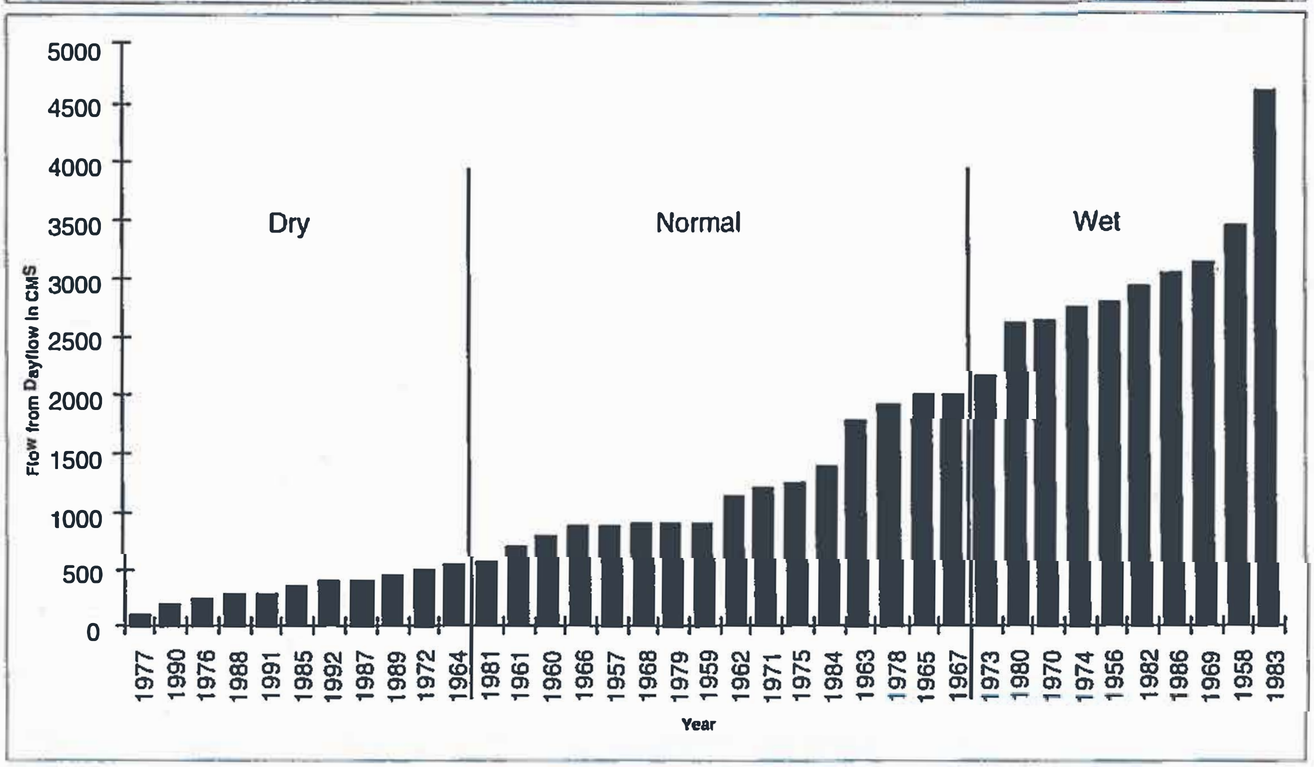
Conversion from Surface to Bottom Measurements. Extrapolation of bottom salinities from surface salinities is also a problem in Suisun Bay, because EC was most often measured at the surface. Salinity stratification in the water column depends on many factors, all of which are interrelated. The depth of the water column has a large impact on stratification, by determining whether mixing by wind and waves will reach the bottom. In addition, the amount of freshwater entering the system at any one time will impact stratification by shifting the location of the stratified zone. This zone can also be shifted by the strength and timing of tidal currents. Finally, stratification at any station within the bay depends on its location along (i.e., from Carquinez to Collinsville) and across (i.e., from the south shore of Suisun Bay to the north shores of Grizzly and Honker bays) the bay.

To address the differences between surface and bottom salinities, continuous surface and bottom data from DWR stations at Martinez and Mallard were compared, along with discrete surface and bottom data from 10 USGS stations in Suisun Bay. Salinity varied greatly over time at each station. In addition, when bottom salinities ranged between 0.5 and 3.0 psu, the difference between surface and bottom salinity was explored. Unfortunately, not much data were available at these lower bottom salinities. However, the data collected showed smaller differences (in the range of 0 to 0.5 psu) between bottom and surface salinities at these low bottom salinities. It can be concluded therefore, that the data available do not allow a simple conversion between surface and bottom salinity; however, for the purpose of this study (examining bottom salinities approaching 2 psu), surface salinity can be considered an accurate indicator of general bottom salinity conditions. One exception is under extremely wet conditions, when surface salinities may vary significantly from bottom salinities.

Year Type Characterization. Salinity variability was analyzed for two seasons: one wet (February to April); and one dry (July to September). These seasons were chosen as the period of record for low and high salinity at the monitoring stations. They also correspond to high- and low-inflow periods, respectively.

In order to examine salinity variability for different year types for the two seasons, a characterization scheme was developed. Freshwater inflow, as calculated by the DAYFLOW program, was rank ordered, including the antecedent month (i.e., January to April and June to September). Boundaries were then drawn separating dry, normal, and wet years, using the 30-30-40 Sacramento Basin Index system, making slight modifications for seasonal flow differences. The cutoffs determined were as follows: for the January to April high-inflow season, dry is considered less than 500 cms, normal is between 500 and 2000 cms, and wet is greater than 2000 cms (Figure 3). For the June to September low-inflow season, dry is considered less than 125 cms, normal is between 125 and 275 cms, and wet is greater than 275 cms (Figure 4). The drought conditions that have prevailed in recent years are evident in both the high-inflow season (where seven of the last 10 years are characterized as dry) and the low-

Figure 3. *Average flow for Suisun Bay - rank ordered by flow (January to April, 1956-1992)*



inflow season (where five of the last 10 years are characterized as dry).

Time Scales of Variability. Many different time scales affect salinity variability in the bay, including hours, days, weeks, months, and years. Each is driven by one or more mechanism, such as tides, winds, freshwater inflow, etc. The dominant time scale of salinity variability can shift over time in an estuary, due to changes in the magnitude of the forcing mechanisms. These shifts can be caused by man-made changes (e.g., damming and diverting freshwater, dredging channels, modifications that affect circulation, etc.), natural changes (extended drought conditions or wet conditions), or combinations of both.

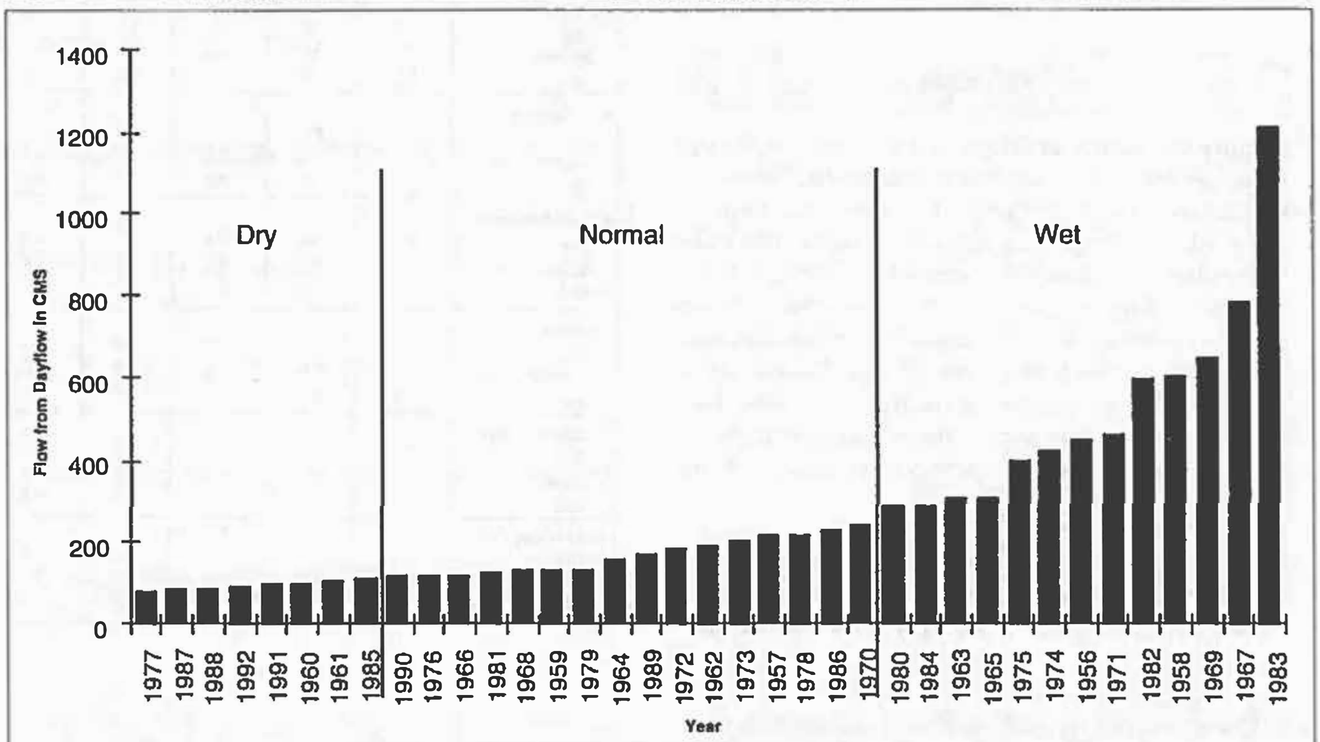
These shifts in the dominant time scales of variability have a great impact on the natural biological system in an estuary. Most studies of salinity in Suisun Bay to date have used a 14-day moving average to dampen smaller time scales of variability, thereby enabling larger shifts to be seen more clearly. However, these averaging schemes mask changes in the magnitude and dominance of the different salinity variability time scales. Six different time scales have been investigated using the seasonal and year-type definitions described above.

In this study, salinity variability was examined in two different ways, by looking at variability at each station, as well as variability of the location of the 2 psu bottom isohaline (X2). Variability was analyzed at five continuous stations and two discrete stations. Because of the difficulties in converting both EC to salinity and surface measurements to bottom measurements, the "X2" location of the 3000 µs/cm isoline at the surface was examined. This number was chosen as representing a value reasonably close to the bottom 2 ppt isohaline. This is the surface EC value that DWR believes represents the bottom 2 ppt (DWR, unpublished). The X2 location was selected by linearly interpolating the position of the 3000 µs/cm surface isoline among seven stations, using hourly data to determine the hourly X2 position and daily data to determine the daily position.

Analysis of the variability of both salinity and X2 was performed for each time scale, year-type group, and station using the following methods:

1. Hours: The maximum minus the minimum hourly values for each day was averaged over each of the three-month periods. For the USBR data prior to 1988, only the daily average, maximum, and minimum were retained. For these years, the hourly variability was calculated as the difference

Figure 4. *Average flow for Suisun Bay - rank ordered by flow (June to September, 1956-1992)*



between these reported maximum and minimum values.

2. Days: The maximum difference in consecutive daily values for each month was averaged over each three-month period.

3. Days to Weeks: The maximum minus the minimum daily averaged values for each month was averaged over each three-month period.

4. Months: The maximum minus the minimum of the monthly averaged values was calculated for each three-month period.

5. Seasons: The difference of the average of the yearly three-month period average for each three-month period (wet versus dry) was calculated.

Results. The average salinity variability for each year type (dry, normal, and wet), station, and time scale is shown both seasonally and annually in Tables 2, 3, and 4. The Mallard and Pittsburg stations have been combined, as they are close to one another and their salinity data were very similar.

The average variability of the X2 position represents the excursion of the X2 location over each of the time scales (Table 5).

Summary

Salinity variability at different time scales in the bay is caused by several forcing mechanisms. Those which have the largest impact on the system are daily tides, spring/neap tides, and freshwater inflow. Wind also plays a role in forcing variability in the bay, but to a lesser extent. At the time scale of hours, the daily tidal cycle is the major forcing mechanism. At the time scales of days, months, and seasons the major forcing mechanism is freshwater inflow. Two forcing mechanisms impact the variability at the days-to-weeks scale: the spring/neap tidal cycle and freshwater inflow.

The average number of days between monthly salinity maximums and minimums (which determines days-to-weeks variability) is 15 to 18 during the February to April period, and 13 to 18 during the July to September period. This implies the influence of the spring/neap cycle, which is about 14 days

Table 2. *Salinity variability in Suisun Bay: high inflow period (in psu)*

Feb- Apr	Hours	Days	Days to Weeks	Months	Average Salinity
Martinez					
Dry	8.1	2.2	5.8	4.0	11.4
Normal	7.6	2.8	6.3	3.0	4.4
Wet	3.6	2.3	3.4	2.9	1.7
Port Chicago					
Dry	6.0	2.2	4.5	3.3	7.4
Normal	3.0	1.8	3.5	1.7	1.4
Wet	1.1	1.3	1.3	1.1	0.5
Mallard/Pittsburg					
Dry	2.7	2.0	3.1	2.3	3.0
Normal	0.3	0.3	0.3	0.2	0.2
Wet	0.1	0.1	0.1	0.1	0.1
Collinsville					
Dry	1.8	1.1	2.0	1.8	1.8
Normal	0.1	0.2	0.2	0.1	0.1
Wet	0.0	0.0	0.1	0.0	0.1
Grizzly Bay (D7)					
Dry	—		—	5.2	7.7
Normal	—		—	1.4	1.2
Wet	—		—	1.1	0.4
Honker Bay (D9)					
Dry	—		—	3.8	4.9
Normal	—		—	0.5	0.4
Wet	—		—	0.2	0.1

Table 3. *Salinity variability in Suisun Bay: low inflow period (in psu)*

July- Sept	Hours	Days	Days to Weeks	Months	Average Salinity
Martinez					
Dry	8.2	1.9	3.2	1.6	16.3
Normal	8.5	2.1	3.6	2.5	13.4
Wet	9.3	1.9	3.7	3.5	5.2
Port Chicago					
Dry	7.7	2.0	2.5	1.2	12.5
Normal	7.7	1.8	3.5	2.6	9.3
Wet	6.1	1.2	2.5	2.4	2.5
Mallard/Pittsburg					
Dry	4.6	1.8	2.3	1.3	5.9
Normal	3.7	0.9	2.0	1.7	3.2
Wet	1.2	0.4	0.8	0.9	0.8
Collinsville					
Dry	3.3	1.0	1.7	0.6	4.6
Normal	2.4	0.6	1.5	1.2	2.2
Wet	0.5	0.2	0.3	0.3	0.5
Grizzly Bay (D7)					
Dry	—	—	—	1.7	11.3
Normal	—	—	—	1.8	8.4
Wet	—	—	—	2.0	3.2
Honker Bay (D9)					
Dry	—	—	—	1.7	7.6
Normal	—	—	—	1.8	4.5
Wet	—	—	—	0.9	1.1

Table 4. *Annual salinity variability in Suisun Bay (in psu)*

Year	Hours	Days	Days to Weeks	Seasons	Average Salinity
Martinez					
Dry	8.1	2.1	4.5	4.9	13.9
Normal	8.0	2.4	5.0	9.0	8.9
Wet	6.5	2.1	3.5	3.4	3.4
Port Chicago					
Dry	6.9	2.1	3.5	5.1	9.9
Normal	5.3	1.8	3.5	8.0	5.3
Wet	3.6	1.2	1.9	2.0	1.5
Mallard/Pittsburg					
Dry	3.7	1.9	2.7	2.9	4.4
Normal	2.0	0.6	1.2	3.0	1.7
Wet	0.7	0.2	0.5	0.7	0.5
Collinsville					
Dry	2.5	1.0	1.8	2.8	3.2
Normal	1.2	0.4	1.5	2.1	1.2
Wet	0.3	0.1	0.3	0.4	0.3
Grizzly Bay (D7)					
Dry	—	—	—	3.6	9.5
Normal	—	—	—	7.3	4.8
Wet	—	—	—	2.8	1.8
Honker Bay (D9)					
Dry	—	—	—	2.8	6.3
Normal	—	—	—	4.1	2.4
Wet	—	—	—	0.9	0.6

Table 5. *Variability of the 3000 µs/cm(in km)*

Year	Hours	Days	Days to Weeks	Months	Seasons	Average Location
Feb.-Apr.						
Dry	9.1	5.6	10.8	9.6	—	82
Normal	—	6.2	11.6	5.5	—	64
Wet	—	5.1	8.1	11.1	—	63
July-Sept.						
Dry	10.9	2.5	4.1	1.7	—	92
Normal	—	2.3	6.4	5.6	—	85
Wet	—	2.6	6.2	7.5	—	72
Year						
Dry	10.0	4.0	7.4	—	10	87
Normal	—	4.2	9.0	—	21	75
Wet	—	3.9	7.2	—	9	68

long. The influence of freshwater inflow can be seen in the individual monthly values, which range from one to 30 days.

The most important change in salinity structure and variability in the system is between normal and dry years. This is because conditions over the past 10 years have become increasingly dry. As illustrated previously in the section on historic changes in freshwater input, seven of the last 10 years have been classified as dry or critically dry, using the Sacramento Basin Index. The drought conditions that have prevailed in recent years are also seen in both the high-inflow season, where seven of the last 10 years are characterized as dry, and in the low-inflow season, where five of the last 10 years are characterized as dry. Therefore, the comparison of normal to dry years approaches a comparison of normal to present day conditions. Changes in salinity variability and structure, and location and excursion of X2, along with the forcing functions causing these changes, are displayed in Figure 5.

The most significant change in salinity structure and variability from normal to dry conditions is the change in the X2 position during the February to April high-inflow season. The location of the X2 in normal years is at Port Chicago (km 64), while in dry years it is located near Collinsville (km 82). This shift of almost 20 km has a major impact on habitat availability.

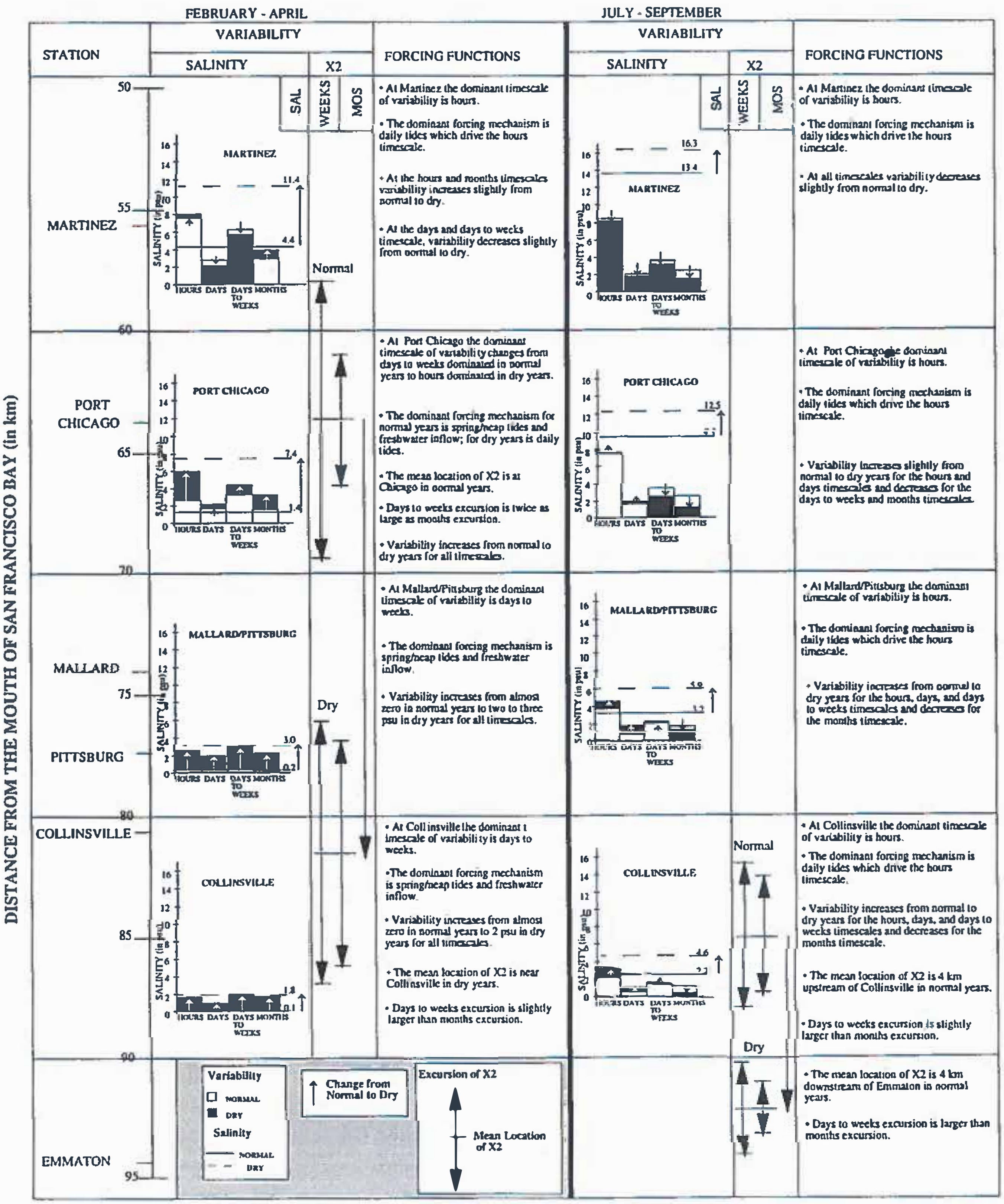
The stationary features in the region around Port Chicago include significant shallow and marshy areas known to be important spawning and nursery habitat for many fish species. Analysis of data for Grizzly Bay, a large shallow embayment to the north of Port Chicago, shows that both salinity structure and variability are similar to Port Chicago, suggesting that when X2 is located at Port Chicago, conditions in Grizzly Bay are favorable for spawning and nursery areas.

In contrast, Collinsville is located at the confluence of the Sacramento and San Joaquin rivers, where the estuary is deep and narrow and there are not many shallow marshy areas. In addition, during the February to April high-inflow period, salinity variability at all time scales is also greater at Port Chicago in normal years than at Collinsville in dry years.

The change in the salinity structure and variability from normal to dry years can also be seen by comparing dry years during the February to April high-inflow season to normal years during the July to September low-inflow season (Figure 6). During dry (or present day) conditions, the high-inflow salinity structure and variability are similar to that of low inflow during normal years. Therefore, the changes in recent years have caused the high-inflow period to be similar to normal conditions during the low-inflow period. This will have a significant impact on species spawning during this high-inflow period.

Because much important habitat is located in the shallow embayments of Grizzly and Honker bays, it

Figure 5. *Normal to dry year changes in salinity variability and structure, and location and excursion of X2*



was necessary to develop a relationship between the main stem of the estuary, where the majority of data are located, and these regions. Biweekly data were available from 1975 to the present for one station in this area. These data show that Grizzly Bay has a similar salinity structure to Port Chicago. The variability is also similar for normal and wet years. However, for dry years the monthly variability is higher, and the seasonal variability lower, than at Port Chicago.

The increase in monthly variability in Grizzly Bay is probably due to a larger impact of freshwater inflow on salinity variability during dry years, possibly due to use of the tide gate on Montezuma Slough to pump freshwater through the marsh. The decrease in seasonal variability is caused by slightly depressed salinities during the low-inflow period in Grizzly Bay, as compared to Port Chicago. In Honker Bay, the salinities are between the values at Port Chicago and Mallard/Pittsburg for dry years and are similar to the values at Mallard/Pittsburg for normal and wet years, while the monthly and seasonal variability is similar to that of Mallard/Pittsburg. This analysis illustrates the importance of collecting continuous data in Grizzly and Honker bays, to facilitate comparison of the hours, days, and days-to-weeks time scales of variability with that of the main stem.

Significant information can also be obtained by examining changes in the location of X2 from normal to wet years. During the high-inflow period, X2 only moves one kilometer downstream between normal to wet years, even though a much larger quantity of freshwater enters the bay. This is because a logarithmic relationship exists between freshwater inflow and the location of X2 in the vicinity of Port Chicago, which is the location of X2 during normal and wet years. Freshwater inflows in excess of a certain threshold value in this area tend to compress longitudinal salinity gradients without significantly moving the position of X2. This is important information for regulating the system since, after a certain point, the addition of more freshwater will have little impact on the position of X2.

Conclusions

The following conclusions can be drawn from this work.

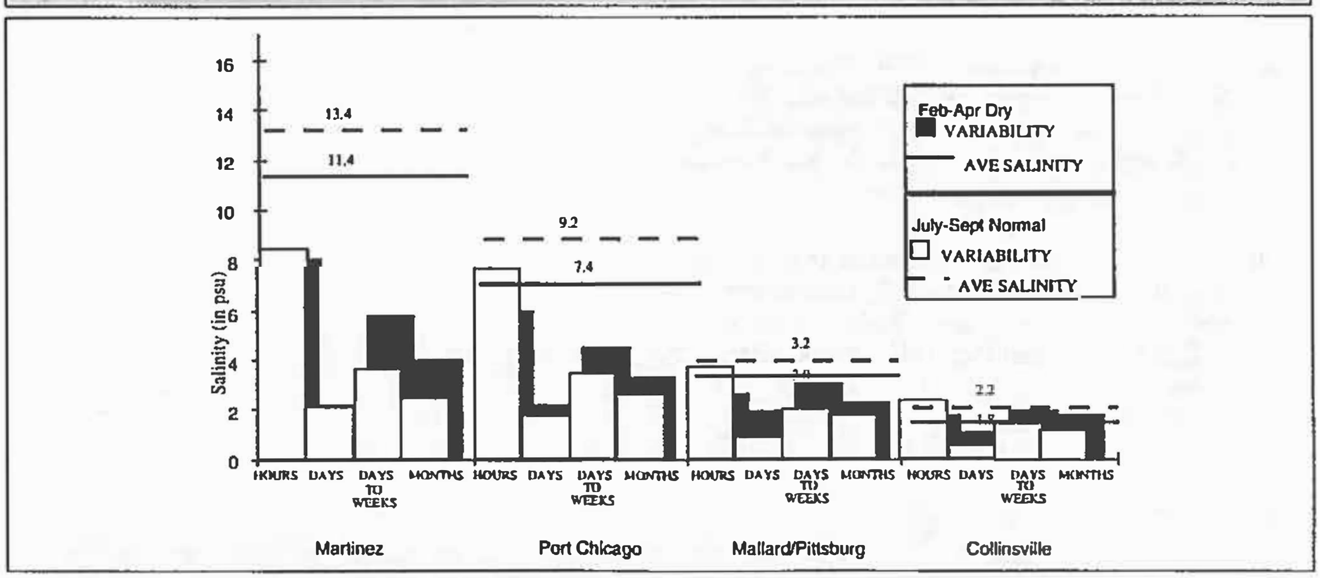
- Water flow conditions in recent years (1987-1992) have become dry, causing the following changes:

1) The position of X2, during the February-April high-inflow season has shifted upstream from Port Chicago (in normal years) to Collinsville (in present years);

2) The area of high productivity associated with X2 has moved from a region with extensive shallows and wetlands to one that is deeply channelized; and

3) Salinity variability has decreased at all time scales.

Figure 6. *Similarities in February-April dry year and July-Sept. normal year salinity structure and variability*



- A logarithmic relationship exists between freshwater inflow and the location of X2 in the vicinity of Port Chicago. Freshwater inflows exceeding a certain threshold value in this area tend to compress longitudinal salinity gradients without significantly changing the position of X2.

- Additional data from Grizzly and Honker bays are required to examine the relationship of the shallow embayments to main stem salinity structure and variability. These data are currently being collected as part of the partnership described in this report.

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