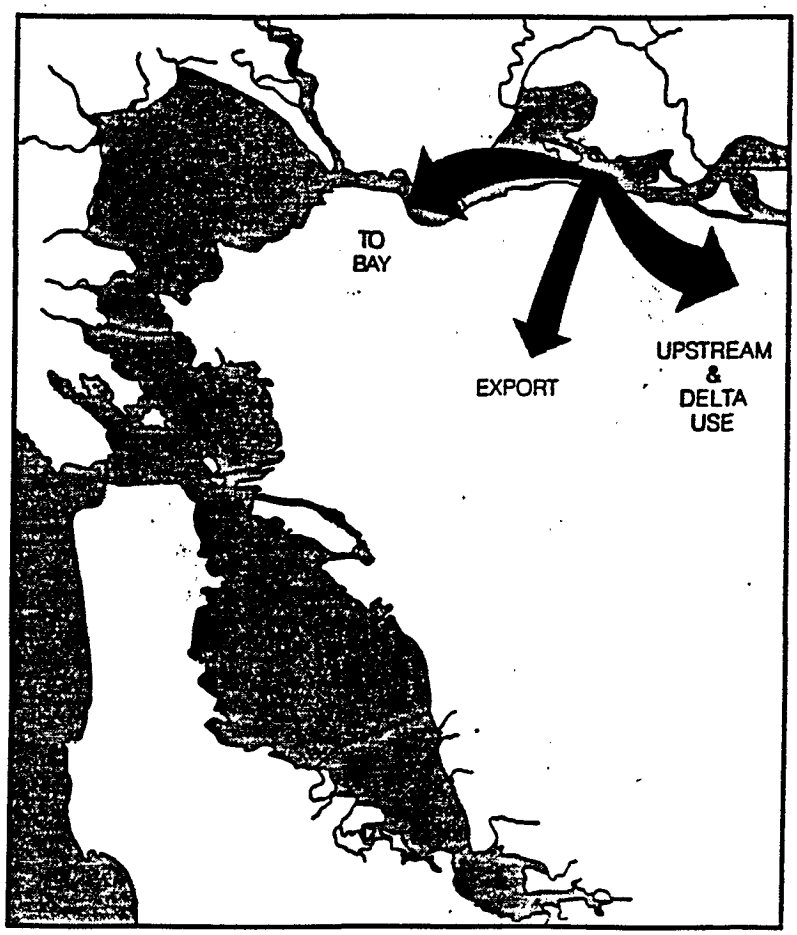
Appendix 2

ANALYSIS OF THE INFLUENCE OF WATER WITHDRAWALS ON RUNOFF TO THE DELTA-SAN FRANCISCO BAY ECOSYSTEM (1921-83)



MAY 1987

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Technical Report Number 87-7

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I.4.2.2 Total Sacramento-San Joaquin River Inflow to the Delta versus the Four River Index (hydrological basis of D1475).

The Four River Index describes total flow behavior only for the four major rivers of the Sacramento River watershed; all other middle and minor tributaries of the upper Sacramento-San Joaquin River basin (the basis of DWR's "modified method" of 1974) as well as runoff from the Sacramento Valley floor, have been excluded from consideration.

The comparison of these two sets of data and their statistics for different probabilities reveals the following (Fig.):

1) There are considerably greater differences between their runoff values (with the exception of the 1976 dry and 1977 drought years) in comparison with the first sets of runoff fluctuations

2) In 64% of the observations for the 58 years, the total natural runoff considerably exceeded the Four River total (Table I.11).

Table I.11 Number of years and ranges of exceedance of the total Sacramento-San Joaquin River inflow to the Delta over the Four River Index (1922-1978)

Range MAF	Number of Years	% of Total Years
1-5	8	13.8
5.1-10	19	32.8
10.1-15	18	31.0
15.1-20	7	12.1
20.1-25	4	6.9
25.1-26	2	3.4
		100.0

It should be emphasized that the largest differences in the runoff of 1969 and 1978 (Table I.10) were almost equal to the unimpaired normal Delta outflow to the Bay (27.3 MAF) as calculated for the same period of observation, and more than 30% of differences constitute half of the normal natural river inflow.

Even in the case of the drought (1977), the difference between the NRI and Four River Index was equal to 1.62 MAF which is slightly higher than the volume of the Delta itself.

Table I.12 Comparison of the Four River Index and the Combined-Sacramento-San Joaquin River Inflow Water-Year-Type Classifications

Probability of Exceedance	Years of Recurrence	Runoff of the Four-River Index MAF	Number of Events and Years	Total Sacramento-San Joaquin River Inflow	Number of Events and Years
0.5-0.8	Historical Wet		5 (1956, 1958, 1969, 1974, 1982)		1 (1983)
1	100 Critical Wet	38	5 (1965, 1967, 1970) 1980, 1984)	65	
5	20 Very Wet	31	2 (1963, 1973)	51	1 (1982)
10	10 Mean Wet	27	4 (1971, 1973, 1975, 1978)	45	5 (1956, 1958, 1969, 1974, 1984)
25	4 Above Normal	21		35	5 (1963, 1965, 1967, 1970, 1980)
Normal		17.2		28.3	1 (1973)
50	2	16	5 (1957, 1962, 1966, 1968, 1979) (median)	26	2 (1971, 1978)
	Sub-Normal		7 (1959, 1960, 1961, 1964, 1972, 1976, 1981)		1 (1975)
75	4 Dry	12		19	7 (1957, 1959, 1962, 1966, 1968, 1972, 1979)
90	10 Critical Dry	9		14	5 (1960, 1961, 1964, 1976, 1981)
95	20 Drought	7	1 (1977)	11	
99	100	5		7	1 (1977)

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diversions during the year.

For example, the comparison of the value of regulated total Sacramento-San Joaquin River inflow to the Delta with the data on flow of different probabilities obtained from the frequency curve for the Four-River Index and for the NRI of the Sacramento-San Joaquin River shows the following:

First. The values of regulated river inflow when compared with the probability of occurrence of runoff of the Four-River Index yields a higher number of years in the wet categories than using the probability of occurrence of the total natural river inflow. (Table I.12).

Second. As a result of the above, even under highly regulated conditions in years like 1962, 1968 and 1978 when the amount of diverted water (NRI-RRI) was equal to 9.0, 7.0 and 17.0 MAF, respectively (which correspond to 36, 34 and 35% diversion of the NRI), according to the Four-River Index, the RRI of these years may be classified as mean wet (21-27 MAF) for 1978, and below normal (16-17.2 MAF) for 1962 and 1968.

However, classification of the same years, according to the ranges of wetness of the total natural Sacramento-San Joaquin River inflow, will place them into categories of below normal (26-28.3 MAF) for 1978 and critical dry (14-19 MAF) for 1962 and 1978.

Third. It must be emphasized that when the Four-River Index is used to categorize the wetness of each year, according to the residual values of the RRI to the Delta, it may lead to the conclusion that there are no shortages of water for the Delta-Bay ecosystem inasmuch as the majority of the RRI corresponds to the Four River Index wetness characterized as years of abnormal or high wetness.

For example, for the years 1959, 1961, 1964, 1972, 1979 and 1981, the RRI to the Delta corresponds to median and sub-normal category of the Four-River Index classification. This may lead to the erroneous conclusion that the riverine-estuarine system has an adequate freshwater supply which can be used to provide additional water diversions without any negative effect to the system. However, for the total Sacramento-San Joaquin River inflow system, they fall into the category of dry and critical dry years (Table I.12).

It should be noted that this range of probability of runoff, i.e., ranging between normal and dry years, is the category of greatest interest to water developers the world over for both short and long-term water supply planning (but not for seasonal flood control) because statistical information on water supply for probabilities 50-95% or even 97-99% is a crucial one for semi-arid zones. (The runoff values which correspond to these probabilities of occurrence are such that any essential changes in annual and monthly flow due to climatological factors and

superimposed water diversions may automatically transform a normal year into a sub-normal, dry, critical dry and even drought year.)

At the same time, the knowledge of the variability of flow (years of different wetness) is of paramount importance to permit the environmental specialist to predict possible ecological changes in water quality, sanitary conditions, residence time, tolerance level of hydrophysical changes, etc. on the estuarine environment which should be incorporated into any type of physical or biological modeling of the riverine-estuarine system.

Fourth. If water planners rely upon water-year-type classification based on the total natural inflow to the Delta and Bay, then it becomes obvious that for the majority of cases there is no excess water supply. However, under the water allocation system based on the Four-River Index, the Delta-Bay system has been subjected to significantly greater diversions over prolonged periods of time (since the beginning of CVP and SWP operation).

Similarly, under the total basin classification system, years of lower than sub-normal wetness are considered relatively rare events. However, the San Francisco Bay ecosystem continues to be subjected to nearly continuous conditions of sub-normal and even lower than sub-normal wetness.

In conclusion, during the last three decades, water planning, construction of water facilities and intensified withdrawals have been based partially or entirely on three different water-year-type classification systems:

1. The Sacramento River inflow to Shasta Reservoir, accounting for 8% of the total (Bureau of Reclamation, 1965);

2. The Sacramento-San Joaquin upper river runoff, comprising 80% of the total (DWR modified method, 1974), and

3. The Four-River Index, corresponding to 67% of the total runoff to the Delta-San Francisco Bay (D1485, DWR; SWRCB, 1978).

The use of these different classification systems raises the following two questions:

1. What ecological principles and hydrological procedures are utilized to develop estuarine basin water-year-type classification systems in the San Francisco Bay system and elsewhere?

2. From the standpoint of both balanced water development and preservation of natural resources of the Delta-Bay ecosystem, which classification system should be employed to guide the balanced management of the Delta-Bay ecosystem: The Four-River

Index or total Sacramento-San Joaquin River runoff?

In response to these questions, the choice of water-year-type classification should not be a matter of arbitrary decisions based on the competing interests and their single-purpose requirements.

The choice of runoff classification should be based on the careful analysis of historic flow patterns derived from 100% of the river watershed. It is this total flow that makes this estuary an estuary. The spatial and temporal distribution of physical and chemical characteristics, diversity of organisms, productivity, etc. are all determined by this flow.

The past, present and future of any estuarine regime depend upon the cumulative interaction between the total freshwater discharges and the total brackish and salty water entering from the adjacent coastal zone, but not on the arbitrary manipulation of their values (Ketchum, 1983; Bowden, 1967; Officer, 1976; Pritchard, 1967; Fischer, 1979)

In this case, the acceptable levels of water withdrawals as well as the establishment of statistically-valid ecological criteria for the riverine-estuarine system, will be based on the genesis of the estuary.

Hence, the water-year-type classification is only of value for consideration of the impact of human activities on the estuary if the integral flow from the entire watershed will be taken into account.

In this report, we have used the year-type classification based on the total natural river inflow/Delta outflow for the analysis of changes of runoff variables which took place because of upstream and Delta and total water diversions.