184

SOUTH DELTA WATER AGENCY

504 BANK OF STOCKTON BUILDING
311 EAST MAIN STREET
STOCKTON, CALIFORNIA 95202
TELEPHONE (209) 943-5551

Chairman
Jerry Robinson
Vice-Chairman
Peter Alvarez
Secretary
Alex Hildebrand
Directors:
Robert K. Ferguson
Natalino Bacchetti

Counsel:
Wilson, Haslett & Whitridge
Engineer:
Gerald T. Orlob

Comments by SDWA for SWRCB June 14 Workshop

We are commenting primarily on Topic 3 of the hearing notice: "Effects of upstream water projects other than the CVP and SWP". However, on the San Joaquin System, the synergism between these projects and the effect of the CVP on river inflow and quality is such that they must be addressed together.

Since about 1950 the inflow of the San Joaquin River to the Delta has been, and still is being greatly reduced. There are long periods when there is no net outflow from the river to the Central Delta (WRINT-SDWA 19). This causes stagnant water reaches with loss of salinity control and inadequate dissolved oxygen for fish. Upstream appropriative rights granted by the State Board often exceed the total yield of the river system, and direct diversion rights are based on diversion amounts rather than on consumptive use. Appropriators, therefore, are able to keep increasing their consumptive use of the water they divert with a consequent reduction in return flows. Exports from the Tuolumne River to the Bay Area bypass the stream system and have increased about five fold over the last forty years. SDWA 121 shows the effects of some of these diversions on the Delta in a dry year such as 1977. Appropriators on the tributaries with junior water rights have not been required to bypass sufficient unimpaired flows to protect senior water rights and natural channel depletions in the San Joaquin River and southern Delta. The net effect of CVP operations alone is to reduce river flow upstream of Vernalis by about 130,000 acre feet in dry years and 560,000 acre feet in below normal years. This is discussed in the June 1980 joint report by USBR and SDWA on "The Effects of the CVP Upon The Southern Delta Water Supply". That report was submitted in Phase I of the Delta Hearings as SDWA 4 and a graph depicting those effects is at SDWA 26.

The substantial increase in river salinity is caused primarily by CVP operations. The June 1980 report indicated that the average increase in salt load at Vernalis attributable to the CVP during the period examined in the report was 102,000 tons in dry years and

129,000 tons in below normal years (SDWA 80). Later updated studies indicate that a very large majority of the more recent level of salt load in spring and summer months is attributable to the CVP, and that the CVP Service Area introduces about 30,000 tons of salt per month into the river in those months when flows are typically low (WRINT-SDWA 17).

This salt load which drains from the portion of the CVP service area that lies within the San Joaquin watershed results form the importation of salt in the water imported via the Delta Mendota Canal and the application of that water to westside lands. SDWA-WQCP 21 shows the amount of new salts being transferred to the San Joaquin Valley via the DMC as now over a million tons per year. This imported salt load will be reduced if all of the proposed South Delta Barriers are installed and operated as needed (WRINT-SDWA 35).

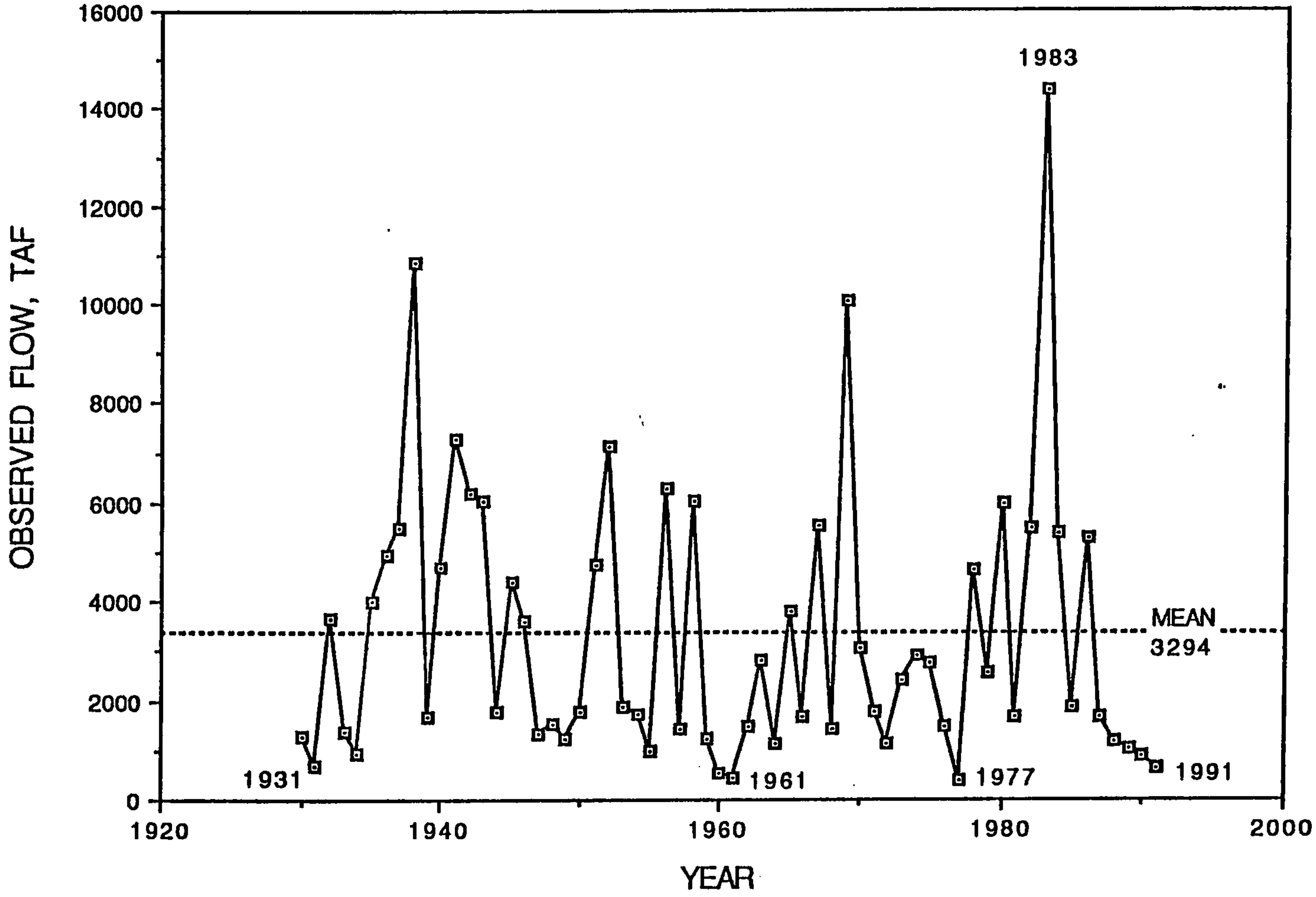
Other exhibits we have included show the reduction in natural flow at Vernalis (WRINT 5 vs. 6), the full natural flow for each of the major tributaries to the San Joaquin Basin from 1906-1991 (WRINT 40), the staging of development and storage capacity on the San Joaquin system (SDWA 13) and the mean annual diversions on each tributary (SDWA 30). Also the net salt accumulation within the S.J. Basin (SDWA-WQCP 24). We hope that the board will review these exhibits and the testimony that accompanied them when considering further action and the effect of upstream diversions.

It is difficult to imagine that the State Water Project can have caused any of the degradation of the San Joaquin River. In fact, the project is probably harmed by this degradation of the river inflow. The CVP has contributed substantially to flow reduction in the San Joaquin River, but it is clearly not the only cause of that reduction and is not an increasing cause. The CVP salt load has impacted agriculture along the main stem and in the south Delta, but it is not clear what effect it has had on each of various aspects of the ecology in and along the river. We do not know whether the impact of reduced flows on resident fishery is as great as the impact of the recent proliferation of non-native aquatic plants, for example. Higher flows would help somewhat to control these plants, but not in oxbows and other backwaters. Massive hyacinth growths have impeded migration to and from salmon spawning beds.

It is also not clear to what extent increased salinity and any increase in toxicities would be a problem to the fishery if the flow were not reduced. The lack of flow might be less serious for some species if there were a channel maintenance program. There is no such program, and the elevation of the river bottom from Vernalis to Paradise Cut has been raised by sedimentation during recent decades from below low tide level to above low tide level.

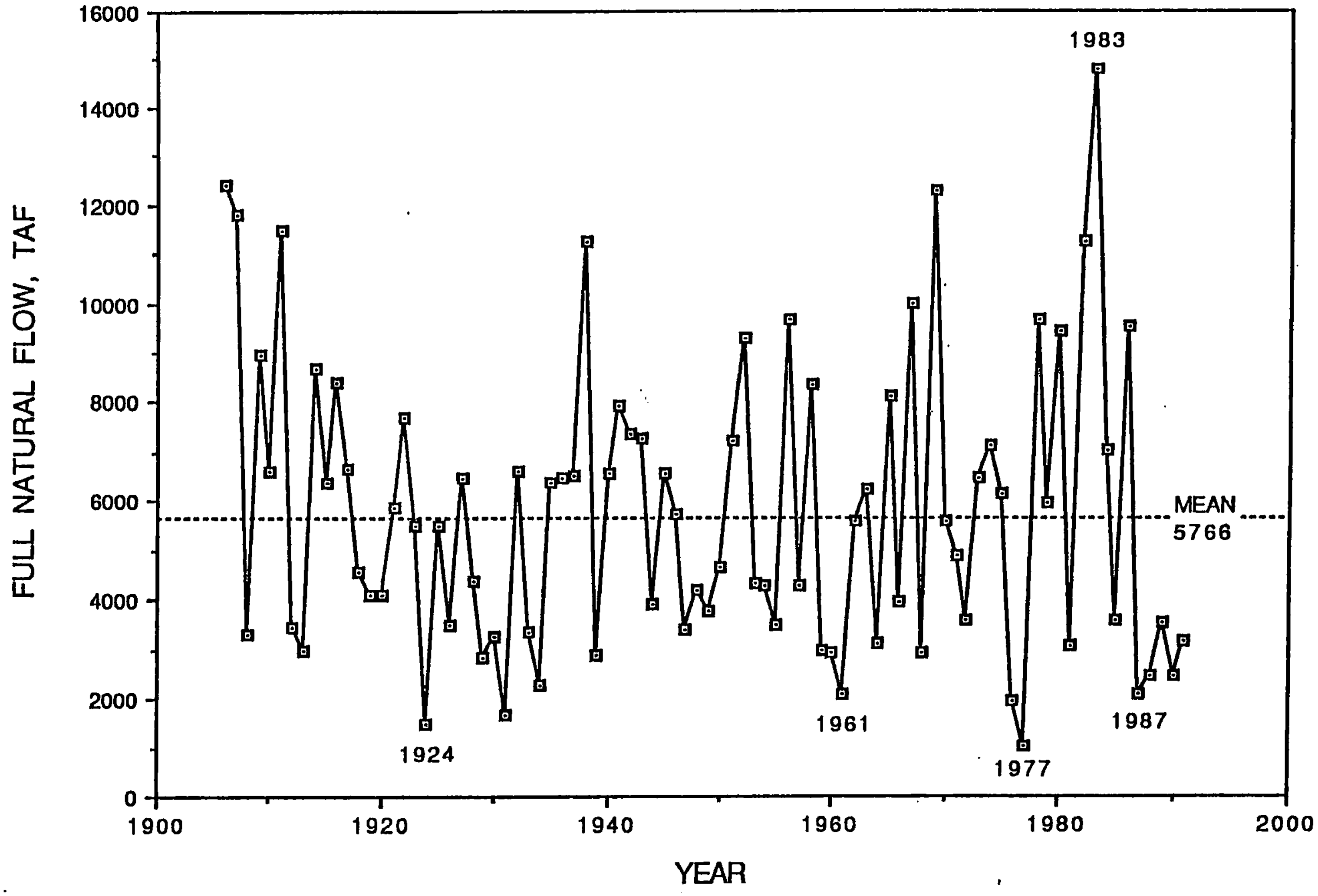
In summary, there has been a major deterioration in the flow and quality of the San Joaquin River during the last forty years for the reasons discussed. The deterioration in flow is continuing due to increasing consumptive use of water by other diverters, but the CVP impact is remaining fairly constant and the SWP is not a cause. Introduced aquatic plants and fish have multiplied rapidly. Any proposed shifts in the season of release of available flows to favor migrant species may further exacerbate the inadequate flow and quality of the river's Delta inflow in summer months, and may foster even more pervasive growth of non-native aquatic plants.

WRINT SDWA NO. 5



OBSERVED FLOW, SAN JOAQUIN RIVER AT VERNALIS, 1930 - 1991

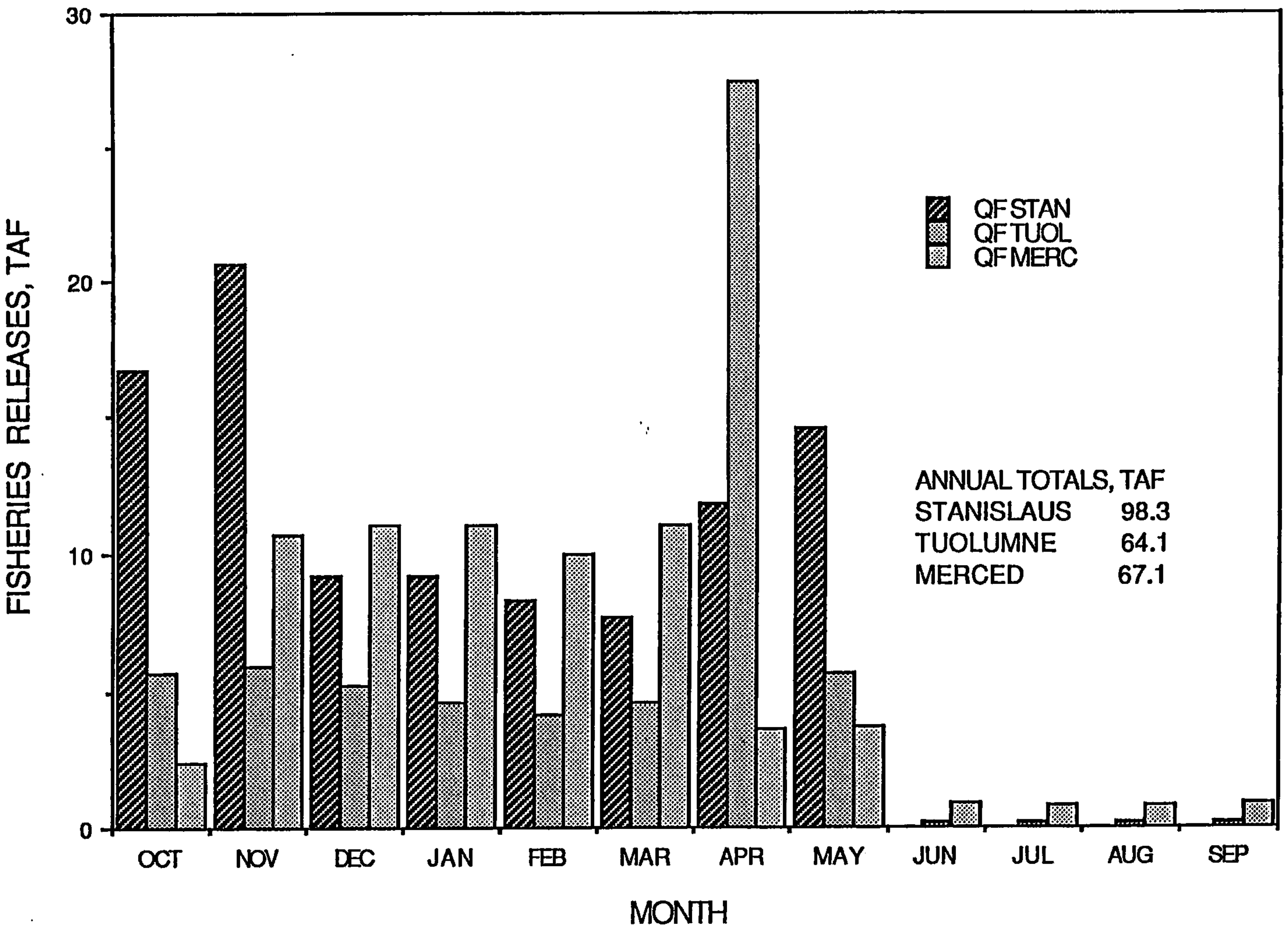
GTO 6/92



FULL NATURAL FLOW, SAN JOAQUIN BASIN, 1906 - 1991

GTO 6/92

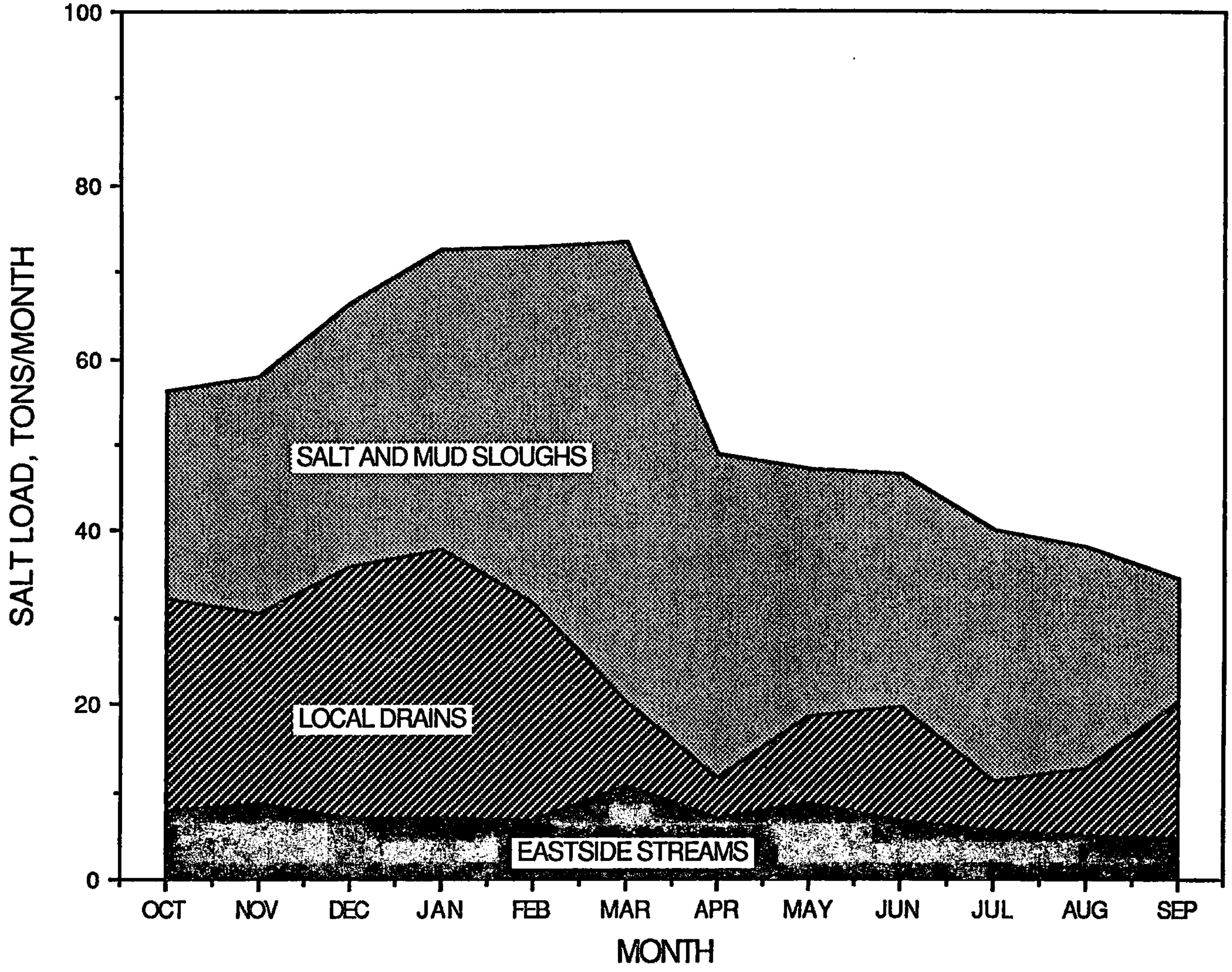
WRINT SDWA NO. 14



FISHERIES RELEASE ALLOCATIONS, EASTSIDE STREAMS

SOURCE: DEPARTMENT OF FISH AND GAME, REGION 4

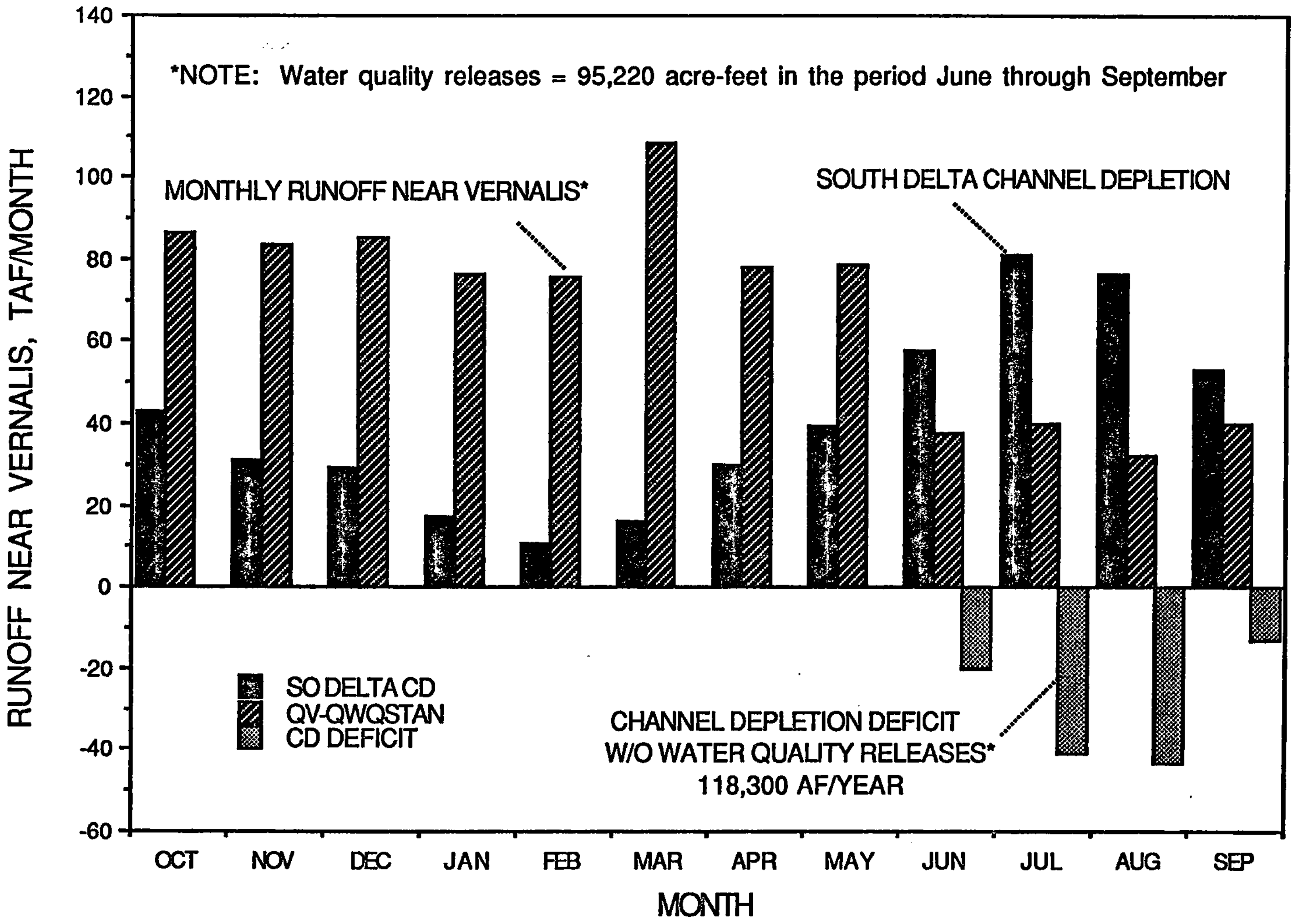
GTO 6/92



SOURCES OF SALT LOAD
SAN JOAQUIN RIVER NEAR VERNALIS, 1990

GTO 6/92

WRINT SDWA NO. 19



*NOTE: Water quality releases = 95,220 acre-feet in the period June through September

CHANNEL DEPLETION DEFICIT
W/O WATER QUALITY RELEASES*
118,300 AF/YEAR

SOUTH DELTA WATER SUPPLY BASE CASE
ACTUAL RUNOFF LESS WATER QUALITY RELEASES FROM NEW MELONES
SAN JOAQUIN RIVER NEAR VERNALIS, 1990

GTO 6/92

FULL NATURAL FLOW FOR THE SAN JOAQUIN BASIN (IN ACRE-

Data from the California Dept. of Water Resources:

MRC - Merced River @ Merced Falls
STR -Stanislaus River @ Goodwin Dan
SJR -San Joaquin River @ Friant
TUO - Tuolumne River @ La Grange

WATER YR	MRC	SJR	STR	TUO	Qu, SJBasin
1906	2035100	4367790	2414500	3610020	12427410
1907	2125800	3113900	2834400	3749500	11823600
1908	517900	1163400	620000	1023560	3324860
1909	1475400	2900700	1925900	2669400	8971400
1910	1065900	2041500	1405800	2131700	6644900
1911	2114600	3586000	2356900	3422100	11479600
1912	514700	1043900	599700	1300280	3458580
1913	440500	879400	594000	1081330	2995230
1914	1415700	2883400	1769400	2623700	8692200
1915	1092800	1966300	1300900	2044880	6404880
1916	1455000	2760500	1668500	2498170	8382170
1917	1126100	1936200	1376900	2223030	6662230
1918	831200	1466800	827500	1461590	4587090
1919	682300	1297500	768000	1347180	4094980
1920	686600	1322500	742600	1342310	4094010
1921	1013600	1604400	1262200	2017930	5898130
1922	1420500	2355100	1430400	2470920	7676920
1923	942000	1654300	1130200	1785980	5512480
1924	252200	444100	261100	542630	1500030
1925	910400	1438700	1224500	1932120	5505720
1926	609800	1161400	606500	1109910	3487610
1927	1083800	2001300	1363500	2051400	6500000
1928	736800	1153700	950000	1525020	4365520
1929	486500	862400	516600	979040	2844540
1930	513000	859100	731700	1147570	3251370
1931	262280	480200	315000	602290	1659770
1932	1113200	2047400	1352900	2114250	6627750
1933	516000	1111400	609400	1104370	3341170
1934	360900	691500	424200	807220	2283820
1935	1171400	1923200	1213500	2102870	6410970
1936	1152000	1853300	1321900	2160210	6487410
1937	1214800	2208000	1108800	1997010	6528610
1938	2079800	3688400	2044800	3424330	11237330
1939	476800	920800	526060	981010	2904670
1940	1094600	1880600	1400410	2212840	6588450
1941	1454100	2652500	1338400	2489360	7934360
1942	1286900	2254000	1485400	2355520	7381820
1943	1288940	2053700	1564940	2369810	7277390
1944	684280	1265400	675810	1295310	3920800
1945	1097400	2138100	1277160	2085740	6598400
1946	942440	1729580	1178050	1879310	5729380
1947	564260	1125500	633710	1094180	3417650
1948	688340	1214800	897710	1408550	4209400
1949	637960	1164100	745180	1246130	3793370
1950	718760	1310500	1076120	1546360	4651740

FULL NATURAL FLOW FOR THE SAN JOAQUIN BASIN (IN ACRE-

Data from the California Dept. of Water Resources:

MRC - Merced River @ Merced Falls
STR -Stanislaus River @ Goodwin Dan
SJR -San Joaquin River @ Friant
TUO - Tuolumne River @ La Grange

WATER YR	MRC	SJR	STR	TUO	Qu, SJBasin
1951	1225130	1859000	1693700	2475180	7253010
1952	1562600	2840100	1919370	2982360	9304430
1953	626240	1226700	967120	1525400	4345460
1954	667720	1313800	888390	1429180	4299090
1955	533990	1161000	680800	1123700	3499490
1956	1674700	2960100	1882700	3152840	9670340
1957	647700	1326600	894000	1417570	4285870
1958	1409400	2631000	1677510	2638370	8356280
1959	455400	949300	584030	989610	2978340
1960	482510	828600	593980	1052380	2957470
1961	312490	646900	403760	732390	2095540
1962	927650	1923600	995030	1765950	5612230
1963	984060	1944900	1267790	2041160	6237910
1964	446990	922200	643410	1130280	3142880
1965	1386350	2272200	1701800	2738370	8098720
1966	669110	1298600	703300	1306100	3977110
1967	1715630	3232200	1931500	3104610	9983940
1968	426200	862100	640400	1006630	2935330
1969	2188400	4040300	2210500	3852260	12291460
1970	882800	1445600	1320400	1962380	5611180
1971	733100	1417500	1074100	1683130	4907830
1972	549800	1039000	775900	1206610	3571310
1973	1108300	2047000	1281300	2030700	6467300
1974	1133400	2190500	1560400	2238900	7123200
1975	1108400	1795700	1241500	2032700	6178300
1976	298280	629200	371160	670630	1969270
1977	150370	361550	154970	382680	1049570
1978	1755660	3401880	1589900	2903010	9650450
1979	1075440	1830260	1163800	1913670	5983170
1980	1645510	2972680	1804450	3005700	9428340
1981	501010	1068040	591000	939740	3099790
1982	1947190	3316050	2345050	3610480	11218770
1983	2786540	4641880	2951580	4430380	14810380
1984	1180610	2048850	1434060	2380830	7044350
*1985	567000	1129020	678040	1228613	3602673
*1986	1556859	3031400	1936205	2970896	9495360
*1987	298643	757631	372040	655593	2083907
*1988	415350	862142	378234	821124	2476850
*1989	532557	939165	778307	1311937	3561966
1990	406419	742516	468849	844889	2462673
1991	560456	1034093	511161	1049525	3155235

*updated values replace those previously reported (1989)

UNIMPAIRED FLOW FOR THE SAN JOAQUIN BASIN (IN ACRE-FEET)

Data from the California Dept. of Water Resources:

MRC - Merced River @ Merced Fal
STR -Stanislaus River @ Goodwin Dam
SJR -San Joaquin River @ Friant
TUO - Tuolumne River @ La Grange

Qu, SJBasin (Unimpaired runoff) is the sum of these rim station flows.

WATER YR	MRC	SJR	STR	TUO	Qu, SJBasin		WATER YR	MRC	SJR	STR	TUO	Qu, SJBasin
1906	2035100	4367790	2414500	3610020	12427410		1950	718760	1310500	1076120	1546360	4651740
1907	2125800	3113900	2834400	3749500	11823600		1951	1225130	1859000	1693700	2475180	7253010
1908	517900	1163400	620000	1023560	3324860		1952	1562600	2840100	1919370	2982360	9304430
1909	1475400	2900700	1925900	2669400	8971400		1953	626240	1226700	967120	1525400	4345460
1910	1065900	2041500	1405800	2131700	6644900		1954	667720	1313800	888390	1429180	4299090
1911	2114600	3586000	2356900	3422100	11479600		1955	533990	1161000	680800	1123700	3499490
1912	514700	1043900	599700	1300280	3458580		1956	1674700	2960100	1882700	3152840	9670340
1913	440500	879400	594000	1081330	2995230		1957	647700	1326600	894000	1417570	4285870
1914	1415700	2883400	1769400	2623700	8692200		1958	1409400	2631000	1677510	2638370	8356280
1915	1092800	1966300	1300900	2044880	6404880		1959	455400	949300	584030	989610	2978340
1916	1455000	2760500	1668500	2498170	8382170		1960	482510	828600	593980	1052380	2957470
1917	1126100	1936200	1376900	2223030	6662230		1961	312490	646900	403760	732390	2095540
1918	831200	1466800	827500	1461590	4587090		1962	927650	1923600	995030	1765950	5612230
1919	682300	1297500	768000	1347180	4094980		1963	984060	1944900	1267790	2041160	6237910
1920	686600	1322500	742600	1342310	4094010		1964	446990	922200	643410	1130280	3142880
1921	1013600	1604400	1262200	2017930	5898130		1965	1386350	2272200	1701800	2738370	8098720
1922	1420500	2355100	1430400	2470920	7676920		1966	669110	1298600	703300	1306100	3977110
1923	942000	1654300	1130200	1785980	5512480		1967	1715630	3232200	1931500	3104610	9983940
1924	252200	444100	261100	542630	1500030		1968	426200	862100	640400	1006630	2935330
1925	910400	1438700	1224500	1932120	5505720		1969	2188400	4040300	2210500	3852260	12291460
1926	609800	1161400	606500	1109910	3487610		1970	882800	1445600	1320400	1962380	5611180
1927	1083800	2001300	1363500	2051400	6500000		1971	733100	1417500	1074100	1683130	4907830
1928	736800	1153700	950000	1525020	4365520		1972	549800	1039000	775900	1206610	3571310
1929	486500	862400	516600	979040	2844540		1973	1108300	2047000	1281300	2030700	6467300
1930	513000	859100	731700	1147570	3251370		1974	1133400	2190500	1560400	2238900	7123200
1931	262280	480200	315000	602290	1659770		1975	1108400	1795700	1241500	2032700	6178300
1932	1113200	2047400	1352900	2114250	6627750		1976	298280	629200	371160	670630	1969270
1933	516000	1111400	609400	1104370	3341170		1977	150370	361550	154970	382680	1049570
1934	360900	691500	424200	807220	2283820		1978	1755660	3401880	1589900	2903010	9650450
1935	1171400	1923200	1213500	2102870	6410970		1979	1075440	1830260	1163800	1913670	5983170
1936	1152000	1853300	1321900	2160210	6487410		1980	1645510	2972680	1804450	3005700	9428340
1937	1214800	2208000	1108800	1997010	6528610		1981	501010	1068040	591000	939740	3099790
1938	2079800	3688400	2044800	3424330	11237330		1982	1947190	3316050	2345050	3610480	11218770
1939	476800	920800	526060	981010	2904670		1983	2786540	4641880	2951580	4430380	14810380
1940	1094600	1880600	1400410	2212840	6588450		1984	1180610	2048850	1434060	2380830	7044350
1941	1454100	2652500	1338400	2489360	7934360		1985	567000	1129020	678040	1169500	3543560
1942	1286900	2254000	1485400	2355520	7381820							
1943	1288940	2053700	1564940	2369810	7277390							
1944	684280	1265400	675810	1295310	3920800							
1945	1097400	2138100	1277160	2085740	6598400							
1946	942440	1729580	1178050	1879310	5729380							
1947	564260	1125500	633710	1094180	3417650							
1948	688340	1214800	897710	1408550	4209400							
1949	637960	1164100	745180	1246130	3793370							

SDWA Exhibit 9

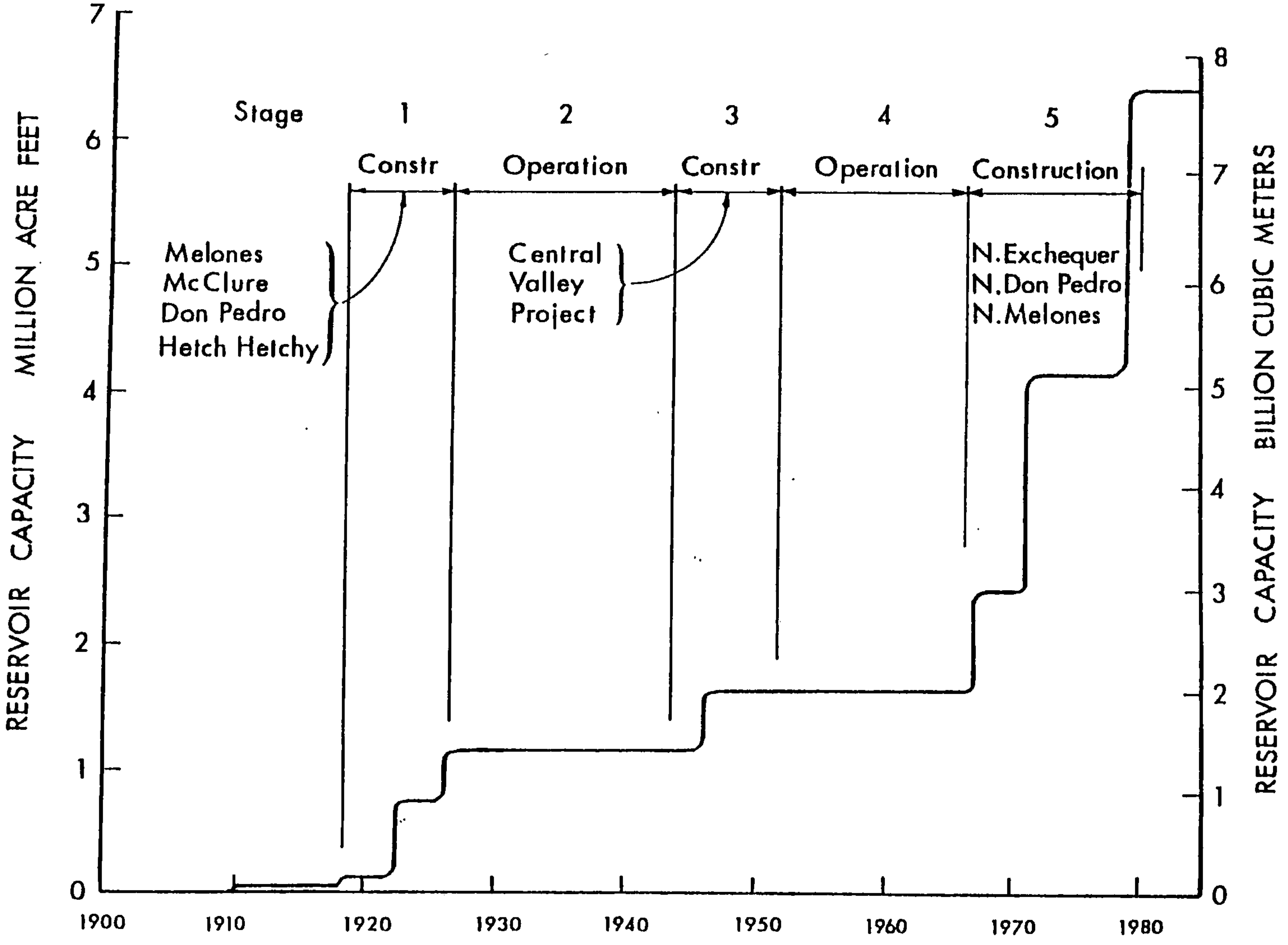
UNIMPAIRED RUNOFF * SAN JOAQUIN RIVER AT VERNALIS, 1906-1985
1000 acre feet

DRY		BELOW NORMAL		ABOVE NORMAL		WET	
Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff
1977	1014	1955	3512	1962	5618	1922	7681
1924	1504	1985	3544	1946	5734	1941	7945
1931	1660	1972	3571	1921	5901	1965	8108
1976	1928	1949	3799	1979	5983	1916	8229
1961	2100	1944	3933	1975	6114	1958	8367
1934	2288	1966	3985	1963	6250	1914	8692
1929	2844	1919	4095	1915	6405	1909	8971
1939	2909	1920	4097	1935	6418	1980	9428
1968	2958	1948	4218	1973	6467	1952	9312
1960	2960	1957	4292	1936	6495	1978	9651
1959	2986	1954	4313	1927	6499	1956	9679
1913	2995	1953	4354	1937	6530	1967	9993
1981	3100	1928	4365	1940	6596	1982	11219
1964	3151	1918	4587	1945	6612	1938	11248
1930	3254	1950	4656	1932	6622	1911	11480
1908	3325	1971	4870	1910	6645	1907	11824
1933	3356	1925	5505	1917	6662	1969	12295
1947	3424	1923	5512	1984	7044	1906	12427
1912	3458	1970	5587	1974	7146	1983	14810
1926	3493			1951	7262		
				1943	7283		
				1942	7370		

---

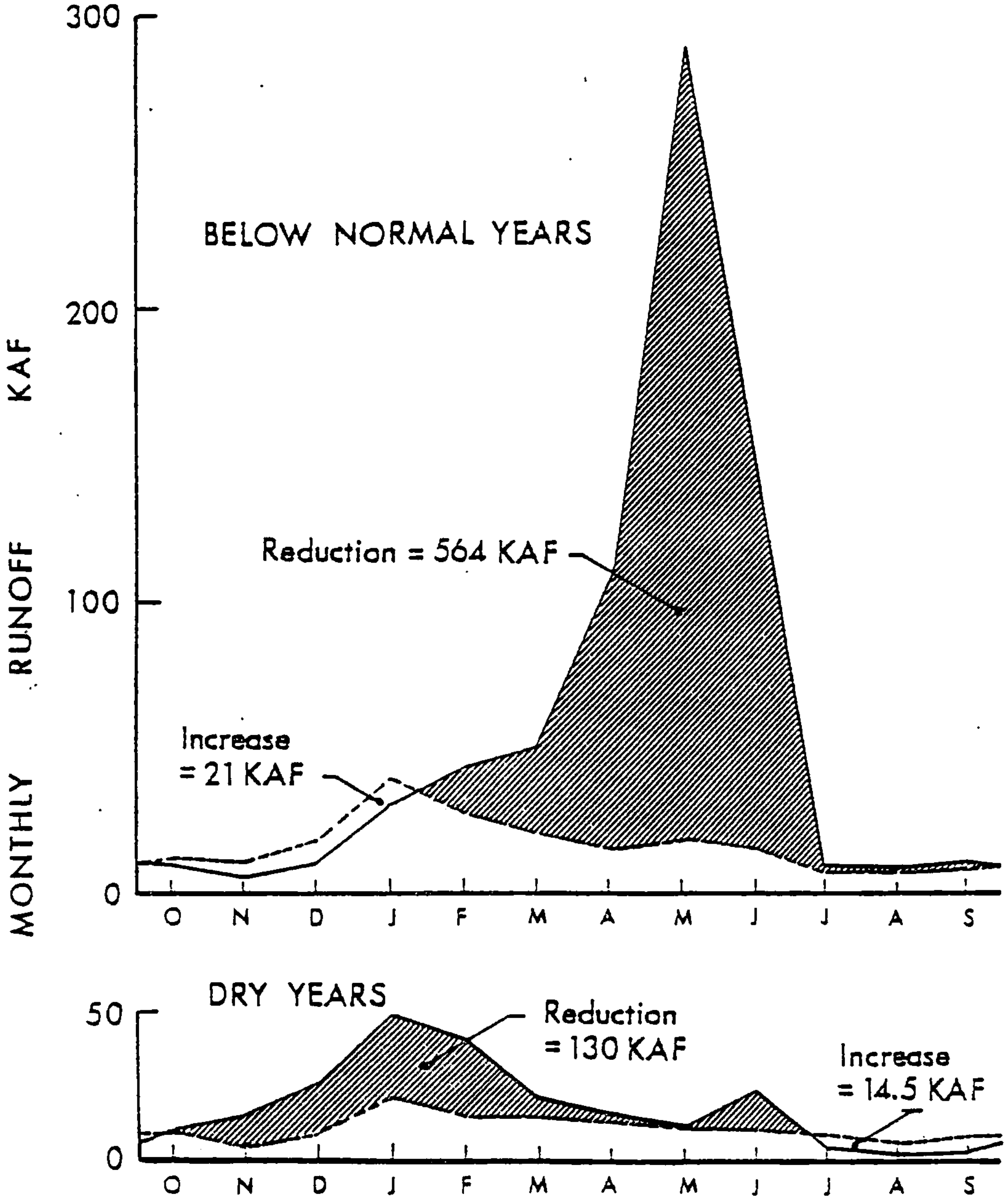
* Sum of unimpaired runoffs for hydrologic year ending 30 September at four stations above major project reservoirs; San Joaquin River at Friant, Merced River at Exchequer, Tuolumne River at Don Pedro, and Stanislaus River at Melones

SDWA Exhibit 10



STAGED DEVELOPMENT OF RESERVOIR CAPACITY IN THE SAN JOAQUIN BASIN, 1900-1985

SDWA Exhibit 13



CHANGES IN SEASONAL RUNOFF, PRE- AND POST-CVP PERIODS
UPPER SAN JOAQUIN BASIN ABOVE MOUTH OF MERCED RIVER

Notes: Changes are equivalent to CVP impact on runoff of San Joaquin River at Vernalis

Dry Years: Pre-CVP = 1930, 31, 33, 34, 39
Post-CVP = 1959, 60, 61, 64, 68

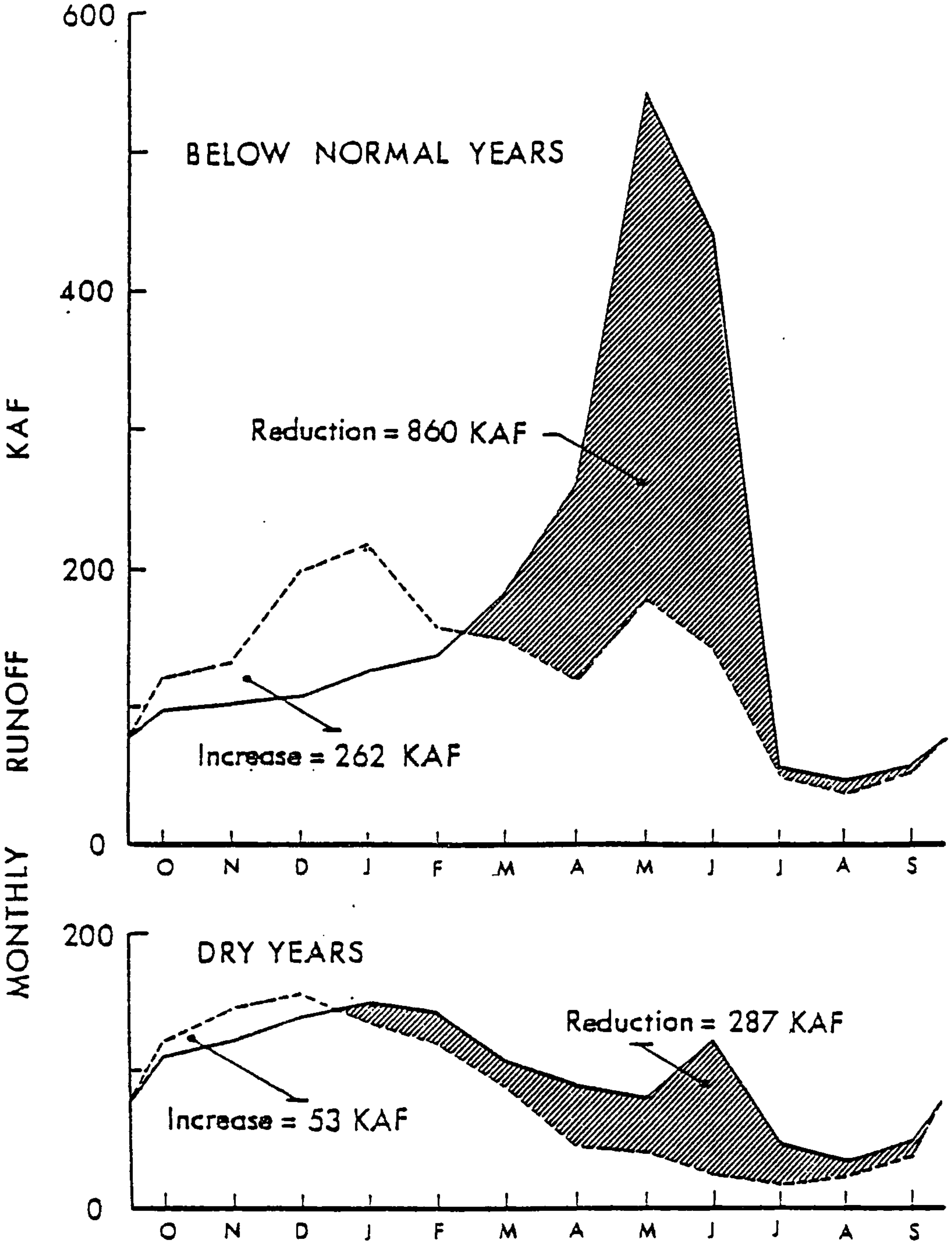
Below Normal Years: Pre-CVP = 1944, 48*, 49*, 50*
Post-CVP = 1953, 54, 55, 57, 66

*adjusted for the operation of Friant Dam during construction

FLOW DIFFERENCES
HISTORICAL PRIOR TO JAN 1944

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1930	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1931	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1932	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1933	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1934	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1935	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1936	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1937	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	1938	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	1939	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	1940	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1941	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	1942	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	1943	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	1944	0.0	0.0	0.0	-29.1	-22.9	-7.2	53.4	278.4	132.8	0.0	1.1	0.0
16	1945	-8.4	22.4	28.7	-14.9	80.9	11.3	12.6	-19.0	64.9	17.5	-8.4	-7.1
17	1946	-11.4	-14.5	-7.2	-93.3	-32.4	98.4	156.5	65.2	63.5	26.5	0.4	-2.8
18	1947	5.7	45.1	37.3	-14.0	22.6	-18.5	0.3	3.5	0.5	0.0	0.0	0.0
19	1948	9.0	2.5	3.4	12.3	13.8	21.9	77.8	279.5	193.8	2.9	0.0	1.9
20	1949	-3.5	-1.9	5.3	6.2	12.5	22.6	115.1	285.7	129.4	0.5	3.5	5.5
21	1950	4.3	3.8	4.0	32.9	52.3	45.5	135.0	274.1	136.7	4.1	3.2	3.3
22	1951	6.5	145.3	244.2	45.2	-55.5	74.8	118.2	119.2	129.1	40.7	3.3	0.2
23	1952	10.7	13.0	40.4	150.1	34.0	186.4	160.2	333.3	278.5	288.4	38.7	5.9
24	1953	-2.2	0.9	-4.8	27.4	22.6	35.6	96.4	135.4	148.7	10.5	5.3	0.0
25	1954	0.4	3.0	1.6	24.4	14.2	57.2	133.2	303.9	95.8	0.0	0.0	0.0
26	1955	-0.4	2.9	6.6	16.3	24.2	34.7	56.6	229.2	167.4	0.0	1.9	1.5
27	1956	5.0	7.5	292.7	236.5	-2.4	321.5	319.0	355.8	499.5	301.0	35.1	8.7
28	1957	4.0	2.8	3.3	17.7	33.3	14.6	56.0	215.9	210.5	0.0	0.0	1.9
29	1958	15.7	11.4	21.6	68.2	216.8	270.3	-25.0	255.8	349.0	237.4	43.3	9.3
30	1959	-0.5	10.4	12.4	23.7	70.3	12.1	5.5	0.0	7.7	0.0	0.0	8.2
31	1960	9.5	6.9	7.2	8.0	32.7	11.0	8.9	3.0	9.9	0.0	0.0	0.0
32	1961	3.9	19.7	33.2	7.6	20.7	4.9	4.4	1.7	7.4	0.0	0.0	0.0
33	1962	3.3	6.5	10.2	17.6	103.9	80.2	243.5	151.4	249.3	77.1	9.8	10.0
34	1963	4.0	-2.1	-1.5	119.1	187.0	83.0	71.2	152.4	218.6	97.8	13.7	16.3
35	1964	-9.4	51.9	31.4	18.8	34.3	49.9	1.0	2.2	10.3	0.0	0.0	0.0
36	1965	-20.1	8.1	97.4	319.9	275.9	310.6	256.6	278.3	407.7	249.1	64.6	9.4
37	1966	2.8	13.1	-19.3	9.8	24.1	63.3	134.9	252.3	67.9	0.0	0.0	0.0
38	1967	3.0	11.3	101.2	178.7	178.8	579.5	38.3	-74.9	374.2	497.9	61.6	25.0
39	1968	1.3	7.7	14.9	21.8	63.2	-3.1	0.0	0.0	6.9	0.0	0.0	0.0
40	1969	10.6	12.1	10.8	622.9	-23.4	-218.5	27.0	209.8	205.4	354.9	51.1	0.0
41	1970	-2.0	-18.6	1.0	52.2	-3.4	11.4	51.2	252.1	132.7	0.4	0.1	0.0
42	1971	-3.9	-3.5	-0.6	51.5	45.3	46.7	71.2	193.2	173.5	2.6	4.1	4.7
43	1972	0.2	0.1	25.0	26.4	25.6	74.4	57.6	188.0	103.9	0.0	0.0	23.5
44	1973	0.0	0.0	12.6	72.8	-31.1	-33.0	100.0	262.9	217.9	38.9	3.4	-3.9
45	1974	-10.3	40.5	44.9	150.0	49.9	184.4	120.5	218.6	231.4	53.2	6.4	-0.7
46	1975	-7.9	-12.1	3.0	38.1	15.4	74.2	38.7	197.0	282.0	49.2	-7.5	-1.0
47	1976	10.4	14.4	14.7	2.4	18.1	-6.3	0.0	0.0	0.0	0.0	0.0	0.0
48	1977	0.0	0.0	0.0	0.0	2.3	0.0	0.1	0.0	10.6	0.0	0.0	0.0
49	1978	6.6	7.7	52.2	303.0	243.9	413.2	-229.2	-27.8	633.9	432.4	65.6	79.0
50	1979	7.3	11.1	15.6	95.9	58.6	163.0	117.1	210.5	160.7	42.1	-3.0	-10.3
51	1980	12.0	7.9	7.4	564.2	385.0	10.5	292.6	242.0	542.5	422.2	41.8	0.0

SUMMARY OF REDUCTIONS IN RUNOFF DUE TO CVP,
SAN JOAQUIN RIVER AT VERNALIS, JANUARY 1944 THROUGH SEPTEMBER 1980
(Runoff in 1000 acre-feet)



CHANGES IN SEASONAL RUNOFF, PRE- AND POST-CVP PERIODS
SAN JOAQUIN RIVER AT VERNALIS

Notes: Changes represent all effects of development upstream of Vernalis including effects of CVP operation on runoff of Upper San Joaquin Basin above mouth of Merced River

Dry Years: Pre-CVP = 1930, 31, 33, 34, 39
Post-CVP = 1959, 60, 61, 64, 68

Below Normal Years: Pre-CVP = 1944, 48*, 49*, 50*
Post-CVP = 1953, 54, 55, 57, 66

*adjusted for the operation of Friant Dam during construction

SDWA Exhibit 26

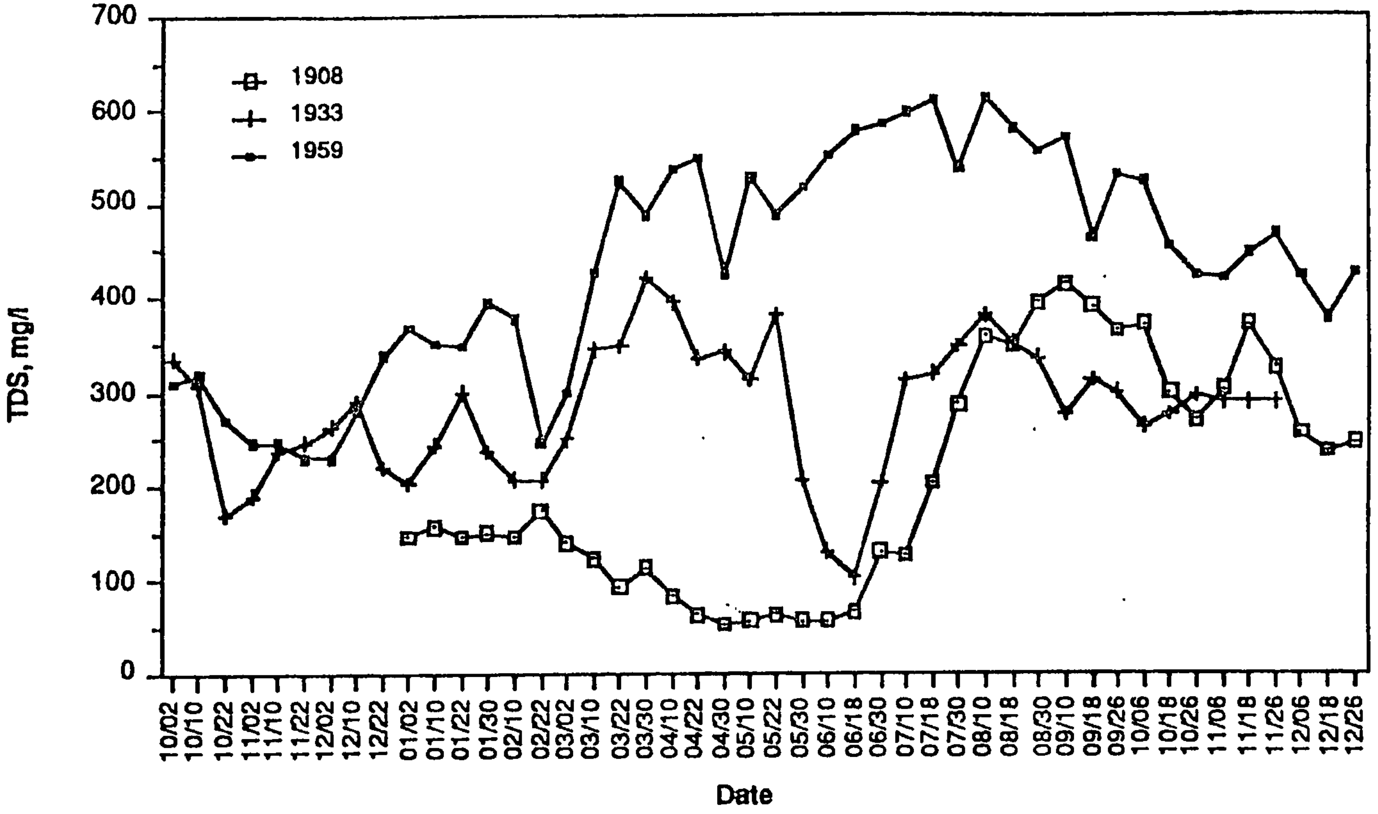
Mean Annual Agricultural Diversions of Major Irrigation Projects in the San Joaquin Basin, 1930-1950

Basin		Diversion, KAF	
Merced River			
North side		22*	
Main Merced I.D.		495*	
Minor		95*	
	Subtotal		612
Tuolumne River			
Turlock I.D.		527	
Modesto I.D.		336	
Minor		18*	
	Subtotal		881
Stanislaus River			
South San Joaquin I.D.		288	
Oakdale I.D.		106	
Minor		73	
	Subtotal		467
San Joaquin River			
	Total		1960

---

* Estimated from "Water Budgets for Major Streams in the Central Valley California" 1961-1977, USGS survey open-file report 85-401, 1985

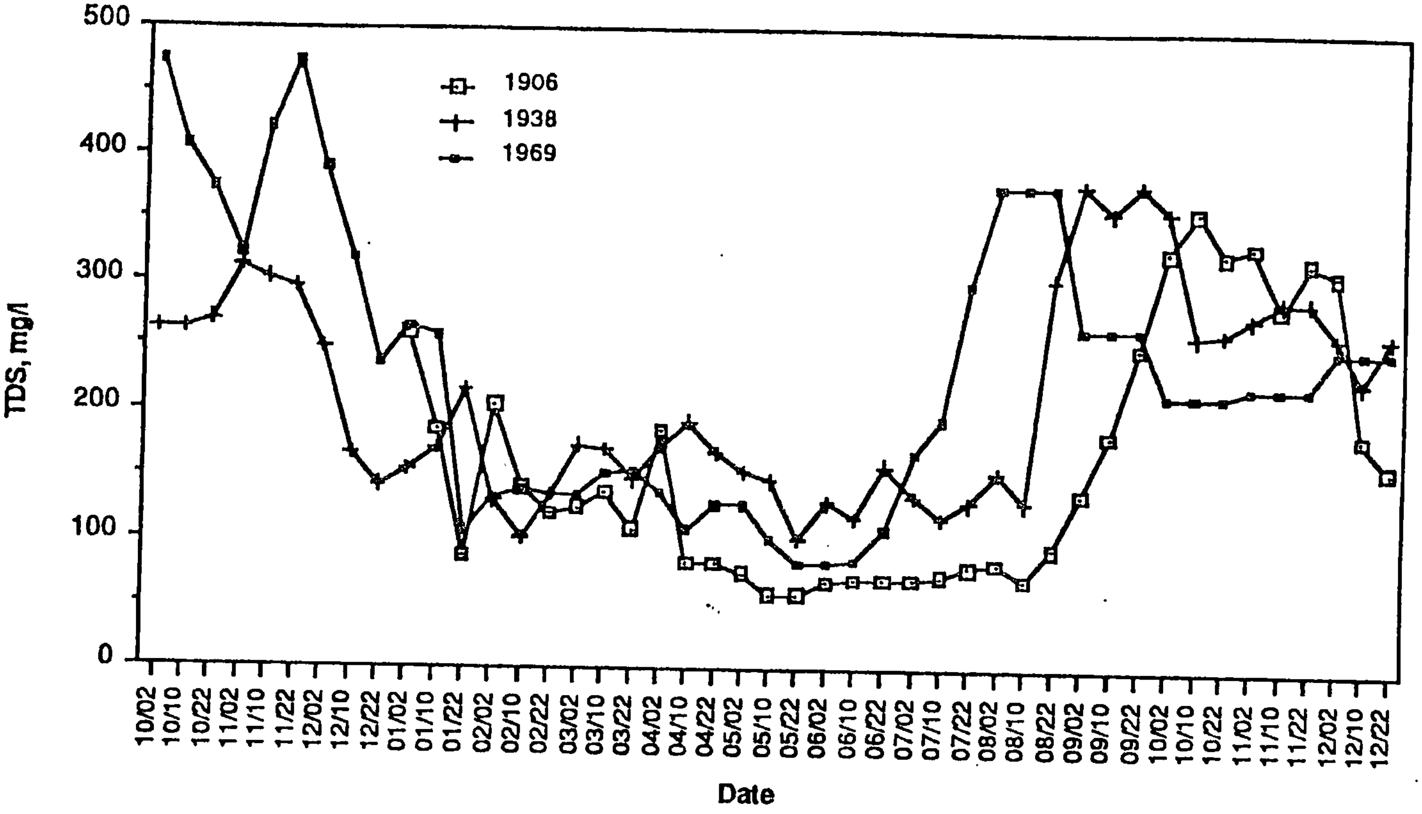
SDWA Exhibit 30



**TOTAL DISSOLVED SOLIDS for THREE DRY YEARS
SAN JOAQUIN RIVER at MOSSDALE**

Note: Unimpaired runoffs were: 1908 (3325 KAF), 1933 (3356 KAF), and 1959 (2986 KAF). Each of the three dry years follows a wet or above normal year, e.g. 1907 (11824 KAF), 1932 (6622 KAF), and 1958 (8367 KAF).

SDWA Exhibit 34



TOTAL DISSOLVED SOLIDS for THREE WET YEARS
SAN JOAQUIN RIVER at MOSSDALE

Note: Unimpaired runoffs were: 1906 (12,427 KAF), 1933 (11,248 KAF), and 1959 (12,295 KAF).

SDWA Exhibit 36

SUMMARY OF THE EFFECTS OF THE CVP ON THE QUANTITY AND QUALITY OF THE SAN JOAQUIN RIVER INFLOW TO THE SOUTHERN DELTA AT VERNALIS

AVERAGE FOR PERIOD 1948-1969

		Year Classification			
Item	Units	Dry	Below Normal	Above Normal	Wet
1. Post-CVP flow	1000 acre-feet				
A-S		196	699	1106	3741
O-M		761	839	1907	2747
Year		957	1538	3013	6488
2. Reduction in flow due to CVP	1000 acre-feet				
A-S		6.5	407	572	760
O-M		111.0	136	350	633
Year		115.5	543	922	1393
3. Post-CVP TDS	mg/L				
A-S		659	430	339	217
O-M		396	312	377	294
Year		528	371	358	256
4. Reduction in Post-CVP TDS due to restoring CVP reduction	mg/L				
A-S		20	140	99	28
O-M		44	37	67	46
Year		51	84	72	36
5. Increase in Salt Load due to CVP average over period 1948-69	1000 tons				
A-S		29	38.5	10.5	21.5
O-M		22	26	9.5	13.5
Year		51	64.5	20.0	35
6. Reduction in Post-CVP TDS due to removal of average CVP contribution to salt load increase	mg/L				
A-S		109	40	7	4
O-M		21	23	4	3
Year		39	31	5	4
7. Reduction in Post-CVP TDS due to restoring CVP flow reduction and removing of average CVP contribution to salt load increase	mg/L				
A-S		125	165	103	32
O-M		63	56	54	49
Year		86	107	76	40

Notes:

1. Based on Tables V-2 through V-17
2. From Table V-21, using average values over the ranges indicated
3. From Table VI-13
4. $$\text{Reduction} = \text{Post-CVP TDS} - \frac{\text{Post-CVP flow} \times \text{Post-CVP TDS} + 50 \times \text{CVP flow reduction}}{\text{Post-CVP flow} + \text{CVP flow reduction}}$$
$$= (3) - \frac{(1) \times (3) + 50 \times (2)}{(1) + (2)}$$
5. From Table VI-34; Average Increase Caused by CVP = Total Increase, 1948-69/2
$$\text{Pre-CVP salt load} = \frac{\text{Salt Load Increase}}{\text{Percent of Pre-CVP}} \times 100$$
6. $$\text{Reduction} = \frac{\text{Salt Load Increase Due to CVP}}{1.36 \times \text{Post-CVP flow}} = \frac{(5) \times 1000}{1.36\ (1)}$$
7. $$\text{Reduction} = \text{Post-CVP TDS} - \frac{\text{Post-CVP flow} \times \text{Post-CVP TDS} - \text{Salt Load Incr.}/1.36 + 50 \times \text{CVP flow reduction}}{\text{Post-CVP flow} + \text{CVP flow reduction}}$$
$$= (3) - \frac{(1) \times (3) - (5) \times 1000/1.36 + 50 \times (2)}{(1) + (2)}$$

SDWA Exhibit 78

SUMMARY OF THE EFFECTS OF THE CVP ON THE QUANTITY AND QUALITY OF THE SAN JOAQUIN RIVER INFLOW TO THE SOUTHERN DELTA AT VERNALIS

DECADE OF THE 1960s

		Year Classification			
Item	Units	Dry	Below Normal	Above Normal	Wet
1. Post-CVP flow	1000 acre-feet				
A-S		190	246	1200	3639
O-M		695	1450	950	2836
Year		885	1696	2150	6475
2. Reduction in flow due to CVP	1000 acre-feet				
A-S		6.5	407	572	760
O-M		111.0	136	350	633
Year		115.5	543	922	1393
3. Post-CVP TDS	mg/L				
A-S		673	683	326	225
O-M		418	284	461	308
Year		546	484	394	267
4. Reduction in Post-CVP TDS due to restoring CVP reduction in flow	mg/L				
A-S		21	395	89	30
O-M		51	20	111	47
Year		57	105	103	38
5. Increase in Salt Load due to CVP, through decade of 1960s	1000 tons				
A-S		58	77	21	43
O-M		44	52	19	27
Year		102	129	40	70
6. Reduction in Post-CVP TDS due to removal of CVP contribution to salt load increase	mg/l				
A-S		224	230	13	9
O-M		47	26	15	7
Year		85	56	14	8
7. Reduction in Post-CVP TDS due to restoring CVP flow reduction and removing CVP contribution to salt load increase	mg/L				
A-S		238	481	98	37
O-M		91	44	121	53
Year		132	148	113	45

Notes:

1. Based on Tables V-2 through V-17 for decade of 1960s
2. From Table V-21, using average values over the ranges indicated
3. From Table VI-13
4. Reduction = Post-CVP TDS $-\dfrac{\text{Post-CVP flow} \times \text{Post-CVP TDS} + 50 \times \text{CVP flow reduction}}{\text{Post-CVP flow} + \text{CVP flow reduction}}$

   $$= (3) - \frac{(1) \times (3) + 50 \times (2)}{(1) + (2)}$$

5. From Table VI-34; increase caused by CVP through the 1960s; Pre-CVP salt load $= \dfrac{\text{Salt Load Increase}}{\text{Percent of Pre-CVP}} \times 100$
6. Reduction $= \dfrac{\text{Salt Load Increase Due to CVP}}{1.36 \times \text{Post-CVP flow}} = \dfrac{(5) \times 1000}{1.36\ (1)}$
7. Reduction = Post-CVP TDS $-\dfrac{\text{Post-CVP flow} \times \text{Post-CVP TDS} - \text{Salt Load Incr.}/1.36 + 50 \times \text{CVP flow reduction}}{\text{Post-CVP flow} + \text{CVP flow reduction}}$

   $$= (3) - \frac{(1) \times (3) - (5) \times 1000/1.36 + 50 \times (2)}{(1) + (2)}$$

SDWA Exhibit 79

SUMMARY OF THE EFFECTS OF THE CVP ON THE QUANTITY AND QUALITY OF THE SAN JOAQUIN RIVER INFLOW TO THE SOUTHERN DELTA AT VERNALIS

DECADE OF THE 1970s

Item	Units	Year Classification			
		Dry	Below Normal	Above Normal	Wet
1. Post-CVP flow	1000 acre-feet				
A-S		196	549	1037	3249
O-M		780	1579	1601	1421
Year		976	2128	2638	4670
2. Reduction in flow due to CVP	1000 acre-feet				
A-S		6.5	407	572	760
O-M		111.0	136	350	633
Year		115.5	543	922	1393
3. Post-CVP TDS	mg/L				
A-S		747	481	382	269
O-M		569	290	325	500
Year		658	385	354	385
4. Reduction in Post-CVP due to restoring CVP reduction	mg/L				
A-S		22	183	118	42
O-M		65	19	49	139
Year		64	68	79	77
5. Increase in Salt Load due to CVP through decade of 1960s	1000 tons				
A-S		58	77	21	43
O-M		44	22	19	27
Year		102	129	40	70
6. Reduction in Post-CVP TDS due to removal of CVP contribution to salt load increase	mg/L				
A-S		218	103	15	10
O-M		41	24	9	72
Year		77	45	11	11
7. Reduction in Post-CVP TDS due to restoring CVP flow reduction and removing CVP contribution to salt load increase	mg/L				
A-S		233	243	128	49
O-M		101	41	56	148
Year		133	104	87	85

Notes:

1. Based on U.S. Geologic Survey records
2. From Table V-21, using average values over the ranges indicated
3. From USBR continuous recorder data
4. Reduction = Post-CVP TDS − $\frac{\text{Post-CVP flow} \times \text{Post-CVP TDS} + 50 \times \text{CVP flow reduction}}{\text{Post-CVP flow} + \text{CVP flow reduction}}$

$$= (3) - \frac{(1) \times (3) + 50 \times (2)}{(1) + (2)}$$

5. From Table VI-34; increase caused by CVP through the 1960s; Pre-CVP salt load = $\frac{\text{Salt Load Increase}}{\text{Percent of Pre-CVP}} \times 100$
6. Reduction = $\frac{\text{Salt Load Increase Due to CVP}}{1.36 \times \text{Post-CVP flow}} = \frac{(5) \times 1000}{1.36\ (1)}$
7. Reduction = Post-CVP TDS − $\frac{\text{Post-CVP flow} \times \text{Post-CVP TDS} - \text{Salt Load Incr.}/1.36 + 50 \times \text{CVP flow reduction}}{\text{Post-CVP flow} + \text{CVP flow reduction}}$

$$= (3) - \frac{(1) \times (3) - (5) \times 1000/1.36 + 50 \times (2)}{(1) + (2)}$$

SDWA Exhibit 80

Tuolumne River Yearly Data
(Acre-ft)

Water Year	HHetchy(1)	Abv La Grnge(2)	Mdsto Cnl(3)	Turlk Cnl(4)	Bw La Grnge(5)	Tuol @TC(6)
1896		1536300			1536300	
1897		2408720			2408720	
1898		904979			904979	
1899		1405120			1405120	
1900		1710080		39310	1670770	
1901		2868550		52320	2816230	
1902		1478310		110900	1367410	
1903		1732873		129200	1603673	
1904		2195340		141000	2054340	
1905		1394289		151000	1243289	
1906		3309514		202600	3106914	
1907		3402910		198300	3204610	
1908		644030		205600	438430	
1909		2253650		229000	2024650	
1910		1784450	143400	150500	1490550	
1911		2895310	184100	298500	2412710	
1912		1050170	158800	255400	635970	
1913		1081250	213200	293000	575050	
1914		2624610	215600	251100	2157910	
1915		2041480	200400	345600	1495480	
1916		2498840	202900	405200	1890740	
1917		2226570	264700	429400	1532470	
1918		1456980	236400	343100	877480	
1919		1337740	232900	325300	779540	
1920		1330760	255000	384900	690860	
1921		2022560	296700	388900	1336960	
1922		2471270	279100	382000	1810170	
1923		1433250	339300	454300	639650	
1924		751370	237300	423300	90770	
1925		1992690	304900	451700	1236090	
1926		1203370	307100	466200	430070	
1927		1911980	320100	465200	1126680	
1928		1607220	271300	503600	832320	
1929		1031530	280100	464900	286530	
1930		1121310	316800	465800	338710	211900
1931		759090	189400	391500	178190	137800
1932		1809000	375500	531200	902300	66500
1933		1149000	325000	511300	312700	256300
1934	11200	964000	274900	492300	196800	152200
1935	38800	1870000	311000	502500	1056500	139300
1936	56800	2077000	355100	499100	1222800	1499100
1937	7200	1994000	314800	490100	1188800	1547700
1938	1700	3153000	333400	426000	2393600	2713700
1939	53200	1221000	322400	537400	361200	605900
1940	24100	2010000	335000	547400	1127600	1432400
1941	19000	2369000	335300	509300	1524400	1825600
1942	14100	2350000	376300	558900	1414800	1745100
1943	25300	2357000	369800	567900	1419300	1723800
1944	47500	1313000	390400	618300	304300	584700
1945	60200	1972000	392800	594500	984700	1291200
1946	61700	1863000	401700	599700	861600	1154000
1947	69400	1121000	296600	541600	282800	530900
1948	68800	1207000	331300	502700	373000	604400
1949	67400	1176000	349600	581900	244500	470500
1950	75400	1416000	360300	590900	464800	754400
1951	81500	2406000	345700	550300	1510000	1743300
1952	49800	2765000	347400	560900	1856700	2063800
1953	94500	1521000	349100	642500	529400	790900
1954	112900	1432000	369200	605700	457100	678600
1955	124700	1023000	292000	549200	181800	377400
1956	80000	2755000	406900	617700	1730400	1925000
1957	123600	1285000	341400	603900	339700	540100
1958	70300	2388000	331300	528500	1528200	2146400
1959	167300	1213000	284300	504700	424000	665500
1960	166600	875200	261300	482100	131800	298300
1961	17400	704200	224800	372000	107400	261900
1962	158500	1151000	364600	634400	152000	425400
1963	127000	1788000	359500	574700	853800	757800
1964	185600	1246000	286500	522400	437100	563700
1965	164700	2254000	405800	653000	1195200	1488300
1966	198400	1410000	282700	500900	626400	754700
1967	182200	2531000	345500	609900	1575600	1839300
1968	223200	1169000	291400	482300	395300	567200
1969	197800	3336000	383500	595200	2357300	2498500
1970	198800	1823000	372300	618500	832200	1017300
1971	213300	1249900	315100	588900	345900	540000
1972	260400	1016800	274600	576900	165300	331000
1973	205600	1092700	340600	587100	165000	431000
1974	215500	1354700	357700	621300	375700	622000
1975	228600	1642400	392500	688400	561500	927000
1976	263700	1533400	392100	780300	361000	668000
1977	222700	504120	237000	200000	67120	155000
1978	161300	1093700	287700	513900	292100	484000
1979	232015	1685500	386400	641900	657200	953000
1980	176384	2580900	413700	660200	1507000	1837000
1981	258510	1559800	389900	728400	441500	726000
1982	154288	2643700	335100	590600	1718000	
1983	169324	4478200	359400	653800	3465000	
1984	232428	2580300	408900	785400	1386000	
1985	273943	1353800	362800	614900	376100	
1986	234617	2069200	312300	622900	1134000	

Ref.#	Source	
1	"Effects of CVP"	
2	USGS	note; after 1969 =sum of blw LGrange,Modesto,& Turlock
3	USGS	note: 1952 is avg value(nd)
4	USGS	
5	USGS	
6	DWR	

Tuolumne River Runoff and Diversions, 1896-1986

GTO
Consulting Engineers
G. T. ORLOB & ASSOCIATES

1850 de Leu Drive, Green Valley, Suisun, CA 94585
(707) 864-1850

12 July 1987
GTOA 4102

Memo:

To: Alex Hildebrand

From: G. T. Orlob

Re: Effects of Reallocation of Hetch Hetchy Diversion to San Francisco on Water Quality at Vernalis During 1977 Irrigation Season

Reallocation of some portion of the Hetch Hetchy diversion to a "Delta Pool" during dry years could improve water quality at Vernalis, depending upon the quality and quantity of the allocated flow, and the flow in the San Joaquin River.

Three scenarios for reallocation are considered:

1. Downstream release of one-half of the average monthly diversion (9.27 KAF during 1977),

2. Downstream release sufficient to control quality at Vernalis to a maximum of 500 mg/L TDS, and

3. Downstream release sufficient to control quality at Vernalis to a maximum of 450 mg/L TDS.

Using historic flows and qualities at Vernalis for the irrigation season of 1977, we obtain the following estimates:

Scenario 1 -- Allocation 1/2 average diversion

Mo.	Vernalis TDS mg/L	H-H Allocation* KAF	Modified TDS mg/L
A-77	864	9.27	482
M	777	9.27	560
J	888	9.27	382
J	942	9.27	341
A	908	9.27	372
S	844	9.27	438
	Total	55.62 KAF	

* TDS assumed at 50 mg/L

Scenario 2 -- Allocate to achieve 500 mg/L TDS

Mo.	Vernalis TDS mg/L	H-H Allocation KAF	Modified TDS mg/L
A-77	864	8.5	500
M	777	13.5	500
J	888	5.3	500
J	942	4.4	500
A	908	5.1	500
S	844	6.8	500
	Total	43.6 KAF	

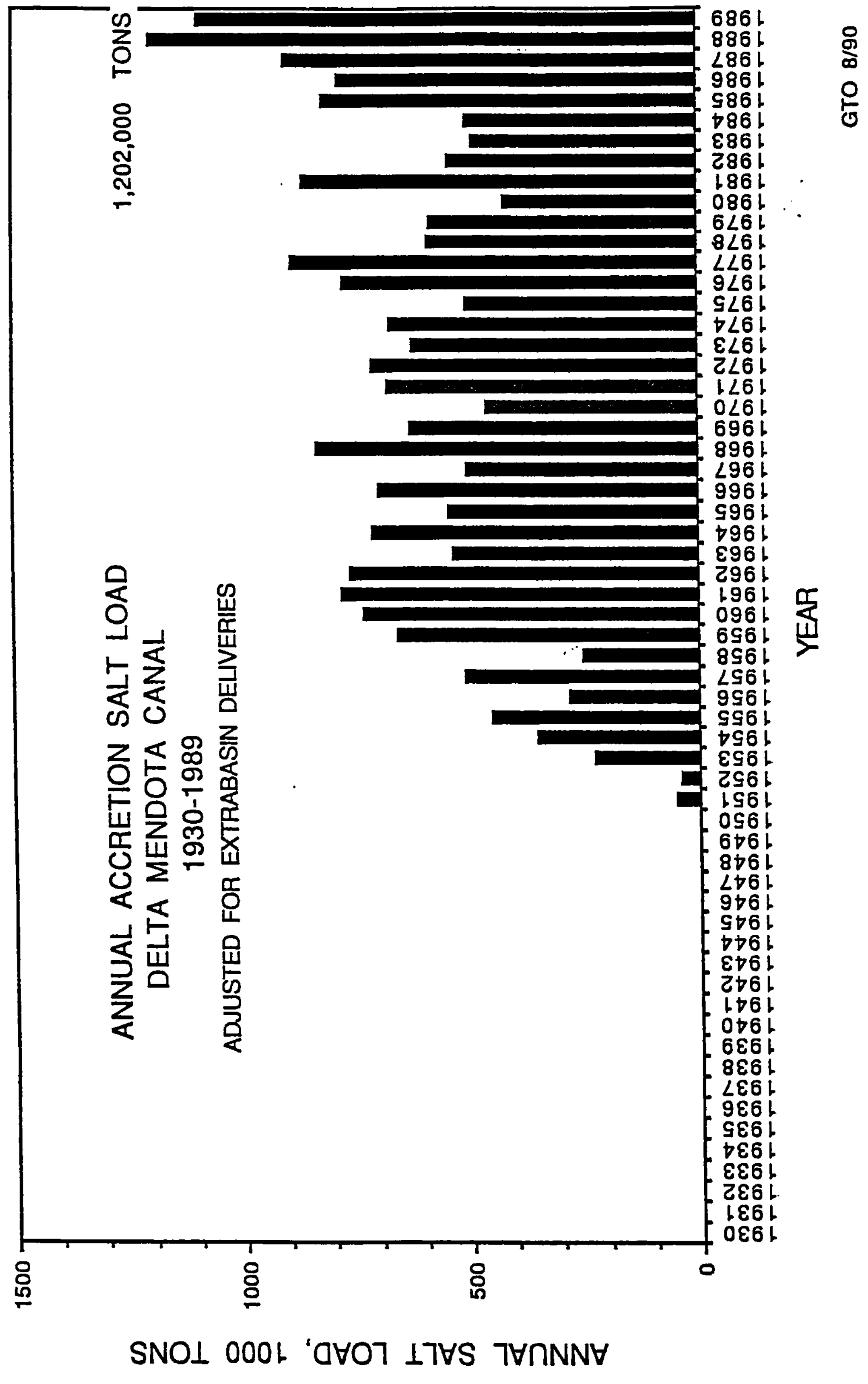
Scenario 3 -- Allocate to achieve 450 mg/L TDS

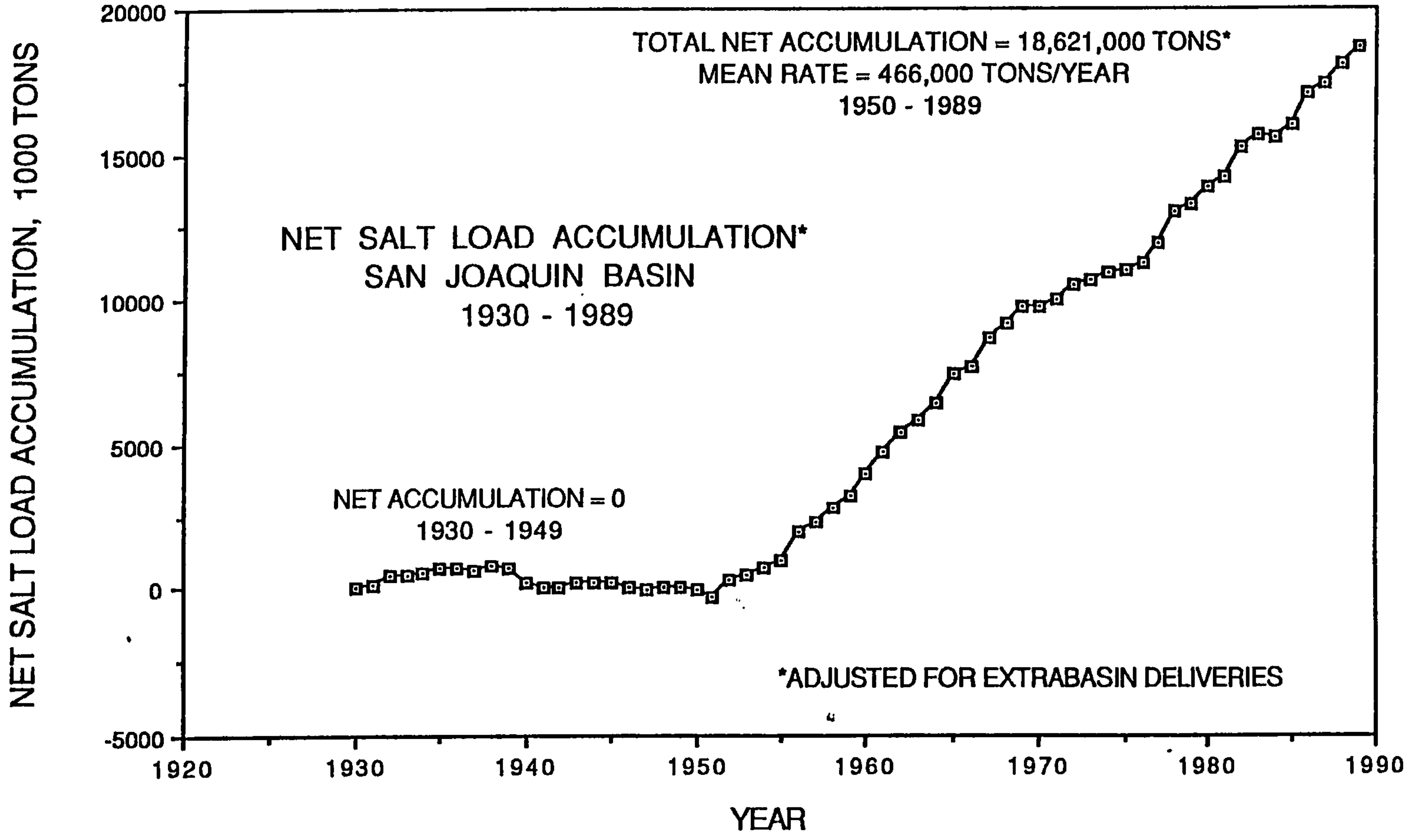
Mo.	Vernalis TDS mg/L	H-H Allocation KAF	Modified TDS mg/L
A-77	864	10.9	450
M	777	18.0	450
J	888	6.7	450
J	942	5.5	450
A	908	6.4	450
S	844	8.8	450
	Total	56.3 KAF	

It appears that an allocation to a "Delta Pool" of about one-quarter of the 1977 Hetch Hetchy diversion of 222.7 KAF would have been sufficient to markedly improve the quality at Vernalis during the 1977 irrigation season. Additionally, such an allocation would have roughly doubled the net flow into the Delta at Vernalis.

GTO:lo

SDWA-WQCP-21


ANNUAL ACCRETION SALT LOAD
DELTA MENDOTA CANAL
1930-1989
ADJUSTED FOR EXTRABASIN DELIVERIES
1,202,000 TONS
ANNUAL SALT LOAD, 1000 TONS
1500
1000
500
0
YEAR
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
GTO 8/90



GTO 8/90

SDWA-WQCP-24

BAY-DELTA OVERSIGHT COUNCIL

DRAFT

BRIEFING PAPER ON INTRODUCED FISH, WILDLIFE AND PLANTS IN THE SAN FRANCISCO BAY/ SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

Bay-Delta Oversight Council

May 1994

EXECUTIVE SUMMARY

INTRODUCTION

Regulatory actions over the past decade in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary have affected the operations of water projects, which provide the water supply for two-thirds of all Californians, as well as irrigation water for millions of acres of agricultural lands. Water management actions have been implemented in the Estuary during this period to protect the native winter-run Chinook salmon, the native delta smelt, and other depleted fishery resources. Some of the water users impacted by those actions have expressed concerns over whether other factors in the Estuary have been given sufficient consideration. One of the factors underlying this concern is the large number of introduced species in the Estuary in relation to the numbers of native species, which have been the focus of these regulatory actions.

In the draft briefing paper, prepared for the Bay-Delta Oversight Council, titled "Biological Resources of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary", specifically the section entitled "Factors Controlling the Abundance of Aquatic Resources", dated September, 1993 the effect of introduced species was presented as a comparatively minor factor affecting the Estuary's fishery resources. Some commentors strongly disagree with this characterization and believe introduced species are a major factor that has and will affect the Council's efforts to "fix" the Delta. One illustration of the concern regarding introduced species is that in 1991 seven of the ten most abundant species salvaged at the State Water Project fish screens were introduced species and the sport catch of introduced species during the 1980s in the Estuary exceeded the catch of native species.

The role of introduced species in the Estuary and any possible limiting effects they may have on the recovery of certain depleted species and the overall restoration and protection of the Estuary ecosystem is not well understood. Conditions in the Estuary are ever changing and new introduced organisms continue to be documented as surveys and field work is conducted in the Estuary.

This briefing paper is intended to provide the Council with an overview of the current state of knowledge with respect to introduced species in the Estuary and discusses how the ecosystem may be affected by their presence.

BACKGROUND

Introduced species can affect native fish, wildlife, and plants through a wide variety of mechanisms. These include: competition for space, competition for existing food resources, predation, disturbance, hybridization, pathways for and sources of disease, and physical alteration of the environment. Non-native plants can contribute to the incremental loss of habitats and biological diversity by affecting the ecological process of succession, productivity, stability, soil formation and erosion, mineral cycling, and hydrologic balance.

Introductions of non-native species have occurred from the initial human settlement of the region. Such introductions, intentional or not, impact the native species populations by competing for available resources and habitat and predation. Intentional introductions were often the result of government agencies' intent to provide additional opportunities for anglers or attempt to control a pest species. Non-intentional introductions are incidental to normal day-to-day activities in the Estuary. Ballast water discharges and containerized freight, for example, are thought to be significant pathways.

Introduced species have probably affected the abundance of native species in the Estuary, but only in a few cases is the data available to document that an introduced species is a significant cause of the decline of native species. The ecological complexities of the Estuary are not well understood and the available data on impacts of native and non-native interactions is somewhat imprecise. Little is known about impacts resulting from early introductions due to limited monitoring. However, even with the more extensive monitoring of introduced species in the last 25 years, the current data may not fully document recent introductions to the system. Developing in-depth data for introduced species is difficult as they often are not noticed or studied in detail until they become nuisances.

The primary focus of concern over the role of introduced species within the Estuary are the processes of predation and competition. Evaluation of the consequences of introductions requires the formulation of evidence of the affects of these processes. This assessment is difficult due to the lack of historic data. Species introduced during the early part of the state's history are interacting with the native biota. Thus, potential impacts are difficult to discern due to this interaction. Additionally, the Estuary's ecology is continually evolving as a result of intensified land use and modifications to water project operations. These changes alter conditions to such an extent that the dynamics of the relationships between introduced species and native species interactions are affected.

Monitoring during the last 25 years has been much more extensive than in previous periods and has led Department of Fish and Game (DFG) biologists to conclude that only the depletion of the native copepod (*Eurytemora affinis*) by introduced copepods, and ,subsequently, the introduced Asian clam provides evidence of competition and predation by introduced species being the principal cause of a decline in the population of a native aquatic species. While another possible example is inland silversides and delta smelt, that needs further evaluation, particularly as to what happened during the 1993 rebound in delta smelt abundance.

Evidence of native wildlife depletion attributable to predation and competition by introduced species is more direct. Adverse effects on native wildlife and plant species by the red fox, Norway rat, Virginia opossum, feral cats, and several terrestrial and aquatic plant species have been documented.

One prominent perspective on the issue of the affects of introduced species on the native flora and fauna is that species such as the striped bass and largemouth bass were introduced into the system and have existed with native species since that time in the Estuary. Although some, and perhaps extensive, alteration of the native fishery resources undoubtedly occurred, the benefits derived from these introduced species were considered sufficient at the time to justify their introduction. In those cases, the non-native species are now considered part of the Estuary's biological system. Many fisheries management experts believe that restoration of the Estuary should include some non-native species such as striped bass which provide important recreational opportunities for sport anglers and contribute to the economy of the State. They also believe that this can be accomplished without compromising the goals of restoring and protecting the Estuary.

A second perspective is that from the very first time that a non-native species was introduced into the system the biotic uniqueness and structure of the Estuary as a whole was altered. This alteration of the Estuary was such that the non-native species were usually the winners and the native species the losers. Advocates of this position also tend to feel that management actions aimed at increasing the abundance of introduced species populations, such as striped bass, are in conflict with goals set for achieving recovery of native species.

A third perspective is held by those experts who contend that recovery efforts should focus on ecosystems in a more global nature. For example, Dr. Peter Moyle of the University of California Davis believes introductions may increase local diversity, but they often cause a decrease in global diversity when native species are driven to extinction. The U.S. Congress Office of Technology Assessment (OTA) states that the concept of "vacant niche", (which holds that some ecological roles may not be filled in a community, and species can be selectively introduced to fill these voids) is inappropriate because few species can fit the narrow ecological vacancies identified by managers, and because it is virtually impossible to predetermine the role a species will assume after it has been released. Dr. Phyllis Windle of the OTA further points out that in focussing on declines of natives and the often-ambiguous data on species extinctions, we lose sight of significant ecosystem changes in structure and function that usually accompany the introduction of non-native species.

Attempts to prevent new species from becoming established in the Estuary has resulted in elaborate, expensive, and difficult control efforts spearheaded by the Department of Fish and Game, Department of Boating and Waterways, and Department of Food and Agriculture.

INTRODUCED SPECIES

The Estuary is home to more than 150 introduced aquatic species of plants and animals including over 27 different non-native fish species and over 100 different species of marine invertebrates. The briefing paper discusses this collection in some detail. A selection of the more significant species are highlighted in this executive summary.

Fish

Government agencies have intentionally introduced certain species to expand the opportunities for angling and commercial fishing, to expand the forage base for predators, and to control pest populations. Other mechanisms for introduction include unauthorized transplants by individuals, and non-intentional introductions occurring incidental to commercial and sporting activities (i.e. discharge of ship ballast water, transport of organisms on the hulls of fishing boats, etc.).

Striped bass (*Morone saxatilis*) were introduced into the Sacramento-San Joaquin Estuary in the late 1800s. Striped bass were stocked by the DFG from 1982 through 1992 in an effort to support and maintain the existing population in the Sacramento-San Joaquin Estuary. This practice was suspended by the DFG in response to concerns that the stocking of striped bass, which was only a small portion of the natural process, was adding predators to the system which could harm populations of the winter-run Chinook salmon.

It is reasonable to believe that a top of the food chain predator like striped bass, which in the late 19th century became a dominant fish in the estuarine ecosystem, must have decreased the abundance of some other species. However, available evidence is not sufficient to identify those declines. Thus striped bass are an important part of the introduced species issue both because their introduction may have influenced the abundance of other species, and because more recent introductions of other species may have a role in the recent decline of striped bass. The evidence indicates striped bass decrease salmon abundance, but are not the principal controlling factor in recent declines of salmon or delta smelt.

The **largemouth bass** (*Micropterus salmoides*), a species introduced in the late 1800's to enhance sport fishing, is one of several members of the sunfish family which, it is theorized, may have collectively out-competed the native Sacramento perch for habitat. They have also been implicated in the decline of the red- and yellow-legged frogs in areas where they coexist. While the prevailing judgement is that largemouth bass probably contributed to declines in various native fishes in the Delta, conclusive evidence has not yet been demonstrated.

The **chameleon goby** (*Tridentigor trigonocephalus*), introduced sometime in the 1950's, had become the third most abundant species identified in the DWR's southern Delta egg and larval sampling by 1989, and it was the most abundant fish by 1990. Chameleon goby was the only species more abundant than 6 mm striped bass in 1991. However, there is insignificant data to assess the impacts of the chameleon goby's on native species.

The **inland silversides** (*Menidia beryllina*) was introduced into Clear Lake and migrated to the Delta by the mid 1970s. DFG biologists have argued that silversides had little effect on other species because increases in silversides did not coincide with the decline in other species. Dr. Bill Bennett of U.C. Davis, however, has hypothesized that predation by silversides on eggs and larvae of delta smelt may be important in the decline of delta smelt. Predation by inland silversides on delta smelt larvae in controlled experiments and the possibility that silversides may be more abundant than the DFG surveys indicate since shoreline areas are not sampled as extensively as midchannel areas has led other experts to concur with his hypothesis. While Dr. Bennett's hypothesis appears to have merit, further evaluation is necessary, particularly to explain the 1993 rebound in delta smelt abundance.

Amphibians

Bullfrogs (*Rana catesbeiana*) successfully introduced into California have been noted to prey upon and out compete native species such as the red-legged and yellow-legged frogs in areas where they coexist.

Reptiles

The impact of introduced **sliders** (*Psuedemys scripta*) and **softshell turtles** (*Trionyx spiniferus*) on native organisms is unknown. However, they do feed on frogs, aquatic invertebrates, and carrion. In addition, the release of aquarium trade turtles has the potential to introduce pathogens and parasites into southwestern pond turtle populations and can result in competition for resources.

Invertebrates

The changes in invertebrate populations have been more dramatic than those for fish in recent years. Several new species of zooplankton have dramatically changed the species composition in the brackish and freshwater portions of the Estuary.

Introduction of the **asian clam** (*Potomocorbula amurensis*) in 1986 and its consequential biological effects on the food chain have been detected by long term monitoring programs. The clam occupies bottom space to the exclusion of other benthic species, as measured by the reductions in their average densities, and also alters the benthic community's species structure. The asian clam has a higher plankton filtration rate than most native invertebrates and has been implicated in the reduction in chlorophyll biomass and production rate in Suisun Bay. Some experts theorize that this reduction in biomass could affect the quality of the entrapment zone and its ability to sustain larval fish and other native invertebrate populations. However, the ecological significance of these changes remains to be evaluated further.

Wildlife

Several non-native wildlife species reside in the Estuary. A number of these species may be viewed as desirable; providing hunting and other recreational opportunities. Other non-native wildlife species which were introduced have expanded their numbers into the Estuary and have increased predation upon the native wildlife populations, thus disrupting natural predator-prey relationships of the Estuary.

Norway rats (*Rattus norvegicus*) introduced and well established in many areas by the 1800s, are predators on waterfowl and nesting California clapper rails; reportedly taking about 33 percent of the eggs laid by clapper rails in southern portions of the Estuary. Once rats become established on colonial bird nesting islands, the reproductive success of these bird colonies may be greatly affected by these opportunistic predators.

Feral cats (*Felix catus*), abandoned and wild, are a major predator for bird and mammal populations in the wetland areas of the Estuary.

Red Fox (Vulpes Vulpes) was brought to California for hunting and for fur farming during the late 1800s. The red fox preys on eggs of Caspian terns and California least terns in the Bay area, causing complete nesting failure of entire colonies. The red fox is also implicated in contributing to the decline of the California clapper rail in the Estuary. Along the bay, red fox prey upon the eggs of black necked stilts, American avocets, and snowy plovers. The increase in the range and population of the red fox is due to the species ability to adapt to urbanization and the subsequent elimination of larger predators such as the coyote which would normally help in controlling the numbers of red foxes.

Terrestrial Plants

There is a long history of concern about the impact of non-native plant species on wetland areas. The extent or cumulative effect of these species on the native vegetation in the Estuary is not fully understood and more information is needed to better understand the complex, usually indirect, interactions of plants in natural environments; both for scientific understanding and to promote better vegetation management.

Broadleaf pepper grass (*Lepidium latifolium*) is widely distributed in the state, difficult to quarantine, and an economic threat to agriculture.

Eucalyptus (*Eucalyptus sp.*), in certain situations, may have crowded out native grasses and forbs by shading out these species, by the destroying the understory with debris and oils released by the trees, and competing for soil and water.

Aquatic Plants

Impacts on the Delta ecosystem from aquatic weeds include blocking flood control channels, increasing mosquito habitat, increasing siltation, changing water temperature, changing dissolved oxygen, obstructing boating recreation activities, and decreasing property values for properties adjacent to affected channels.

Waterhyacinth (*Eichhornia crassipes*) provides additional escape cover for fish and other organisms, but the relative value of escape cover provided by submerged native aquatic plants in contrast to cover provided by the submerged portion of hyacinths is not known. Although the effects on fish and wildlife are not well understood, the additional shade provided by the waterhyacinth negatively impacts phytoplankton and can cause rooted submergent plants to die.

PERSPECTIVES ON INTRODUCED SPECIES

An earlier version of the draft briefing paper was submitted to a diverse review panel representing federal, state, and local organizations for review and comment. In addition, they were requested to submit a separate perspective paper based on the particular focus of their agency or group which may have differing viewpoint than presented in the briefing paper. These perspective papers are reproduced, as submitted, and included as part of this briefing packet. The following summaries highlight only certain points within the papers and should not be considered substitutes for the full text.

The United States Congressional Office of Technology Assessment (OTA) submitted a report brief on "Harmful Non-indigenous Species in the United States" The brief states that harmful non-indigenous species have exacted a significant toll on U.S. natural areas, ranging from wholesale changes in ecosystems to more subtle ecological alterations. They have found that fundamental changes in structure and function of habitat were as much of a concern as species declines. That is, non-natives change the players, but can also change the rules of the game. The OTA believes the concept of "vacant niche", (which holds that some ecological roles may not be filled in a community, and species can be selectively introduced to fill these voids) is inappropriate because few species can fit the narrow ecological vacancies identified by managers, and because it is virtually impossible to predetermine the role a species will assume after it has been released.

Dr. Phyllis Windle of the Office of Technology Assessment comments that in focussing on declines of natives and the often-ambiguous data on species extinctions, we lose sight of these significant ecosystem changes. In addition, Dr. Peter Moyle of the University of California Davis comments that introductions may increase local diversity, but often cause a decrease in global diversity when native species are driven to extinction.

Lars Anderson of the Agricultural Research Service (ARS) comments that the objectives of the ARS are to sustain species diversity and improve aquatic habitats, as well as to conduct ongoing research and advise several state/federal programs which complement and partially address specific objectives of the BDOC process. In addition, he identifies three major needs: 1) increased systems-level approach to answering questions related to "fixing" the Delta; 2) efficient research coordination across federal, state, university, and private groups; and 3) current vegetation surveys coupled with the generation of GPS/GIS to establish a "baseline" so that future research can be planned and executed efficiently and effectively.

In support of the opinion that introduced species add diversity and value to the Estuary, Don Stevens, a senior biologist of the DFG comments that an appropriate goal is to restore a biologically diverse ecosystem which maximizes production of desirable recreational and economically important species while not jeopardizing the existence of natives. He states that, for the most part, native fishes have endured despite numerous more or less indiscriminate intentional introductions that have dominated the Delta's fish fauna for more than a century. In addition, he comments that the present declines of both native and introduced species have occurred concurrently with major changes in water management.

Randy Brown, Chief of the Environmental Services Office in the Department of Water Resources comments that introduced species and other factors result in a constantly changing Estuary and one where few management measures can be successfully used to control these species. He states that the scientific community does not have a good understanding of the interactions between newly introduced species and those already present. He comments that without a stable system it is almost impossible to define management actions that will result in specific changes in populations of target species and that deliberations regarding these actions should recognize that they may not achieve their intended objectives because of this instability. In addition, he believes federal and state agencies must do all in their power to limit future introductions, since it is essentially impossible to control species in the Estuary once they are introduced. He states that one of the most important unresolved issues related to introduced species, especially fish, is their impacts on native species through competition for the same, often scarce, food resources.

Dr. Peter Moyle of the University of California Davis comments that even when species overlap in diet and use of space does not mean they compete since the food source or space may not be in short supply. He continues that because competition has not been demonstrated it does not mean that it does not exist.

Karen Wiese, of the California Native Plant Society (CNPS) comments that the CNPS views the introduction and proliferation of non-native plants in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary as a threat that disrupts and displaces native ecosystems resulting in a loss of biodiversity. She states that the loss of biodiversity implies reduced functional values (or benefits) to the ecosystem and the region as a whole. In addition, she comments that introduced plants have had a history of detrimental effects on the native flora, thus, adversely altering the biodiversity of the ecosystem. The CNPS recommends that when aggressive non-native plants threaten to displace and destroy native plant habitat, control and eradication programs be implemented for those invasive species.

Ross O'Connell of the California Department of Food and Agriculture (CDFA) comments that the potential introduction and establishment of additional non-native species is not addressed in the briefing paper. He states that Hydrilla verticillata and the zebra mussel could be very devastating if they become established in the Delta. The CDFA has an eradication program that spends approximately one million dollars a year in eradication and detection survey efforts. In addition, various biocontrol agents are used to help in the control of "A" rated weeds in situations where current technology makes eradication unfeasible due to terrain or the size of the infestation. Plants rated "A", present an economic threat to agriculture and occur in very localized areas of the state.

Larry Thomas of the Department of Boating and Waterways (DBW) comments that there are at least three other non-native species (Egaria, Parrot feather, and Waterprimrose) in addition to waterhyacinth which have become a problem, or have the potential to become a problem. He states that the DBW agrees studies should be undertaken to better understand the significance of introduced species on the Estuary's fish, wildlife, and plants.

CONCLUSIONS

This paper acknowledges that the effects of introduced species and ecological complexities in the Estuary are far from definitive and more study is necessary to define the problem. Hence, continuing analysis of existing data and additional studies are warranted. However, by necessity, the BDOC will likely need to consider the issue utilizing existing information.

The effect of introduced plants has been pronounced in the Estuary. Aggressive non-native plants have significantly altered the California landscape and the Bay-Delta Estuary is no exception. Introduced fish species have undoubtedly affected the abundance of native species in the Estuary, but the magnitude of such effects is very uncertain.

Few opportunities exist to effectively reduce or eliminate introduced species from the Estuary. Most introduced species cannot be totally eliminated from the Estuary. Still, most resource managers agree that additional introductions are generally undesirable. Consequently, management activities focus on preventing additional incidental introductions and managing the existing mix of species. The desire to minimize the likelihood of new species becoming established has resulted in elaborate, expensive, and difficult control efforts. Efforts to control non-native predatory mammals such as red fox and Norway rats and invasive aquatic species such as white bass and northern pike should continue. In addition, a more aggressive effort to manage ballast water discharges, inclusion of invasive plant control in native plant restoration programs, and biological control of introduced invasive aquatic plants should also be undertaken. Future management actions will have to be undertaken recognizing that the full extent of impacts from introduced species on the Estuary is uncertain.

The Council and its technical advisors will need to consider how introduced species help define the Estuary's ecosystem and how they may impede recovery of specific native species. Properly considering introduced species in the context of evaluating alternatives to "fix" the Delta will help define a realistic, achievable plan for restoring the Estuary.

March 30, 1994

MEMORANDUM RE ECOLOGICAL PROBLEMS OF THE SAN FRANCISCO BAY-DELTA ESTUARY

by Alex Hildebrand and Stan Barnes,
with substantial input from others

The ecological problems of the Bay-Delta Estuary are many and varied and their causes are many and varied. See Attachment "A", hereto.

It is evident that there are so many potentially serious causative factors that one cannot assume with any confidence that any selected few are so determinative that the rest need not be addressed in order to achieve substantial environmental improvement. Californians cannot wait until all factors and their interrelations are fully understood and evaluated. On the other hand, we should not implement mitigative measures involving very large financial and/or water costs without at least having a carefully evaluated and considered opinion that such measures can provide significant environmental improvement in the absence of measures addressing other potentially significant factors. In particular, we need to ask that the impact of introduced species of all types be better evaluated. It has not been technically or scientifically established that some of the presently and most seriously proposed water management measures can be substantially effective unless something can be done about the competition within the entire food chain by introduced species.

It is urged that the above points be pursued before proposals by the EPA and other Club-Fed members lead to major disruptions of Delta operations.

Most certainly, Californians can and should protect the environment better than we have in the past, at each increasing level of our human population. However, the environment will not be better protected in the long run if efforts to protect it are inept or disregard human needs. The irreversible impacts of continuing human population growth and of competition by the pervasive populations of introduced aquatic species throughout the food chain simply must be addressed. A social and political backlash will result if mandated Delta standards prove to cause substantial losses in water and associated economic and social costs and most particularly if they prove to be far less effective environmentally than is predicted.

More attention must be given to six broad areas of concern if we are to be successful:

1) The need to quantify the benefit or injury to fish, wildlife and other environmental values of adding or removing an increment of flow at various times and locations within the Bay-Delta Estuary and streams tributary thereto. The human and economic benefits of water used for municipal, industrial and agricultural purposes are readily determinable on reasonably dependable bases. To justify very large quantities of water being precluded from such traditional beneficial uses, future societies will insist that at least some general quantitative bases be developed on which to measure environmental increments and decrements from changing conditions.

2) The probable limitations of potential environmental improvement through management of diversions and outflows because of the competition between native and introduced species throughout the aquatic food chain. Some introduced species have only recently become recognized to cause serious problems in the Bay-Delta Estuary. This competition between native and exotic species may very well render the proposed new EPA and/or any similar standards

substantially ineffective, until and unless other effective measures can be implemented to deal with this serious problem. It is important to recognize that the introduction of such exotic species may already be limiting the population of ESA endangered and protected species and, in the future, may limit the effectiveness of proposals to require modifications of Delta water management in order to achieve protection and enhancement of threatened and endangered species.

3) The impact upon food supply from the proposed Delta standards which are intended to achieve environmental protections. The presently proposed standards will cause urban pain, but the burdens will fall heaviest on the agricultural economy and the State's ability to continue to feed its growing population. There are predicted to be 63% more Californians to feed over the next thirty years. There is no State policy or plan on how to feed these people. Yet there are many proposals to reduce the agricultural water supply substantially. California now provides a substantial portion of the nation's table food. Some of the remainder is being grown in the plains states by overdrafting groundwater at a rate comparable to the flow of the Colorado River. This cannot be sustained. Can we afford to set environmental standards without considering the effect on the food supply?

4) Recognition of the overcommitted water yield of streams in the Central Valley watersheds. These supplies were already overcommitted before it was decided that increased flows were needed for fish, for endangered species, and for wildlife refuges. Meeting such mandates and the EPA's proposed striped bass salinity standard will, therefore, not be physically possible without a major reduction in water for the valley's domestic needs and for the agricultural economy of the region. Furthermore, any resulting increase in striped bass

populations will mean more competition for the salmon which we are trying to restore.

5) Potential adverse impact on water quality conditions, particularly in the lower San Joaquin River. As more water is released for spring and fall fish flows, there will be poorer water quality and lower stream flows in the summer. There will then be less food production, some loss of riparian habitat, and the reduction in irrigated agriculture will reduce the associated protection of open space and the habitat provided by agricultural operations.

6) Adverse impacts on the environment resulting from decreased agricultural water supplies. A number of examples can be cited, one being a limitation on water to grow rice in the Sacramento Valley and particularly to flood rice ground in the winter time, which provides feeding and resting areas for wildfowl. The interrelationship between productive agriculture and environmental values should be given more serious attention and study.

Just as we must pay more attention to biodiversity, we must also pay more attention to the interrelationships among water needed for environmental aquatic needs, environmental terrestrial needs, human domestic needs, and the production of food.

If we assume that something approximating 2 ppt (parts per thousand) salinity is required to keep the Estuary's null zone in a productive location (Suisun Bay) during certain parts of different water year types, we should think of this as an objective, not a standard. Such an objective should be implemented gradually, consistent with:

a) Balancing social and economic impacts against environmental objectives;

b) Information gained by monitoring the effects on fisheries of gradual, or staged, implementation;

c) Ability to compensate for social and economic impacts by further water development (dams, transfers, conservation, etc.);

d) Ability to allocate water supply impacts consistent with water rights priorities (including "area of origin" rights), and nonproject created impacts.

The initial objective should be to reverse downward trends of significant organisms; long-range objectives should be to create a reasonable balance among competing interests.

****

ATTACHMENT "A"

I. PROBLEMS

A. Significant human impacts on the environment of the Bay-Delta Estuary began in the second half of the nineteenth century and have increased over the years as California's population has grown from about 1.5 million at the turn of the century to more than 32 million today. At present rates of growth, there will be 40 million by about 2005 and 50 million by about 2020.

B. The current physical and hydraulic conditions in the Delta are unsatisfactory for the ecosystem and for users of water within or diverted from the Delta.

C. Because the complex Estuary conditions change with time, due to a variety of factors, the planned solutions to the Estuary's problems cannot be static.

D. Because of the complexity of the issues and the limitations on the total water supply and money available, it is highly unlikely that there can be a perfect quick fix solution; therefore, compromises must be made in arriving at a program or programs which will provide satisfactory solutions for each of the interests:

1. ecology of the Estuary;
2. flood control, water supply and water quality within the Delta;
3. adequate quantities of good quality water at reasonable cost for municipal, industrial and agricultural uses, on a reliable basis.

E. Restrictions on the SWP and CVP export pumps now imposed by administration of the Clean Water Act and the Endangered Species Act have limited diversions by the SWP and the San Luis Division of the CVP in this 1993 wet year.

F. Federal and/or state water quality standards applying to the Bay-Delta Estuary are often too strict, too inflexible, in conflict with standards of other agencies, and exacerbate potential solutions to Estuary problems. At the root of this serious situation is the fact that the specified standards are often based on very weak scientific evidence.

G. In some cases, water quality standards may be too "narrow" (i.e. what's good for drinking may not be good for fish); there is not agreement regarding appropriate standards for a diversity of uses.

H. Some technically qualified people have serious reservations regarding the reliability of present computer models of Bay-Delta conditions. There is a need to improve the modeling of hydrologic systems and to link such improved hydrologic models with ecosystem model processes.

II. CAUSATIVE FACTORS RE DETERIORATION OF THE ECOLOGICAL ENVIRONMENT OF THE ESTUARY

A. Based on many studies and discussions, the following can be stated with some certainty:

1. The fishery problems of the Sacramento and San Joaquin rivers and of the Bay-Delta Estuary are many and varied;

2. The causes of the problems are many and varied;

3. Some of the causative factors, but by no means all of such factors, are attributable to water resource development projects;

4. Some, but not all, of the adverse impacts on fisheries which are attributable to water resource development projects can, in turn, be attributed to the State Water Project and the Central Valley Project.

B. The causes of fish and wildlife problems in the Bay-Delta Estuary have been indicated by the California Department of Fish and Game and others to include the following:

Category 1 (Directly associated with CVP and/or SWP activities.)

1. Reduced flows and altered timing
2. Cross Delta flows
3. Reverse flows
4. Diversions and entrainment
5. Reduced egg production
6. Food supply
7. Predation
8. Handling of screened fish
9. Dams and barriers
10. Increased temperatures
11. Water quality
12. Flooding of upland wildlife habitat
13. "Rafting" of ducks in Clifton Court Forebay area

Category 2 (Not a direct CVP or SWP responsibility but possible mitigation and/or enhancement opportunities)

1. Dams and barriers by nonfederal or state projects
2. Reduced flows and altered timing by nonfederal or state projects

3. Irrigation return flows and agricultural drainage from saline lands
4. Levee management practices
5. Channelization and dredging
6. Erosion

Category 3 (Not related to CVP or SWP)

1. Dams or barriers by nonfederal or state projects
2. Agricultural diversions
3. Agricultural drainage
4. Mine drainage and other contaminants

    a) Adult mortality
    b) Egg resorption

5. Contaminated discharges from M&I sources
6. Water quality, generally
7. Increased temperatures due to nonfederal or state projects
8. Reduced egg production
9. Food supply
10. Predation and competition
11. Dredging and dredge material disposal
12. Recreational use throughout the Bay-Delta Estuary and the Central Valley rivers system
13. Fishing mortality (legal and illegal, local and coastwide)
14. Hunting mortality (legal and illegal, local and statewide)

C. In the past few years, new information has become available on changing ecological conditions in the Bay-Delta Estuary. These changes appear to be having a very substantial impact on the food chain of the established fisheries, independent of the operation of any water resource development projects.

D. Recent examples of dramatic changes in the Bay-Delta ecological system brought about by the inadvertent introduction of exotic species, including the following:

1. Potamocorbula, the clam that has changed the food web in the Suisun Bay area;

2. Sinocalanus, an Asian copepod, not well-liked by young striped bass, that has tended to displace the copepod, Eurytemora, a favorite food of the young striped bass;

3. Pseudodiaptomus, another Asian copepod, also not well-liked by young striped bass;

4. Yellowfin Goby, a fish that eats young striped bass;

5. Melosira, a chain diatom, actually a long-term resident of the Delta that, in the 1980s, became the predominant organism comprising algal blooms in the Delta.

*****