RTD-192

Staff Report of the

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

TOTAL MAXIMUM DAILY LOAD FOR SELENIUM IN THE LOWER SAN JOAQUIN RIVER

August 2001

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Executive Summary

The lower San Joaquin River (SJR) is listed on the Federal Clean Water Act's 303(d) list as impaired for selenium, which is toxic to waterfowl at high levels. The impairment extends from the Salt Slough confluence to the Airport Way Bridge near Vernalis. The 303(d) listing requires development of a Total Maximum Daily Load (TMDL) for selenium in the lower SJR. The major source of selenium is from an area called the Drainage Project Area (DPA) that is currently under regulations to reduce selenium loading. Load allocations have been developed to specify how much selenium can be discharged while still maintaining a healthy ecosystem. Based on these load allocations, waste discharge requirements are assigned to the DPA's drainage system, the Grassland Bypass Project (GBP). This report outlines the development of a TMDL for the lower SJR to reduce the selenium impairment in the river and outlines load allocations that will be implemented for the GBP.

Selenium is a naturally occurring trace element known to be hazardous to waterfowl at elevated levels. Death and deformities of waterfowl at Kesterson Wildlife Refuge in 1983 first focused attention on agricultural drainage and selenium. The Central Valley Regional Water Quality Control Board (Regional Board) has adopted the U.S. Environmental Protection Agency aquatic life criterion for total selenium of 5 µg/L four-day average as the selenium water quality objective for the lower SJR. While selenium occurs naturally throughout the lower SJR Basin, elevated concentrations of selenium occur in the shallow groundwater in the 97,000 acre DPA contained within the Grassland Watershed. Subsurface agricultural drainage discharges from this area are the major source of selenium.

Load allocations for agricultural subsurface drainage discharges from the DPA were first developed in a 1994 Regional Board report. The load allocations in this TMDL are based on the methods used in the 1994 report; they are designed to meet selenium water quality objectives downstream of the Merced River confluence. The methods group a thirty year historical flow record by water year type and season, resulting in monthly load allocations for the DPA as displayed in the *TMDL Summary* section. A linkage analysis was developed as a check of the load allocation methods. This linkage analysis considers historical discharges, background selenium loads, and estimated load allocations. The analysis confirmed the ability of the load allocations for meeting monthly selenium water quality objectives.

The program to implement this TMDL was adopted by the Regional Board in a 1996 Basin Plan Amendment for the Control of Agricultural Subsurface Drainage Discharges. Included in this program is a compliance time schedule for meeting the four-day average and monthly mean water quality objectives for selenium. Landowners within the DPA formed a group called the Grassland Area Farmers and developed a plan to divert drainage from wetland supply channels and direct all of the drainage through the GBP into Mud Slough, a tributary of the lower SJR. The Regional Board assigned waste discharge requirements to the GBP in 1998 that require the Grassland Area Farmers to reduce the discharge of selenium from pre-GBP load levels. The waste discharge requirements are currently being revised using the load allocations included in this TMDL. Reductions in selenium loading will be achieved through use of blending, drainage recycling, and selenium extraction technologies.

TMDL Summary

Water body: San Joaquin River

Total Size: 330 miles

Impaired: 50 miles from the Salt Slough confluence to the Airport Way Bridge near Vernalis

Pollutant: Selenium

Source: Major: Subsurface agricultural return flows (tile drainage) from the 97,000-acre Drainage Project Area of the Grassland Watershed (88% of total load)

Minor: Distributed inputs throughout the San Joaquin River Basin

Schedule: Level 1 (three year timeframe)

Priority: High

Report Date: August 2001

The following load allocations for the Drainage Project Area are based upon meeting a 5 µg/L four-day average water quality objective for the lower San Joaquin River. There is no waste load allocation for this Total Maximum Daily Load.

Drainage Project Area Monthly Load Limits (pounds)												
Water Year Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Critical	151	93	92	101	105	69	70	75	57	55	55	152
Dry/Below Normal	319	185	184	193	197	130	131	137	235	233	233	319
Above Normal	398	472	472	490	497	212	214	225	264	260	260	398
Wet	211	488	488	506	512	354	356	366	332	328	328	211

Problem Statement

The lower San Joaquin River (SJR) is listed in accordance with Section 303(d) of the Clean Water Act for exceeding selenium water quality objectives. Areal extent of the impairment was listed as 50 river miles from the Salt Slough confluence to the Airport Way Bridge near Vernalis. This water quality limited segment was listed in 1988 as part of the water quality assessment and 303(d) listing process.

Environmental Setting and TMDL Scope

The southern part of the Central Valley of California is comprised of two hydrologic basins: the SJR and the Tulare Lake Basins. The SJR Basin (Figure 1) is drained by the SJR, which discharges to the Sacramento-San Joaquin Delta. The Tulare Lake Basin is for the most part an internal drainage basin that occasionally overflows into the SJR Basin during extremely high flood flow periods.

The SJR Basin is bounded by the Sierra Nevada Mountains on the east, the Coast Ranges on the west, the Delta to the north, and the Tulare Lake Basin to the south. From its source in the Sierra Nevada Mountains, the SJR flows southwesterly until it reaches Friant Dam. Most of the water is diverted at Friant Dam into the Friant-Kern Canal and out of the SJR Basin. Only flood flows during wet years continue to flow into the SJR Basin. Below Friant Dam, the SJR flows westerly to the center of the SJR Basin near Mendota, where it turns northwesterly to eventually join the Sacramento River in the Sacramento-San Joaquin Delta. The main stem of the SJR is about 300 miles long and drains approximately 13,500 square miles. The geographic scope of this TMDL is 50 miles of the lower SJR from the Salt Slough confluence to the Airport Way Bridge near Vernalis. This reach of the SJR drains an area of approximately 2.9 million acres. Mud Slough and Salt Slough are tributaries to the SJR that drain the 370,000-acre Grassland Watershed. These sloughs contain a mix of agricultural return flows, runoff from managed wetlands, rainfall runoff, and flood flows. Mud Slough discharges to the SJR approximately two miles upstream of the confluence between the SJR and the Merced River. Salt Slough flows into the SJR approximately 6 miles upstream of the Mud Slough confluence. Flow in the lower SJR is limited by the presence of Mendota Dam and Sack Dam, both of which are located upstream of the Salt Slough confluence.

Soils on the west side of the SJR Basin are derived from rocks of marine origin in the Coast Range that are high in selenium and salts. Major land uses in the watershed include agriculture and managed wetlands. Dry conditions make irrigation necessary for nearly all crops grown commercially in the watershed. Irrigation of the soils derived from these marine sediments leaches selenium and salt into the shallow groundwater. Subsurface drainage is produced when farmers drain the shallow groundwater from the root zone to protect their crops. This subsurface agricultural drainage water is high in naturally occurring salts and selenium. Soils and shallow groundwater with the highest concentrations of selenium in the SJR Basin are located in a 97,000-acre area that has alternately been called the Drainage Study Area, Drainage Problem Area, and most recently, the Drainage Project Area (DPA).

Selenium is a highly bioaccumulative trace element, which, under certain conditions, can be mobilized through the food chain, and cause both acute and chronic toxicity to waterfowl.

Deformities and deaths of waterfowl have been linked to toxic concentrations of selenium. The lower SJR was placed on the Section 303(d) list in 1988 because water routinely exceeded the U.S. Environmental Protection Agency's (U.S. EPA) criteria for total selenium of 5 µg/L. The effects of selenium on waterfowl are the driving force behind current criteria. Subsurface agricultural drainage is the primary source of selenium in the lower SJR Basin although selenium sources at low concentrations (less than 2 µg/L) are widespread.

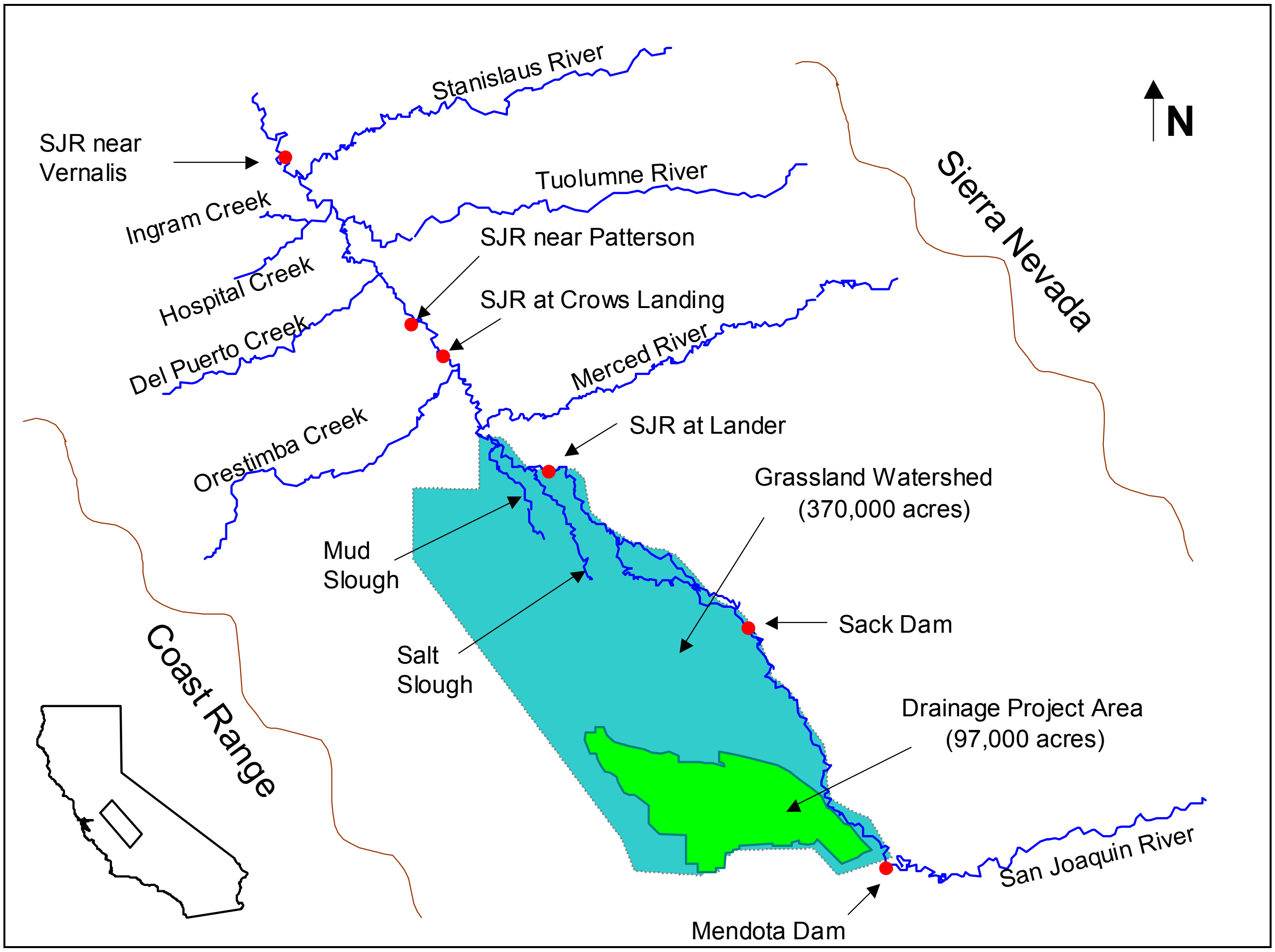

Figure 1. Location map of the lower San Joaquin River Basin

Regulatory History

Selenium in subsurface agricultural drainage was found to be the cause of waterfowl death and deformity at Kesterson Reservoir in 1985. Subsurface agricultural drainage was conveyed from Westlands Water District in the Tulare Lake Basin to Kesterson Reservoir via the partially completed San Luis Drain. Discovery of the adverse impacts of selenium in agricultural drainage water resulted in the closure of the Kesterson Reservoir and cessation of the use of the San Luis Drain to convey water from Westlands Water District. Westlands Water District is just south of the DPA and the two areas share similar characteristics in agricultural drainage water quality. Subsurface agricultural drainage water in the Grassland Watershed has historically drained to the SJR via a network of constructed and natural channels. These same channels are also used to convey fresh water supplies for managed wetlands.

Regional Board staff commenced a program of monitoring and assessment of waterbodies in the Grassland Watershed in 1985. A 1988 Regional Board Basin Plan Amendment for the Control of Agricultural Subsurface Drainage Discharges identified water conservation measures as a means of reducing selenium concentrations and loads in the SJR and wetland supply channels. From 1985 to 1996, channels in the Grassland Water District were used to alternately convey agricultural drainage water and freshwater (Figure 2). An agreement between Grassland Water District and agricultural districts in the DPA allowed use of a series of wetland supply channels to convey drainage through the north and south portions of the Grassland Water District. Drainage water was alternately conveyed to Mud Slough via the San Luis and Santa Fe Canals or to Salt Slough via the Blake-Porter Bypass. This flip-flop system was used to try to keep freshwater supplies separated from subsurface agricultural drainage water. The increased demand for freshwater supplies, and continued environmental concern with this arrangement, led to development of the Grassland Bypass Project (GBP) and the Regional Board's 1996 Basin Plan Amendment for the Control of Subsurface Agricultural Drainage (1996 Basin Plan Amendment).

The GBP was implemented in September 1996 to divert agricultural drainage water from the DPA out of the Grassland Water District water supply channels (Figure 3). This diversion allows refuge managers greater control over their supply and release operations, so they can receive and apply all of their fresh water allocations according to optimum habitat management schedules. Diversion of agricultural drainage water away from the Grassland Water District channels reduces the selenium exposure to fish, wildlife, and humans in the wetland channels and Salt Slough. Other pollutants of concern in the drainage water, such as salt and boron, may also be reduced. Combining agricultural drainage flows into a single concrete-lined structure, the San Luis Drain, allows for better monitoring, potentially leading to a more detailed evaluation as well as effective control of selenium and agricultural drainage. The establishment of an accountable drainage entity has provided the framework necessary for responsible watershed management in the Grassland Watershed.

Total Maximum Daily Load (TMDL) reports have been completed for selenium in Salt Slough and the Grassland Marshes (CRWQCB-CVR, 1999 and 2000). These TMDLs have been implemented through the Regional Board's 1996 Basin Plan Amendment. In accordance with the 1996 Basin Plan Amendment, Waste Discharge Requirements for discharges from the GBP were issued in July 1998.

Target Analysis

Water quality objectives were adopted in the Regional Board's 1996 Basin Plan Amendment. The amendment contained selenium water quality objectives for Mud Slough (north), Salt Slough and wetland supply channels in the Grassland Watershed and for the main stem of the SJR from Sack Dam to Vernalis. The U.S. EPA aquatic life criterion of 5 µg/L was adopted as the SJR objective. This objective, which was approved by the State Water Resources Control Board and the Office

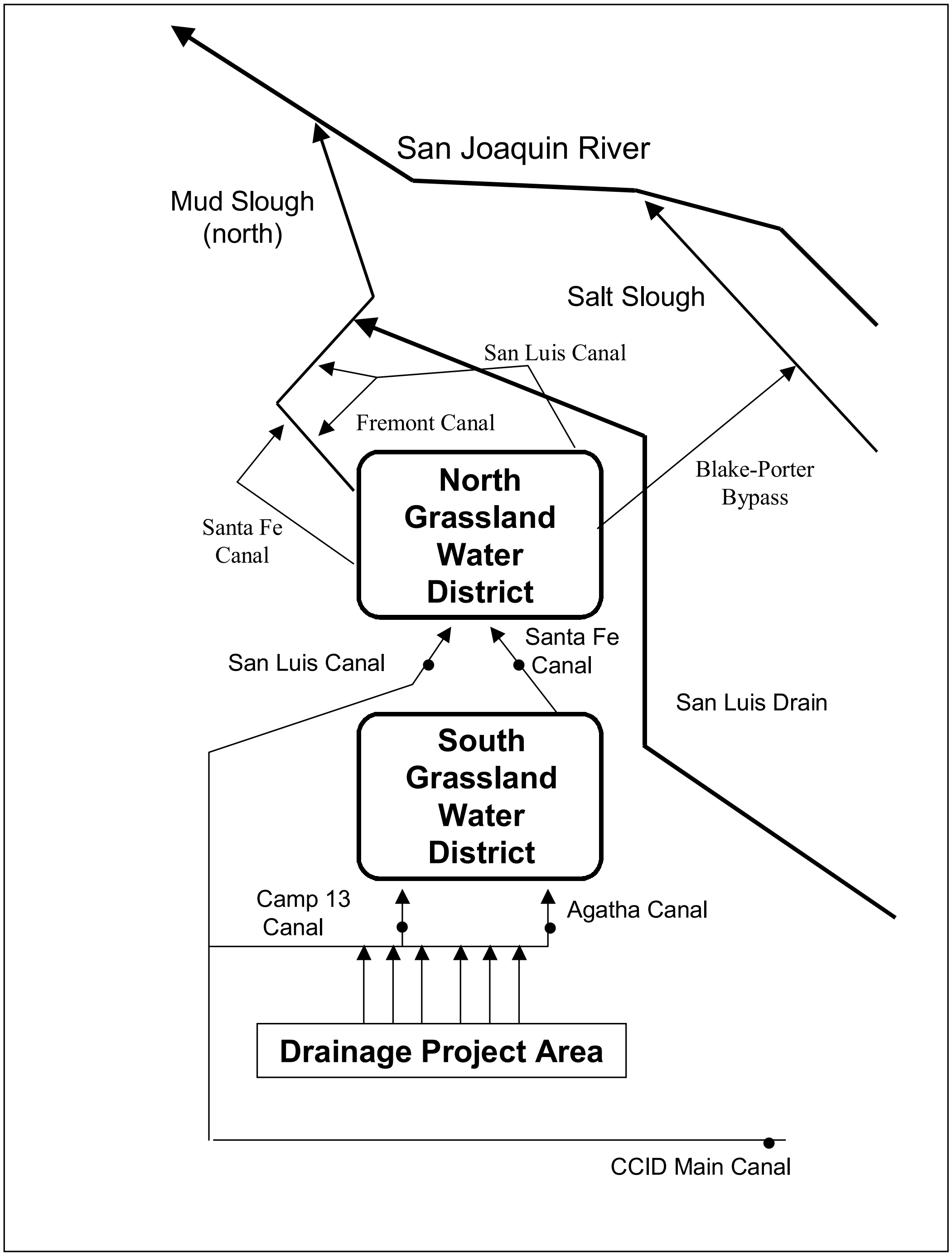

Figure 2. Wetland water supply schematic before Grassland Bypass Project

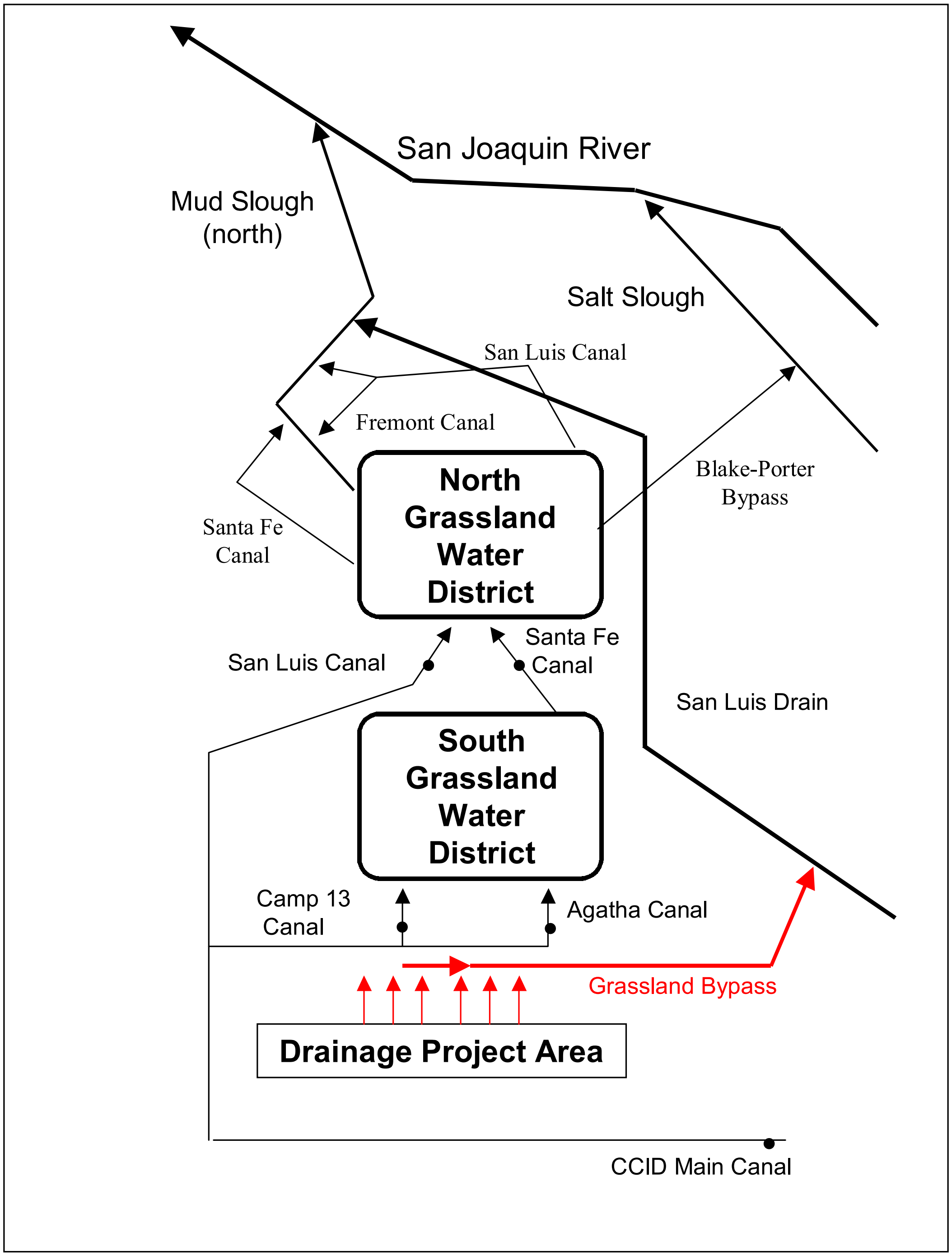

Figure 3. Wetland water supply schematic after Grassland Bypass Project

of Administrative Law, is a four-day average concentration of 5 µg/L (CRWQCB-CVR, 1998a). This TMDL uses the four-day average 5 µg/L objective as the numeric target. Targets adopted for other impaired waterbodies in the SJR Basin include 2 µg/L monthly mean for the Grassland wetland supply channels, 2 µg/L monthly mean for Salt Slough, and 5 µg/L four-day average for Mud Slough. Selenium water quality objectives and performance goals are shown in Table 1.

Table 1. Selenium Water Quality Objectives[1] (in bold) and Performance Goals (in italics)

Water Body/Water Year Type	10 January 1997	01 October 2002	01 October 2005	01 October 2010
Salt Slough and Wetland Water Supply Channels listed in Appendix 40 of the Basin Plan	**2 µg/L monthly mean**			
San Joaquin River below the Merced River; Above Normal and Wet Water Year types		*5 µg/L monthly mean*	**5 µg/L four-day average**	
San Joaquin River below the Merced River; Critical, Dry and Below Normal Water Year types		*8 µg/L monthly mean*	*5 µg/L monthly mean*	**5 µg/L four-day average**
Mud Slough (north) and the San Joaquin River from Sack Dam to the Merced River				**5 µg/L four-day average**

[1]Copy of table found in the Water Quality Control Plan for the Sacramento and San Joaquin Rivers (CRWQCB-CVR, 1998a)

Source Analysis

Subsurface agricultural return flows from the DPA in the Grassland Watershed are the primary source of selenium in the lower SJR Basin. There are no municipal or industrial sources. Selenium is a naturally occurring element found in sediments of the Coast Ranges on the west side of the lower SJR Basin. Selenium can therefore be found in surface runoff and groundwater throughout the west side of the lower SJR Basin. Although selenium exists naturally in the soils of this watershed, some land use practices may accelerate its movement to ground water and surface water.

Sources of Selenium

Selenium is added to the lower SJR from a wide range of sources including subsurface agricultural return flows, surface agricultural return flows, wetland discharges, groundwater accretions, and tributary inflows.

Subsurface Agricultural Return Flows

Subsurface agricultural return flows, also known as tile drainage, occur as the result of efforts to control groundwater levels to maintain agricultural productivity. Tile drains are installed in areas of high groundwater to lower the water table below the root zone. The lower SJR Basin has many areas with high groundwater levels due to poorly drained soils and application of irrigation water. Tile drainage may have high selenium concentrations, especially in the Grassland Watershed. Drainage from tile drains in the DPA is the primary source of selenium in the Grassland Watershed and the SJR. A survey of tile drainage in the lower SJR Basin (Chilcott et al., 1988) found the highest concentrations of selenium in the Grassland Watershed. Eighty-two percent of the samples collected at 173 tile drainage sites in the Grassland Watershed had selenium concentrations ranging from 11 to 500 µg/L. Six percent of the samples had selenium concentrations above 500 µg/L and twelve percent had selenium concentrations below 11 µg/L. Tile drainage from areas outside of the Grassland Watershed has selenium concentrations significantly lower than the Grassland Watershed and the DPA. A survey of agricultural drainage found that the range of selenium concentrations in tile drainage that discharges directly to the SJR from areas north of the DPA was 0.2 to 9.3 µg/L, with a median of 2.2 µg/L (Westcot et al., 1989).

Surface Agricultural Return Flows and Wetland Discharges
Surface agricultural return flows and wetland discharges from the west side of the SJR have the same selenium concentration as the source water. The selenium concentration depends on whether the source is groundwater, SJR diversions, or the Delta-Mendota Canal. A survey of agricultural discharges to the SJR (Westcot et al., 1989) found the mean selenium concentration of surface return flows, with source water from a mix of SJR and Delta-Mendota Canal water, to be 2.2 µg/L, with a range from 1.8 to 2.7 µg/L.

Subsurface agricultural return flows were alternately discharged to Mud Slough and Salt Slough before use of the GBP. Monthly selenium concentrations averaged 14 µg/L for Salt Slough and 7 µg/L for Mud Slough (Grober et al., 1998) from 1986 to 1995. With use of the GBP, Salt Slough no longer received subsurface agricultural return flows, only surface agricultural return flows and wetland discharges. Mud Slough received no surface agricultural return flows upstream of the San Luis Drain confluence; flows are now comprised mostly of wetland discharges. Annual selenium concentration was 1 µg/L for Salt Slough during water year 1997 (Chilcott et al., 1998). Annual selenium concentration was 1 µg/L for Salt Slough and 1 µg/L for Mud Slough upstream of the San Luis Drain during water year 1998 (Chilcott et al., 2000).

Groundwater Accretions
The lower SJR, downstream of the Grassland Watershed, is generally a gaining stream. The U.S. Geological Survey (USGS) investigated the quality and quantity of groundwater inflow to the SJR from Newman to Patterson (Phillips et al., 1991). Average groundwater inflow was 2.0 cfs/mile, with a range of 1.1 to 3.2 cfs/mile. This flow translates to about 1,500 acre-ft/mile annually and 75,000 acre-ft for the impaired 50 mile stretch of the SJR. The concentration of selenium in the groundwater was estimated to be 0.9 µg/L. Assuming a mean groundwater inflow of 2.0 cfs/mile at a selenium concentration of 0.9 µg/L, groundwater contributes approximately 200 pounds of selenium per year along the impaired 50-mile stretch of the SJR.

Tributary Inflows
A survey of the water quality of ephemeral west side SJR tributaries between 1984 and 1988 (Westcot et al., 1991) found median selenium concentrations generally less than or equal to 1.0 µg/L for Del Puerto, Orestimba and Hospital Creeks. Ingram Creek had a median selenium concentration of 4.3 µg/L. The maximum annual load contributed to the SJR by these and 36 other ephemeral streams was estimated to be approximately 600 pounds per year. Little data is available on selenium concentrations for the Merced, Tuolumne and Stanislaus Rivers. Most of the samples collected from these rivers between 1985 and 1988 (USGS, 1988 and USGS, 1991) had selenium concentrations below the detection limit of 1.0 µg/L but some samples from each

tributary had concentrations at the detection limit. Selenium concentrations for the SJR at Lander Avenue (upstream of discharges from the DPA) have ranged from 0.1 to 1.3 μg/L in water years 1993 through 1995 (Chilcott et al., 1995 and Steensen et al., 1996). The east side tributaries and the SJR at Lander Avenue contribute selenium to the lower SJR at concentrations well below the water quality objective of 5 μg/L. The load they contribute may be highest during periods of high discharge when extremely low concentrations may still account for significant loads. For example, a discharge of 100,000 acre-ft per month at a selenium concentration of 0.2 μg/L would account for a monthly selenium load of 54 pounds. During wet years, flow from east side tributaries can be in excess of 200,000 acre-ft per month. Such a flow may account for 108 pounds of selenium per month.

San Joaquin River Selenium Loads

The Regional Board has conducted water quality sampling at numerous sites in the Grassland Watershed and the lower SJR since 1985. Results from the first ten water years of this sampling program, 1985 through 1995, are summarized in two Regional Board staff reports (Steensen et al, 1998 and Grober et al, 1998). Results for water years 1996 through 1998 are summarized in Chilcott et al, 1998 and Chilcott et al, 2000. These reports include monthly and annual flow and selenium load information for discharges from the DPA, the Grassland Watershed, the SJR near Patterson, and the SJR near Vernalis. The reports demonstrate that the DPA accounts for, on average, 88% of the selenium load in the lower SJR.

Discharge

Water discharges from the DPA account for a small percentage of the total flow volume in the lower SJR (Table 2). The mean annual discharge from the DPA from 1986 through 1998 was 48 thousand acre-feet (taf) per year. The mean annual discharge from the Grassland Watershed and in the SJR near Vernalis was 223 and 3,075 taf, respectively. Discharge from the DPA, on average, accounts for only two percent of the total flow volume in the SJR near Vernalis. The range of discharge is most pronounced in the SJR near Vernalis, with a low of 657 taf in 1991 to a high of 8,489 taf in 1998. Grassland Watershed discharges ranged from a low of 85 taf in 1992 to a high of 378 taf in 1998. DPA discharges varied from a low of 25 taf in 1992 to a high of 75 taf in 1987. Discharge in the SJR and the Grassland Watershed is much more highly variable than discharge from the DPA.

Selenium Loading

The mean annual selenium load from the DPA from 1986 through 1998 was 8,660 pounds. The mean annual selenium load in the SJR near Vernalis during this same period was 9,788 pounds (Table 3). The mean annual difference of 1,128 pounds (Table 4) is attributable to distributed sources of selenium throughout the lower SJR Basin. Distributed sources are primarily from background sources and include all non-DPA sources of selenium. On average, the DPA has accounted for 88 percent of the mean annual selenium load in the SJR near Vernalis (Table 5). There is significant annual variability in the differences in loads between the DPA and the SJR near Vernalis, ranging from a loss of approximately 1,670 pounds in 1988 to a gain of 5,077 pounds in 1986. In other words, DPA loads have accounted for 120 percent (Water Year 1988) to 65 percent (Water Year 1986) of the loads in the SJR near Vernalis. A portion of the positive (gain) and negative (loss) differences in loads can be attributed to measurement and calculation error although no consistent source of error has been identified (Grober et al, 1998). Losses are also attributable to water diversions from the SJR. Gains are attributable to distributed sources of selenium throughout the basin. Variability in selenium loads is also shown in Figure 4. This data shows lower loads from all sources during dry years and higher loads during wet years.

Table 2. Annual discharge[1] (thousand acre-ft) of three locations in the lower San Joaquin River Basin

Water Year	Drainage Project Area	Grassland Watershed	SJR near Vernalis
1986	67	284	5,226
1987	75	234	1,813
1988	65	230	1,168
1989	54	211	1,059
1990	42	195	916
1991	29	102	657
1992	25	85	700
1993	41	168	1,702
1994	39	184	1,219
1995	58	264	6,299
1996	50	270	3,950
1997	40	290	6,770
1998	46	378	8,489
average	48	223	3,075

[1]Data from Steensen et al., 1998

Table 3. Annual selenium loading[1] (pounds) at three locations in the lower San Joaquin River Basin

Water Year	Drainage Project Area	Grassland Watershed	SJR near Vernalis
1986	9,524	6,643	14,601
1987	10,959	7,641	8,502
1988	10,097	8,132	8,427
1989	8,718	8,099	8,741
1990	7,393	7,719	7,472
1991	5,858	3,899	3,611
1992	5,083	2,919	3,558
1993	8,856	6,871	8,905
1994	8,468	7,980	7,760
1995	11,875	10,694	17,238
1996	10,034	9,491	11,431
1997	6,959	7,722	11,190
1998	8,760	9,630	15,810
average	8,660	7,495	9,788

[1]Data from Steensen et al., 1998

Table 4. Differences in selenium loading[1] (pounds) between three locations in the lower San Joaquin River Basin

This site:		Grassland Watershed	SJR near Vernalis	
Minus this site:		Drainage Project Area	Drainage Project Area	Grassland Watershed
Water Year	1986	-2,881	5,077	7,958
	1987	-3,318	-2,457	861
	1988	-1,965	-1,670	295
	1989	-619	23	642
	1990	326	79	-247
	1991	-1,959	-2,247	-288
	1992	-2,164	-1,525	639
	1993	-1,985	49	2,034
	1994	-488	-708	-220
	1995	-1,181	5,363	6,544
	1996	-543	1,397	1,940
	1997	763	4,231	3,468
	1998	870	7,050	6,180
	average	-1,165	1,128	2,293

[1]Data from Steensen et al., 1998

Table 5. Percent difference in selenium loading[1] between three locations in the lower San Joaquin River Basin

Difference between:		Grassland Watershed	SJR near Vernalis	
and:		Drainage Project Area	Drainage Project Area	Grassland Watershed
Water Year	1986	143%	65%	45%
	1987	143%	129%	90%
	1988	124%	120%	96%
	1989	108%	100%	93%
	1990	96%	99%	103%
	1991	150%	162%	108%
	1992	174%	143%	82%
	1993	129%	99%	77%
	1994	106%	109%	103%
	1995	111%	69%	62%
	1996	106%	88%	83%
	1997	90%	62%	69%
	1998	91%	55%	61%
	average	116%	88%	77%

[1]Data from Steensen et al., 1998

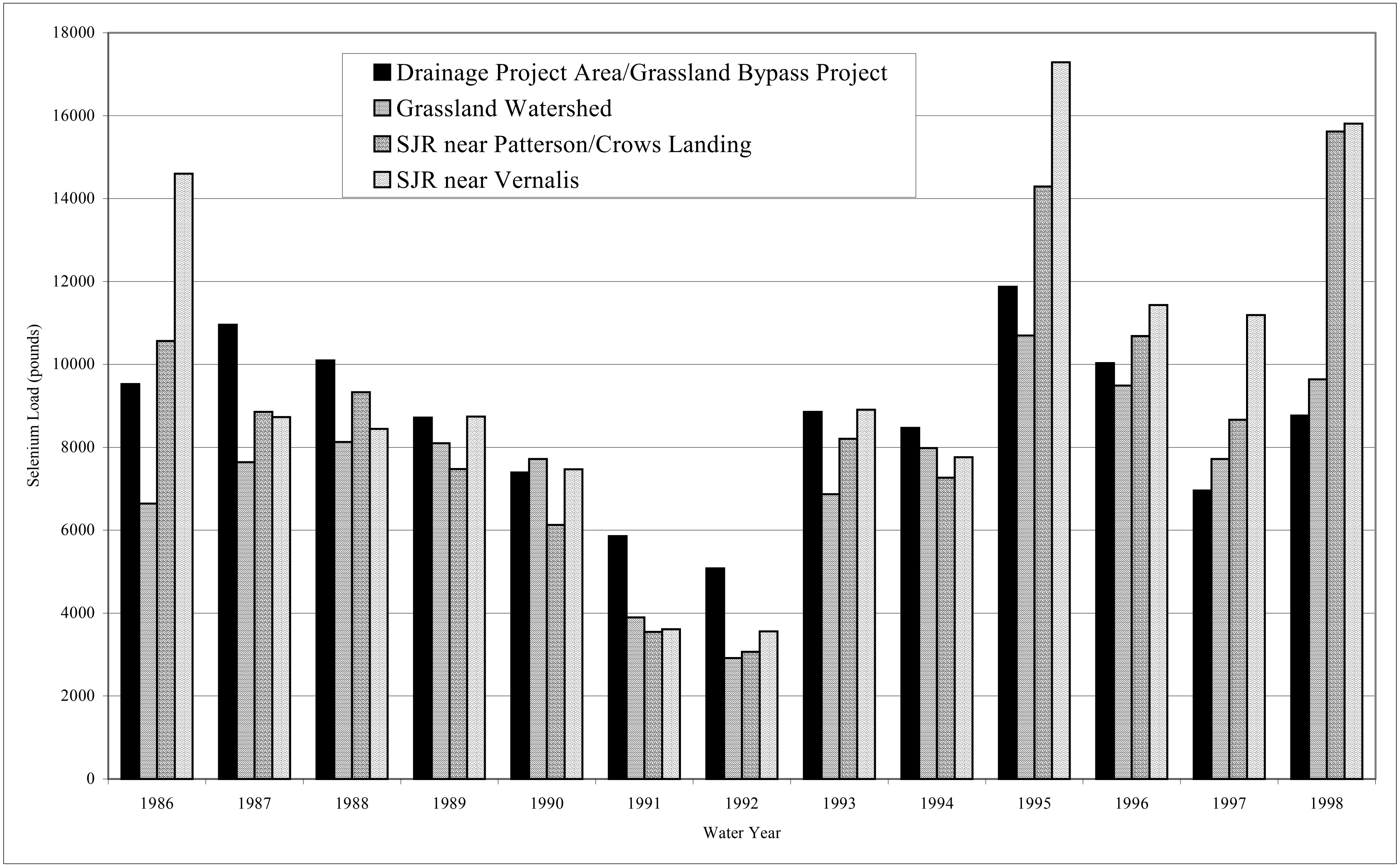

Figure 4. Annual selenium loading from four locations in the lower San Joaquin River Basin

Selenium Concentration

Discharges from the DPA are the most concentrated source of selenium in the lower SJR. The mean annual selenium concentration for discharge from the DPA from 1986 through 1998 was 68 µg/L (Table 6). The mean annual selenium concentration for the SJR near Patterson and SJR near Vernalis was 3.8 and 1.8 µg/L respectively. The time series of mean monthly selenium concentrations for the DPA and the SJR near Vernalis is shown in Figure 5. As already indicated, the high selenium concentration discharges from the DPA account for most of the selenium load in the lower SJR. Discharge and selenium load information already presented can be used to estimate the selenium concentration for unmeasured, distributed sources of selenium in the lower SJR Basin.

Table 6. Annual selenium concentrations (µg/L) from three locations in the lower San Joaquin River Basin

Water Year	Drainage Project Area	SJR near Patterson[1]	SJR near Vernalis
1986	52	1.5	1.0
1987	54	4.9	1.8
1988	57	6.2	2.7
1989	59	6.3	3.0
1990	65	5.6	3.0
1991	74	5.4	2.0
1992	76	4.4	1.9
1993	79	3.7	1.9
1994	81	5.4	2.3
1995	76	1.5	1.0
1996	70	2.7	1.1
1997	68	0.8	0.6
1998	70	1.1	0.7
average	68	3.8	1.8

[1]Data for water years 1996 to 1998 is based on SJR at Crows Landing

The concentration of the unmeasured selenium sources can be estimated by calculating a concentration from the unmeasured selenium loads and flows (Table 7). Calculated concentrations for SJR near Patterson and SJR near Vernalis are all less than 1.4 µg/L and most are less than 0.5 µg/L. The average concentration of these sources of selenium for water years 1986 through 1998 was approximately 0.3 µg/L. This data shows that the DPA is the primary source of selenium in the Grassland Watershed and in the lower SJR Basin.

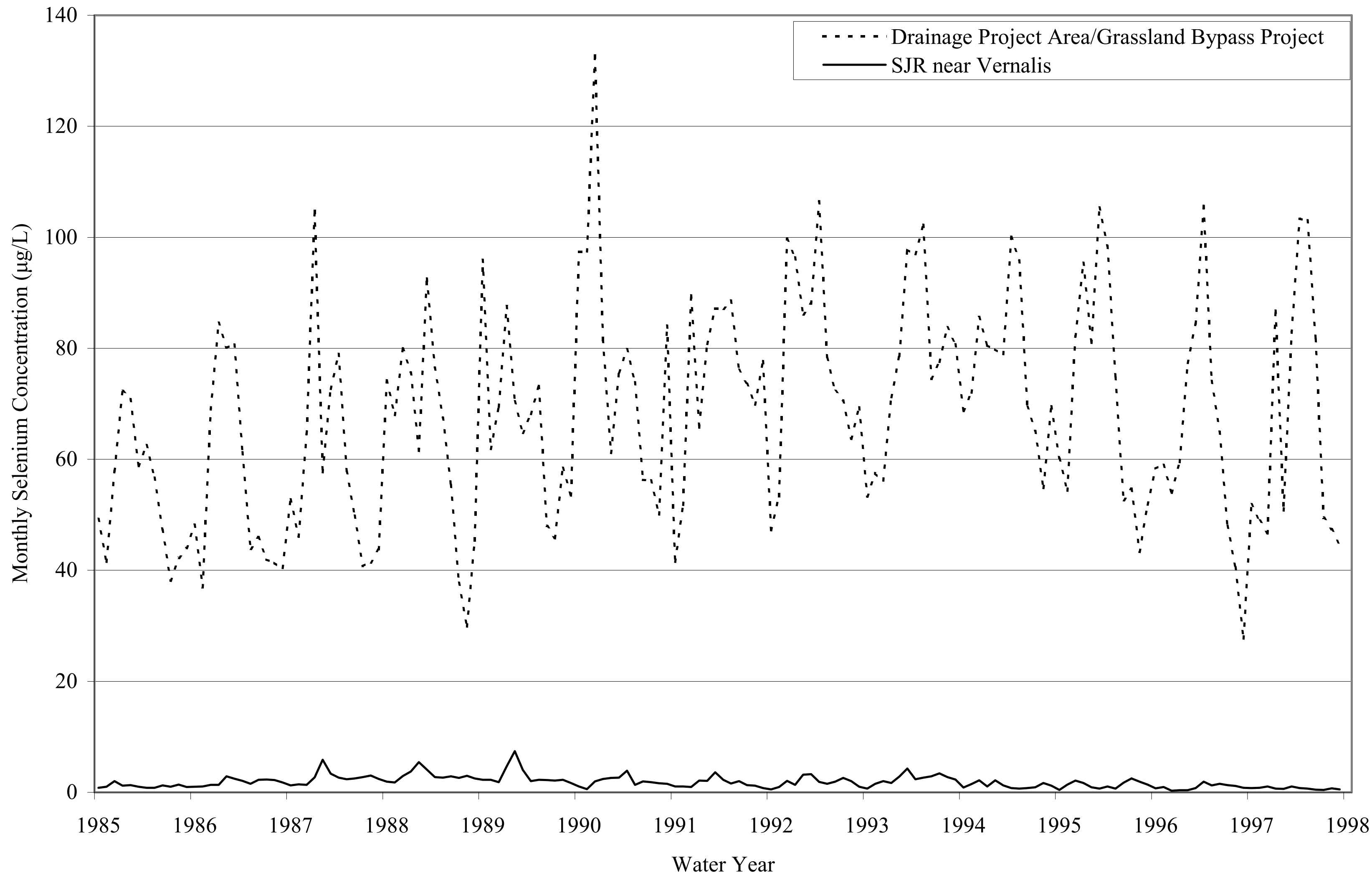

Figure 5. Monthly selenium concentrations for the Drainage Project Area and the San Joaquin River near Vernalis

Table 7. Unmeasured selenium concentrations[1] (µg/L) from three locations in the lower San Joaquin River Basin

Water Year	SJR near Patterson[2]	SJR near Vernalis
1986	0.72	0.48
1987	1.04	-0.11
1988	1.38	-0.54
1989	-1.01	0.75
1990	-2.80	0.97
1991	-0.68	0.06
1992	0.24	0.46
1993	0.77	0.24
1994	-0.69	0.27
1995	0.41	0.39
1996	0.37	0.11
1997	0.09	0.36
1998	0.35	0.21
average	0.32	0.28

[1]Data from Steensen et al., 1998
[2]Data for water years 1996 to 1998 is based on SJR at Crows Landing

Load Allocations

Load allocations for discharges from the DPA were first developed in a 1994 Regional Board staff report, *Total Maximum Monthly Load Model for the San Joaquin River* (Karkoski, 1994). This report presented a description of a Total Maximum Monthly Load (TMML) model and the methods used in the model to calculate selenium load allocations. This TMML model is a simple spreadsheet model that calculates monthly selenium load allocations for the SJR based on critical flow conditions for the SJR at Crows Landing and an acceptable violation rate of the water quality objective. Load allocations in this TMDL are established for meeting the selenium water quality objective in the SJR downstream of the Merced River confluence. There would be effectively no allocation of selenium load in the absence of Merced River dilution flows. The source analysis has shown that subsurface agricultural return flows form the DPA are the primary source of selenium load in the lower SJR Basin. The source analysis has shown that the selenium concentration of all other SJR inflows is much lower than the water quality objective. The selenium water quality objective for the entire SJR downstream of the Merced River will therefore be attained when the water quality objective is attained at a point just downstream of the Merced River confluence.

The schedule for compliance with selenium water quality objectives in the SJR (Table 1) shows that the 5 µg/L objective must be met for the SJR from Sack Dam to the Merced River confluence starting in October 2010. Prior to this date, selenium loads from the DPA may continue to be discharged to the SJR upstream of the Merced River confluence. Attainment of the selenium water quality objective upstream of the Merced River confluence may require significant changes to the DPA discharge, including the relocation of the discharge point.

Through September 2010, the SJR at Crows Landing is the water quality compliance point of the selenium water quality objective in the SJR and is also used to calculate the TMDL. This site is used as the compliance point because the dominant source of selenium in the lower SJR Basin is discharged to the river upstream of the Merced River confluence. The SJR at Crows Landing is the first easily monitored site downstream of the Merced River confluence. The source analysis has identified no additional concentrated sources of selenium downstream of the SJR at Crows Landing. The model uses historical flow records, grouped by season and water year type, to calculate critical flow or design flow conditions. Design flows are multiplied by the water quality objective to calculate the TMML or assimilative capacity. A monthly load limit is established, rather than a daily limit, since most agricultural water districts lack the facilities needed to manage drainage on a daily basis.

Application of design flows to calculate load allocations requires use of a hydrology that is similar to the present and future hydrology. Completion of New Exchequer Dam on the Merced River caused a significant change in hydrology because of the increase of reservoir capacity from 281,000 to 1,024,000 acre-feet. Since this dam had an impact on both the Merced River and SJR, only the hydrology subsequent to dam filling and completion in 1969 is used in the calculation of design flows.

Data Sources

The SJR at Crows Landing is the compliance point for selenium water quality objectives in the lower SJR but flow data for this site is only available for water years 1969 through 1972 and 1996 through 1999. Flow data for water years 1972 through 1995 must be reconstructed based on SJR near Patterson flow data that is available from 1969 through 1999. Reconstruction of the flow record at Crows Landing was done using Patterson flow data and the mass balance model SJRIO-2. SJRIO-2 can be used to do a mass balance accounting of monthly flow and water quality (Kratzer, 1987) for water years 1977 through 1996. When run in calibration mode, the model provides a monthly flow record for any site in the lower SJR from upstream of Salt Slough to Vernalis.

Crows Landing flow data for water years 1977 through 1995 was calculated using:

$$(1) \qquad Q_{Crows,\,Calc} = \frac{Q_{Crows,\,Model} \cdot Q_{Pat,\,Hist}}{Q_{Pat,\,Model}}$$

where

$Q_{Crows,\,Calc}$ = calculated streamflow at Crows Landing
$Q_{Crows,\,Model}$ = SJRIO2 model calculated streamflow at Crows Landing
$Q_{Pat,\,Hist}$ = historical measured streamflow at Patterson
$Q_{Pat,\,Model}$ = SJRIO2 model calculated streamflow at Patterson

SJR at Crows Landing flow data for 1970 through 1991 was presented in the Regional Board staff report describing the original selenium TMML (Karkoski, 1994). Flow for 1992 through

1999 was presented in the U.S. Bureau of Reclamation (USBR) update to the model (USBR, 2000). This combined dataset, using a combination of historical (1970 through 1976 and 1996 through 1999) and calculated (1977 through 1995) hydrology, was used to calculate the design flows in this TMML. The flow data is presented in Appendix A.

Seasonal Variations and Flow Regimes

The model develops flow regimes by categorizing flow data based on water year type and season. Water year type is based on the SJR Index of unimpaired flows (CDWR, 2000). This water year classification scheme identifies water years as Critical (C), Dry (D), Below Normal (BN), Above Normal (AN), or Wet (W). The SJR Index is composed of the unimpaired runoff from the four major rivers in the Basin:

Stanislaus River inflow into Melones Reservoir
Tuolumne River inflow into Don Pedro Reservoir
Merced River inflow into Exchequer Reservoir
San Joaquin River inflow into Millerton Reservoir

The index is determined as follows:

60% current year April to July runoff
20% current year October to March runoff
20% of the previous year index, not exceeding 0.9 million acre-ft

(2) $SJR\ Index = 0.6\,(Apr\ to\ Jul\ runoff) + 0.2\,(Oct\ to\ Mar\ runoff) + 0.2\,(previous\ year\ SJR\ Index)$

The water year classifications are based on threshold values of the SJR Index:

Year Type	Threshold (million acre-feet)
Critical	$C < 2.1$
Dry	$2.1 \le D < 2.5$
Below Normal	$2.5 \le BN < 3.1$
Above Normal	$3.1 \le AN < 3.8$
Wet	$3.8 \le W$

The three water year groupings used in the original selenium TMML model are C, D/BN and AN/W. The seasonal grouping divides the year into four seasons, with months grouped by time of year. The four seasonal groupings are September through November, December and January, February through May, and June through August. The seasonal grouping represents the distinct seasonality of flow in the SJR and DPA drainage flows. High drainage flows occur from February through August and high river flows occur from December through May. The seasonal groupings divide the water years into seasons that cover the combinations of high and low river flows and high and low drainage flows. This seasonal grouping allows the discharger to make the necessary adjustments to meet the load allocation for the particular season. The three water year groupings and four seasonal groupings are combined into 12 flow regimes. The current update to the model increased the number of water year groupings from three to four, resulting in

16 flow regimes instead of 12. The new groupings are C, D/BN, AN, and W. The increased number of groupings maximizes flexibility to dischargers in the DPA by accounting for increased temporal variations of flow.

Violation Rate and Design Flow

After assigning the flow data into appropriate flow regimes, an acceptable violation rate of the objective was needed. The U.S. EPA criterion continuous concentration (chronic toxicity) is the four-day average concentration of a pollutant in water that should not be exceeded more than once every three years on average. The compliance point for this TMDL is the SJR at Crows Landing, which has an incomplete historical flow record. For the years 1969-1972 and 1996-1999, flow data is available at Crows Landing, and a four-day average flow can be calculated. Daily flow at Crows Landing is not available for the years 1973-1995. The model SJRIO-2 was used to calculate monthly flow data for Crows Landing for these years (see *Data Sources*), but daily data is not available. In order to obtain a four-day average for this site, a site with similar flow patterns and a daily flow record must be used. A coefficient must be developed for the similar flow site to convert monthly data to four-day average data. The SJR at Patterson was used to develop these coefficients since it is selected as the closest site with daily data (Karkoski, 1994).

The equation for calculating the four-day average flow on "n"th day of the month is:

$$(3) \qquad \textit{Four - Day Average Flow} = \frac{\sum_{i=0}^{3} Q_{n-i}}{4}$$

The lowest four-day average flow for the month was selected. In situations when data from the Patterson site was required, a coefficient from the ratio of the four-day average low flow to the mean monthly flow for the site was found:

$$(4) \qquad C_{Pat} = \frac{Q_{Pat,\,Four\text{ - }day,\,low}}{Q_{Pat,\,mean\,Monthly}}$$

where

C_{Pat} = monthly to daily coefficient at Patterson
$Q_{Pat,\,Four\text{-}day,\,low}$ = four-day average low streamflow at Patterson
$Q_{Pat,\,mean\,Monthly}$ = mean monthly streamflow at Patterson

This coefficient was multiplied by $Q_{Crows,\,Calc}$ (from equation 1) to determine the monthly equivalent of the four-day average low flow at Crows Landing:

$$(5) \qquad Q_{Crows,\,Four\text{ - }day,\,low} = C_{Pat}\left(Q_{Crows,\,Calc}\right)$$

where

C_{Pat} = monthly to daily coefficient at Patterson
$Q_{Crows,\ Four\text{-}day,\ low}$ = four-day average low streamflow at Crows Landing
$Q_{Crows,Calc}$ = monthly calculated streamflow at Crows Landing

The allowable number of violations is calculated based upon an average exceedance rate of once every three years. This calculation involves multiplying the period of record by the allowable frequency of violations.

$$(6)\quad Allowable\ Number\ of\ Violations\ =\ Period\ of\ Record\ \times Allowable\ Frequency\ of\ Violations$$

There are 10 allowable violations for a one in three year violation frequency over the 30-year flow record under consideration. These violations may be distributed between the various flow regimes. Future rates of violation in this TMDL are based on the observed historical hydrology. This historical hydrology includes water years 1977, and 1987 through 1992, which are some of the driest water years on record in the SJR Basin (CDWR, 2000) The low flow condition, or design flows are calculated for each flow regime by rank ordering the historical flows.

For each flow regime, the flows are rank-ordered from the lowest to highest observed flow. A user-defined percentile is then assigned to each rank-ordered flow regime. Selection of the 0^{th} percentile means the lowest observed flow is selected as a design flow. Selection of the 100^{th} percentile means the highest flow is selected. The Microsoft Excel™ percentile function is used to select a consistent position for the user-defined percentile within each flow distribution. This function interpolates, as necessary, between actual observed flows. The design flow for most of the flow regimes is based on the 0th percentile or the lowest observed flow. If the lowest flow for any flow regime is lower than the C year design flow, the C year design flow is used for that flow regime.

For the 1994 selenium TMML for the lower SJR, all violations were grouped in the C water year groupings with the assumption that dischargers would have the most difficulty in meeting water quality objectives during C water years. Experience of the drainers in the DPA with operating the GBP has identified difficulty also in meeting load limits during wet periods. As a result, some violations have now been assigned to AN and W water years as well as C water years by selecting a user-defined percentile for these flow regimes (Table 8). A 0^{th} percentile (lowest observed flow) is used for all other flow regimes.

Calculating the TMML

Calculation of a TMML follows the same steps required for a TMDL. The TMML is the full assimilative capacity of the water body. The assimilative capacity is calculated by multiplying the design flow (Q_{DF}) by the water quality objective (WQO) and applying a conversion factor.

$$(7)\qquad TMML\ (pounds)\ =\ Q_{DF}(acre\text{ - }ft)\ \times\ WQO\ (\mu g/L)\ \times\ 0.0027\ \ (conversion\ factor)$$

Table 8. Year type, seasonal grouping, percentile rank, design flow and the number of violations over a 30 year period for the San Joaquin River at Crows Landing

Year Type	Grouping	Percentile Rank	Design Flow acre-ft	Number of Violations
C	Sep-Nov	0.07	5,016	2
D/BN	Sep-Nov	0	20,298	0
AN	Sep-Nov	0	22,667	0
W	Sep-Nov	0	27,850	0
C	Dec-Jan	0.08	13,187	2
D/BN	Dec-Jan	0	27,263	0
AN	Dec-Jan	0	35,297	0
W	Dec-Jan	0	19,260	0
C	Feb-May	0.03	9,308	2
D/BN	Feb-May	0	17,132	0
AN	Feb-May	0.05	43,155	1
W	Feb-May	0.02	45,623	1
C	Jun-Aug	0.07	6,188	2
D/BN	Jun-Aug	0	11,402	0
AN	Jun-Aug	0	18,877	0
W	Jun-Aug	0	30,191	0

The total assimilative capacity, or TMML, must be distributed between a waste load allocation (WLA) for point sources, a load allocation (LA) for non-point sources, a margin of safety (MOS), and a background load (BL).

$$TMML = WLA + LA + BL + MOS \qquad (8)$$

Point sources include any concentrated discharge that can be controlled at a point, such as a municipal wastewater treatment plant. There are no point sources of selenium in the lower SJR Basin, so there is no waste load allocation. The DPA is the only non-point source in this TMML. With no waste load allocation component, the load allocation for the DPA can be calculated using:

$$LA = TMML - BL - MOS \qquad (9)$$

Background Load

Distributed selenium loads from low selenium concentration sources in the lower SJR are assigned to the background load of the TMML. Background load values must be calculated for the three main sources of flow and selenium upstream of Crows Landing and exclusive of the DPA: the Merced River, the SJR at Lander Avenue, and the Grassland wetlands. Table 9 contains data used to calculate flow values from each source based on design flows. Design flows are calculated for year type (column a) and grouping (column b) which are combined to provide sixteen flow regimes. For each flow regime, a design flow for the SJR at Crows Landing (column c) has already been determined based on historical Crows Landing flows (Appendix A). The historical Crows Landing flow (column d) that is closest to the design flow (column c) is determined. The month and year of the historical Crows Landing flow (column e) is used to select monthly flows for the Merced River (column f) and the SJR at Lander (column g). The historical Merced River and SJR at Lander Avenue flows are given in Appendix B. The four-day average low flow equivalent to monthly average coefficient (column h) is used to convert monthly flows for both the Merced River and the SJR at Lander Avenue to the four-day average equivalent. This is the same coefficient used to convert from a monthly average to a four-day average low flow for the SJR at Crows Landing, as explained in the *Violation Rate and Design Flow* section above. The monthly average flows are multiplied by the four-day average low flow equivalent to monthly average coefficient to obtain the four-day low flow average for the Merced River (column i) and the SJR at Lander Avenue (column j).

Table 9. Flow from various sources used to calculate background loads of selenium in the lower San Joaquin River Basin

Year Type	Seasonal Grouping	SJR @ Crows Design Four-day average low flow[1] ac-ft	SJR @ Crows Historical Four-day average low flow[2] ac-ft	Similar Flow Month	Merced Historical Monthly flow[3] ac-ft	SJR @ Lander Historical Monthly flow[3] ac-ft	Four-day average low flow equivalent to Monthly flow coefficient[4]	Merced Four-day average low flow equivalent[5] ac-ft	SJR @ Lander Four-day average low flow equivalent[5] ac-ft
a	b	c	d	e	f	g	h	i	j
C	Sep-Nov	5,016	5,345	Nov-77	7,220	269	0.45	3,242	121
D/BN	Sep-Nov	20,298	20,298	Sep-72	54,860	4,580	0.29	16,085	1,343
AN	Sep-Nov	22,667	22,667	Oct-70	13,430	2,188	0.80	10,719	1,746
W	Sep-Nov	27,850	27,850	Sep-97	5,470	389	0.93	5,109	364
C	Dec-Jan	13,187	11,817	Dec-77	11,250	615	0.77	8,630	472
D/BN	Dec-Jan	27,263	27,263	Dec-71	17,140	2,029	0.84	14,374	1,702
AN	Dec-Jan	35,297	35,395	Jan-73	22,420	38,660	0.38	8,531	14,710
W	Dec-Jan	19,260	19,260	Jan-78	21,410	41,330	0.23	4,981	9,616
C	Feb-May	9,308	9,272	May-77	4,000	519	0.57	2,291	297
D/BN	Feb-May	17,132	17,132	Apr-72	12,250	1,401	0.62	7,640	874
AN	Feb-May	43,155	43,931	Apr-70	16,730	6,248	0.92	15,376	5,742
W	Feb-May	45,623	46,101	Feb-93	21,166	39,330	0.48	10,065	18,702
C	Jun-Aug	6,188	6,314	Aug-77	548	330	0.81	446	269
D/BN	Jun-Aug	11,402	11,402	Jul-72	6,220	412	0.71	4,433	294
AN	Jun-Aug	18,877	18,877	Jul-70	8,960	1,615	0.82	7,354	1,326
W	Jun-Aug	30,191	30,191	Aug-97	3,925	1,139	0.80	3,149	914

[1]Data from Table 8
[2]Data from Appendix A
[3]Data from Appendix B
[4]Coefficient calculated using Equation 4
[5]Results from multiplying historical flow (column f,g) by a coefficient (column h)

Concentration data for these background sources are based on fixed values. The concentration of the Merced River is 0.2 µg/L (Westcot et al., 1990) and the SJR at Lander is 0.5 µg/L (Chilcott et al., 2000). Wetland flow data was obtained from a USBR analysis of wetland discharges in an assessment of water quality impacts of the GBP (Swain and Quinn, 1991). Wetland water quality is 1.0 µg/L, based on improvements in wetland supply water quality in the Grassland Watershed. With the operation of the GBP, Salt Slough and Mud Slough upstream of the San Luis Drain confluence no longer convey subsurface agricultural return flows; they convey only surface agricultural return flows and wetland discharges. Annual selenium concentration was 1 µg/L for Salt Slough during water year 1997 (Chilcott et al., 1998). Annual selenium concentration was 1 µg/L for Salt Slough and 1 µg/L for Mud Slough upstream of the San Luis Drain during water year 1998 (Chilcott et al., 2000).

Margin of Safety
No consistent errors have been identified in the flow and selenium water quality information used to generate this TMML. An explicit ten percent MOS is applied to account for errors in flow measurements and selenium concentrations and uncertainty in the TMML analyses. The same ten percent MOS was used in the 1994 TMML (Karkoski, 1994). The ten percent MOS is applied to the calculated assimilative capacity or TMML:

$$(10) \qquad MOS = 0.10 \times TMML$$

Load Allocation
After accounting for the margin of safety and background loads, the remaining load is assigned to the load allocation for the DPA. The TMML and background load vary according to season and water year type. Since the TMML and background load determine the load allocation, the load allocation varies according to season and water year type. Load allocations are higher during wet seasons and years due to higher assimilative capacity in the SJR. Calculation of background load, margin of safety and load allocation is displayed in Table 10 on an annual basis and Table 11 on a monthly basis. A detailed look at calculation of monthly values for TMML, background load, margin of safety, and load allocation is displayed in Table 12.

Table 10. Annual values for the calculation of load allocations for four water year types

Time Period	Year Type	Total SJR @ Crows Landing Design Flow acre-ft	Total TMML pounds	Total Merced Flow acre-ft	Total SJR @ Lander Flow acre-ft	Total Wetland Flow acre-ft	Total Background Load pounds	Total Margin of Safety pounds	Total Load Allocation pounds
Oct-Sept	C	97,214	1,320	37,489	3,301	33,300	115	132	1,073
Oct-Sept	D/BN	218,155	2,963	120,859	11,807	33,300	172	296	2,495
Oct-Sept	AN	367,846	4,996	132,784	61,605	65,400	333	500	4,163
Oct-Sept	W	395,136	5,367	74,994	97,872	65,400	351	537	4,479

Linkage Analysis

A linkage analysis is used to describe the relationship between the numeric targets, identified sources, and the total assimilative capacity (loading capacity) of the waterbody. The linkage analysis for this TMDL was used to determine if numeric targets would have been met if the proposed load allocations had been applied to historic flows and background loads from 1986 through 1999. Background flows and selenium loads for this historic period were compiled and calculated for the SJR at Lander Avenue, Merced River, Mud Slough, and Salt Slough (Appendix C). Monthly flows are based on daily USGS flow measurements. Selenium concentrations for the SJR at Lander Avenue and the Merced River are assumed to be 0.5 and 0.2 µg/L respectively. Selenium concentration in Mud Slough and Salt Slough is assumed to be

Table 11. Calculation of load allocation for each month and year type

Month	Year Type	Design Flow acre-ft	TMML	Background Load	Margin of Safety	Load Allocation
			------------------- pounds	-------------------	-------------------	-------------------
Sep	C	5,016	68	5	7	57
Sep	D/BN	20,298	276	13	28	235
Sep	AN	22,667	308	13	31	264
Sep	W	27,850	378	8	38	332
Oct	C	5,016	68	7	7	55
Oct	D/BN	20,298	276	15	28	233
Oct	AN	22,667	308	17	31	260
Oct	W	27,850	378	12	38	328
Nov	C	5,016	68	7	7	55
Nov	D/BN	20,298	276	15	28	233
Nov	AN	22,667	308	17	31	260
Nov	W	27,850	378	12	38	328
Dec	C	13,187	179	10	18	152
Dec	D/BN	27,263	370	14	37	319
Dec	AN	35,297	479	33	48	398
Dec	W	19,260	262	24	26	211
Jan	C	13,187	179	10	18	151
Jan	D/BN	27,263	370	15	37	319
Jan	AN	35,297	479	34	48	398
Jan	W	19,260	262	25	26	211
Feb	C	9,308	126	21	13	93
Feb	D/BN	17,132	233	25	23	185
Feb	AN	43,155	586	55	59	472
Feb	W	45,623	620	70	62	488
Mar	C	9,308	126	21	13	92
Mar	D/BN	17,132	233	25	23	184
Mar	AN	43,155	586	55	59	472
Mar	W	45,623	620	70	62	488
Apr	C	9,308	126	13	13	101
Apr	D/BN	17,132	233	16	23	193
Apr	AN	43,155	586	37	59	490
Apr	W	45,623	620	52	62	506
May	C	9,308	126	9	13	105
May	D/BN	17,132	233	13	23	197
May	AN	43,155	586	31	59	497
May	W	45,623	620	45	62	512
Jun	C	6,188	84	7	8	69
Jun	D/BN	11,402	155	9	15	130
Jun	AN	18,877	256	18	26	212
Jun	W	30,191	410	15	41	354
Jul	C	6,188	84	6	8	70
Jul	D/BN	11,402	155	8	15	131
Jul	AN	18,877	256	16	26	214
Jul	W	30,191	410	14	41	356
Aug	C	6,188	84	1	8	75
Aug	D/BN	11,402	155	3	15	137
Aug	AN	18,877	256	6	26	225
Aug	W	30,191	410	3	41	366

Table 12. Stepwise calculation of load allocation, including design flow, TMML, background load and margin of safety

Time Period	Year Type	Water Quality Objective[1] µg/L 1	SJR @ Crows Landing Design Flow[2] acre-ft 2	TMML[3] 1 x 2 pounds 3	Merced Flow acre-ft 4	Merced Conc.[4] µg/L 5	SJR @ Lander Flow acre-ft 6	SJR @ Lander Conc.[4] µg/L 7	Wetland Flow[5] acre-ft 8	Wetland Conc.[6] µg/L 9	Background Load 4 x 5 + 6 x 7 + 8 x 9 pounds 10	Margin of Safety[7] 3 x 10% pounds 11	Load Allocation 3 - 10 - 11 pounds 12
Sep	C	5	5,016	68	3,242	0.2	121	0.5	1,000	1	5	7	57
Sep	D/BN	5	20,298	276	16,085	0.2	1,343	0.5	1,000	1	13	28	235
Sep	AN	5	22,667	308	10,719	0.2	1,746	0.5	1,900	1	13	31	264
Sep	W	5	27,850	378	5,109	0.2	364	0.5	1,900	1	8	38	332
Oct	C	5	5,016	68	3,242	0.2	121	0.5	1,700	1	7	7	55
Oct	D/BN	5	20,298	276	16,085	0.2	1,343	0.5	1,700	1	15	28	233
Oct	AN	5	22,667	308	10,719	0.2	1,746	0.5	3,300	1	17	31	260
Oct	W	5	27,850	378	5,109	0.2	364	0.5	3,300	1	12	38	328
Nov	C	5	5,016	68	3,242	0.2	121	0.5	1,700	1	7	7	55
Nov	D/BN	5	20,298	276	16,085	0.2	1,343	0.5	1,700	1	15	28	233
Nov	AN	5	22,667	308	10,719	0.2	1,746	0.5	3,300	1	17	31	260
Nov	W	5	27,850	378	5,109	0.2	364	0.5	3,300	1	12	38	328
Dec	C	5	13,187	179	8,630	0.2	472	0.5	1,600	1	10	18	152
Dec	D/BN	5	27,263	370	14,374	0.2	1,702	0.5	1,600	1	14	37	319
Dec	AN	5	35,297	479	8,531	0.2	14,710	0.5	3,200	1	33	48	398
Dec	W	5	19,260	262	4,981	0.2	9,616	0.5	3,200	1	24	26	211
Jan	C	5	13,187	179	8,630	0.2	472	0.5	1,700	1	10	18	151
Jan	D/BN	5	27,263	370	14,374	0.2	1,702	0.5	1,700	1	15	37	319
Jan	AN	5	35,297	479	8,531	0.2	14,710	0.5	3,300	1	34	48	398
Jan	W	5	19,260	262	4,981	0.2	9,616	0.5	3,300	1	25	26	211
Feb	C	5	9,308	126	2,291	0.2	297	0.5	7,200	1	21	13	93
Feb	D/BN	5	17,132	233	7,640	0.2	874	0.5	7,200	1	25	23	185
Feb	AN	5	43,155	586	15,376	0.2	5,742	0.5	14,400	1	55	59	472
Feb	W	5	45,623	620	10,065	0.2	18,702	0.5	14,400	1	70	62	488
Mar	C	5	9,308	126	2,291	0.2	297	0.5	7,300	1	21	13	92
Mar	D/BN	5	17,132	233	7,640	0.2	874	0.5	7,300	1	25	23	184
Mar	AN	5	43,155	586	15,376	0.2	5,742	0.5	14,400	1	55	59	472
Mar	W	5	45,623	620	10,065	0.2	18,702	0.5	14,400	1	70	62	488
Apr	C	5	9,308	126	2,291	0.2	297	0.5	4,000	1	13	13	101
Apr	D/BN	5	17,132	233	7,640	0.2	874	0.5	4,000	1	16	23	193
Apr	AN	5	43,155	586	15,376	0.2	5,742	0.5	7,800	1	37	59	490
Apr	W	5	45,623	620	10,065	0.2	18,702	0.5	7,800	1	52	62	506
May	C	5	9,308	126	2,291	0.2	297	0.5	2,700	1	9	13	105
May	D/BN	5	17,132	233	7,640	0.2	874	0.5	2,700	1	13	23	197
May	AN	5	43,155	586	15,376	0.2	5,742	0.5	5,300	1	31	59	497
May	W	5	45,623	620	10,065	0.2	18,702	0.5	5,300	1	45	62	512
Jun	C	5	6,188	84	446	0.2	269	0.5	2,400	1	7	8	69
Jun	D/BN	5	11,402	155	4,433	0.2	294	0.5	2,400	1	9	15	130
Jun	AN	5	18,877	256	7,354	0.2	1,326	0.5	4,600	1	18	26	212
Jun	W	5	30,191	410	3,149	0.2	914	0.5	4,600	1	15	41	354
Jul	C	5	6,188	84	446	0.2	269	0.5	2,000	1	6	8	70
Jul	D/BN	5	11,402	155	4,433	0.2	294	0.5	2,000	1	8	15	131
Jul	AN	5	18,877	256	7,354	0.2	1,326	0.5	3,900	1	16	26	214
Jul	W	5	30,191	410	3,149	0.2	914	0.5	3,900	1	14	41	356
Aug	C	5	6,188	84	446	0.2	269	0.5	0	1	1	8	75
Aug	D/BN	5	11,402	155	4,433	0.2	294	0.5	0	1	3	15	137
Aug	AN	5	18,877	256	7,354	0.2	1,326	0.5	0	1	6	26	225
Aug	W	5	30,191	410	3,149	0.2	914	0.5	0	1	3	41	366

[1] 1 in 3 year exceedance rate of a 4-day standard
[2] Flow record WY 1970-WY 1999
[3] Conversion Acre-ft x µg/L to lbs. = 0.0027
[4] Concentration for Merced River is from Westcot et al., 1990 and for SJR at Lander is from Chilcott et al., 2000
[5] Flow for Grassland wetlands is from Table 2C in Appendix 4 of CRWQCB-CVR, 1996
[6] Concentration for Grassland wetlands is from Chilcott et al., 2000
[7] Margin of Safety (MOS) is 10% from Karkoski, 1994

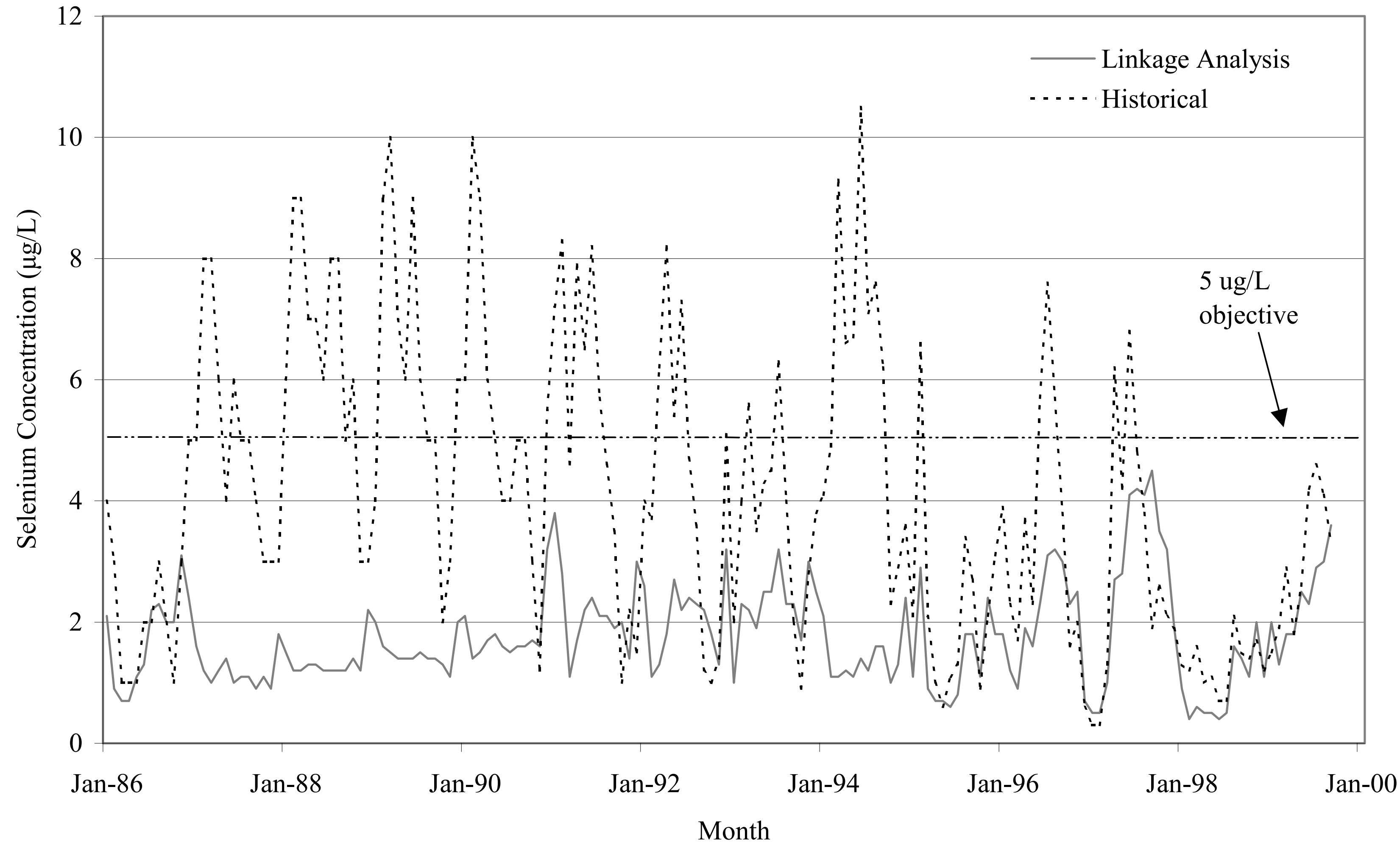

Figure 6. Comparison of monthly historical concentration, linkage analysis concentration and the water quality objective from water year 1986 through water year 1999 for the SJR at Crows Landing

1.0 μg/L. The sum of the monthly background load and the monthly TMML load allocation is divided by the total monthly flow to obtain a monthly selenium concentration (Appendix D). Based on these assumptions there would have been no violations of a 5 μg/L monthly selenium objective for this 14-year period. Historical monthly selenium concentrations in the SJR were significantly higher than those that would have occurred if TMML load limits had been in place (Figure 6). A detailed look, using the methods described above, at daily concentrations for water years 1991 and 1997 shows that there would have been only 6 violations of the 5 μg/L four-day average (Appendix E and F). This rate of exceedance is in line with the allowable rate of violations (1 in 3 years for a total of 5 over 15 years) and validates use of the TMML model to establish load limits that will achieve compliance with water quality objectives.

Implementation Plan

The program to implement this TMDL and the selenium TMDLs for Salt Slough and the Grassland Marshes was adopted in the Regional Board's 1996 Basin Plan Amendment. Included in this 1996 Basin Plan Amendment is a timetable for meeting selenium water quality objectives in the lower SJR (Table 1). The 5 μg/L four-day average water quality objective for the SJR below the Merced River must be met in AN and W years starting in water year 2006. The 5 μg/L four-day average objective must be met for C, D and BN years starting in water year 2011. The 5 μg/L four-day average water quality objective must also be met for all year types in Mud Slough and the SJR from Sack Dam to the Merced River starting in water year 2011. Starting in water year 1997, this amendment also prohibited discharge of agricultural subsurface drainage to Grassland Watershed wetland supply channels and Salt Slough if the discharge results in concentrations exceeding the 2 μg/L water quality objective established for these channels.

Concurrent with development of the 1996 Basin Plan Amendment, the San Luis and Delta Mendota Water Authority (SLDMWA) and the USBR entered into an agreement to use a portion of the San Luis Drain to convey agricultural subsurface drainage directly to Mud Slough. This *Agreement for Use of the San Luis Drain* (1995 Use Agreement) (USBR-SLDMWA, 1995) (Appendix G) allowed use of a 28-mile segment of the San Luis Drain as part of the GBP for a five-year period starting in November 1995. The GBP commenced operation on September 23, 1996. Since September 1996, the GBP has isolated and rerouted agricultural subsurface drainage from the DPA away from Salt Slough and the wetland supply channels by using a portion of the San Luis Drain to convey agricultural subsurface drainage directly to Mud Slough. The San Luis Drain discharges to Mud Slough approximately nine miles upstream of the SJR confluence.

Interim load limits were established for the first five years of operation of the GBP as part of the 1995 Use Agreement. Load limits were agreed upon by consensus of the dischargers in the DPA, the U.S. EPA, the U.S. Fish and Wildlife Service and the USBR (CRWQCB-CVR, 1996). The annual load limit for the first two years of the project, water years 1997 and 1998, was set at 6,660 pounds per year. This annual load limit was reduced by five percent per year for the next three years. The 1995 Use Agreement was renewed in 1999 to extend use of the San Luis Drain for an additional two-year period that concludes September 30, 2001.

These consensus-based monthly and annual selenium load limits for August 1998 through September 2001, were incorporated into *Waste Discharge Requirements for San Luis and Delta-Mendota Water Authority and United Sates Department of the Interior Bureau of Reclamation*

Grassland Bypass Project Fresno and Merced Counties, Order Number 98-171 (CRWQCB, 1998b) (Appendix I). In the absence of new load limits from a new Use Agreement or TMDL for the period after September 2001, these 1998 Waste Discharge Requirements establish monthly and annual selenium load limits based upon the draft TMML presented in the 1996 Basin Plan Amendment.

The USBR has drafted a new use agreement, *Agreement for Use of the San Luis Drain* (2001 Use Agreement) (USBR-SLDMWA, 2001) (Appendix H) that, if approved by the USBR and SLDMWA, will permit the SLDMWA to implement the GBP through December 2009 (Table 13). This draft 2001 Use Agreement establishes monthly and annual load limits that continue the five percent per year reduction in load limits through water year 2004. Starting in water year 2005, load limits diverge based on water year type, as shown in Figure 7 (USBR-SLDMWA, 2001). Starting in water year 2005, the load limits specified in the use agreement are based, in part, on load limits in this TMDL. The Basin Plan specifies that the water quality objective of 5 µg/L must be met in the SJR downstream of the Merced River in AN and W water years starting in water year 2006. The draft 2001 Use Agreement contains load limits calculated in this TMDL to meet water quality objectives in AN and W water years starting in water year 2005. The water quality objective for D/BN and C water years must be met starting in water year 2011. The draft 2001 Use Agreement contains load limits calculated in this TMDL to meet water quality objectives in D/BN and C water years starting in water year 2011. The draft 2001 Use Agreement load limits are also incorporated in the *Tentative Waste Discharge Requirements for San Luis and Delta-Mendota Water Authority and United States Department of the Interior Bureau of Reclamation Grassland Bypass Project (Phase II) Fresno and Merced Counties* (CRWQCB-CVR, 2001) (Appendix J).

Table 13. Annual load allocations from this TMDL and 2001 Tentative Waste Discharge Requirements (WDR) (CRWQCB-CVR, 2001)

Year Type	2001 TMDL Load Allocation	2003 WDR Load Allocation	2006 WDR Load Allocation	2010 WDR Load Allocation
C	1,073	4,995	3,853	1,073
D/BN	2,495	4,995	3,995	2,495
AN	4,163	4,995	4,163	4,163
W	4,479	4,995	4,479	4,479

Selenium load reduction is being achieved through a variety of control methods used by the Grassland Area Farmers. The Grassland Area Farmers is a consortium of water and irrigation districts responsible for agricultural subsurface drainage collected and discharged to the San Luis Drain as part of the GBP. The Grassland Area Farmers have a comprehensive program in place that evaluates and implements a variety of regional, district-level, and farm-level activities to reduce selenium discharge. Following is a partial listing of these activities:

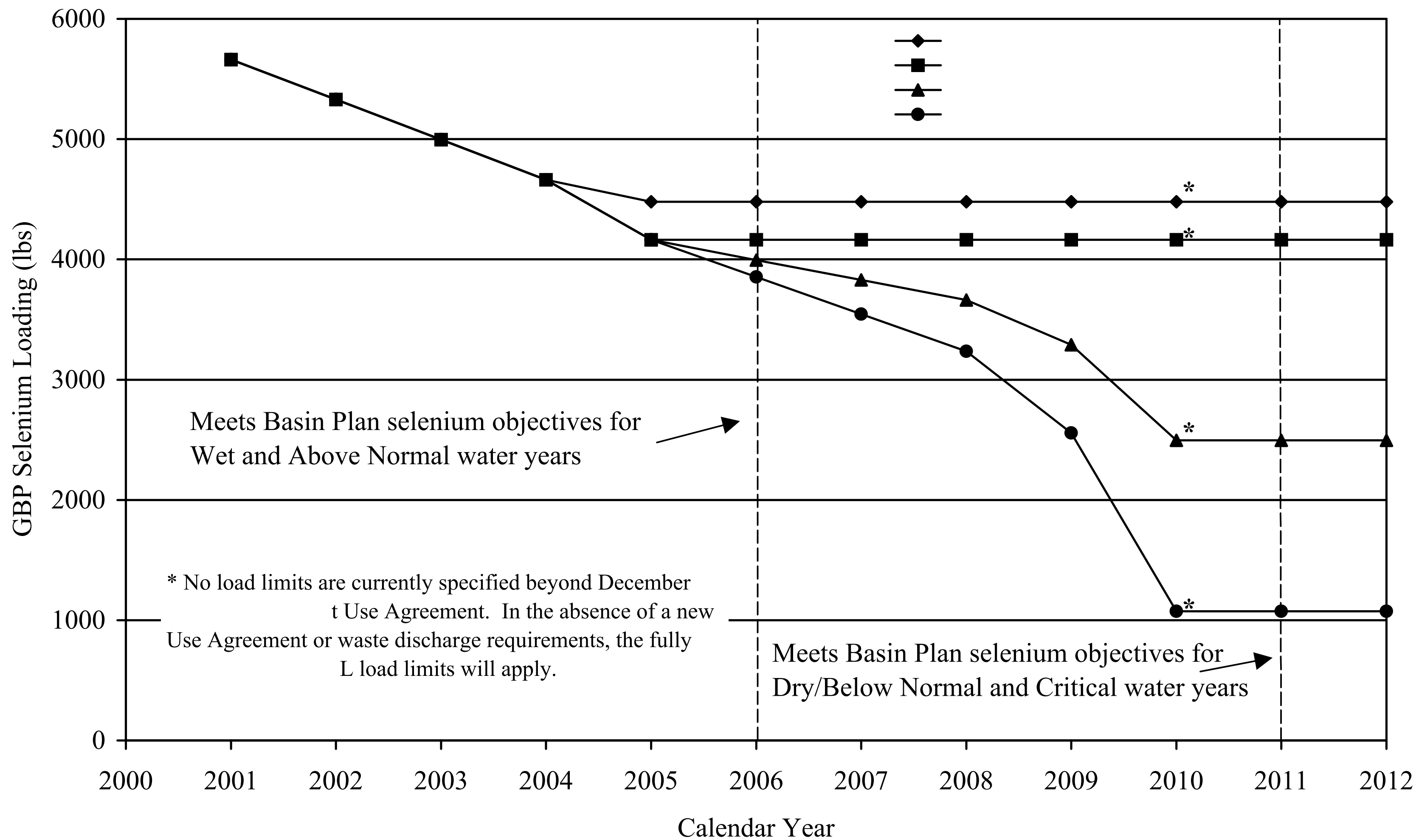

Figure 7. Load allocations and compliance dates for the Grassland Bypass Project (GBP) as outlined in the 2001 Draft Use Agreement for the San Luis Drain (USBR-SLDMWA, 2001) and 2001 Tentative Waste Discharge Requirements (CRWQCB-CVR, 2001)

Regional Components
- Regional Drainage Entity (Activity Agreement)
- Regional Drainage Coordinator
- Irrigation and Drainage Workshops
- Active Land Management Program
- Economic Incentives Program

District Level Components
- Low interest water conservation equipment loans
- Tiered water pricing
- Sprinkler pre-irrigations
- Tailwater recirculation
- Sump management
- Drainage water recycling
- Drainage water displacement
- Drainage water treatment
- Limited water transfers

Farm Level Components
- Improved irrigation methods
- Tailwater return ponds
- On-farm recycling

Full description of these activities is available in the *1998-1999 Annual Report of the Grassland Bypass Project* (USBR, 1999).

Performance Measures and Feedback

There has been on-going water quality monitoring of the GBP, conducted by several agencies, including the Regional Board and the Grassland Area Farmers, since September 1996. The monitoring plan is described in the *1998-1999 Annual Report of the Grassland Bypass Project* (USBR, 1999). The purpose of monitoring is to verify compliance with selenium objectives in the Basin Plan. If monitoring demonstrates that the water quality objectives are not being met, then additional load reductions or amendments to the TMDL will be required.

Public Participation

The Regional Board held workshops and public hearings for the 1996 Basin Plan Amendment. The State Water Resources Control Board also held approval hearings. Comment letters (Appendix K) and a response to comments (Appendix L) are included in this report. The administrative record (Appendix M) for the workshops and public hearings held for the 1996 Basin Plan Amendment are on file at the Regional Board in five 3.5 inch binders.

Additional meetings have been held as part of the *Environmental Impact Statement and Environmental Impact Report for the Grassland Bypass Project* (URS, 2001) that has been prepared for the continued use of the GBP. Appendix N contains a list of meeting dates and list of commenters. The response to comments section is also included (Appendix O).

A Regional Board staff workshop was held on 16 May 2001 that presented this TMDL to all interested parties. Appendix P contains a copy of the workshop announcement, a list of attendees at this workshop, a copy of the material presented, and a copy of the mailing list used to notify interested parties. Load allocations in this report and the methods used to calculate them were presented at this staff workshop.

The *Waste Discharge Requirements for San Luis and Delta-Mendota Water Authority and United States Department of the Interior Bureau of Reclamation Grassland Bypass Project (Phase II) Fresno and Merced Counties* are being considered as an agenda item (Appendix Q) for the 6-7 September 2001 Regional Board meeting. Stakeholders including Environmental Defense, San Luis & Delta-Mendota Water Authority, Contra Costa County, Panoche Drainage District, Contra Costa Water District, and Camp 13 Drainage District are supportive of these Waste Discharge Requirements and the TMDL load limits as indicated by their 22 August 2001 letter of support (Appendix R).

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