EXECUTIVE SUMMARY

Since May 1985, the Central Valley Regional Water Quality Control Board has conducted a water quality monitoring program in the San Joaquin Valley of California to assess the impacts of agricultural subsurface drainage on wetland water supply channels in the Grassland Watershed. The Grassland Watershed is a 370,000-acre area, west of the San Joaquin River covering portions of Merced and Fresno counties between the Tulare Lake Basin and the Orestimba Creek alluvial fan. The watershed contains both farmed land, including a 90,000 acre area known as the Drainage Project Area (DPA), and approximately 100,000 acres of wetland habitat, including State and Federal wildlife refuges and private gun clubs. The watershed is tributary to the San Joaquin River, with Mud Slough (north) and Salt Slough serving as the main drainage arteries. During the period covered by this report, 1 October 1995 through 30 September 1997 (Water Years 1996 and 1997[1]), a major change occurred in the agricultural drainage water management in the Grassland Watershed: the advent of the Grassland Bypass Project (GBP). The project began operation on 23 September 1996 and consolidated subsurface agricultural drainage, which historically flowed through wetland water supply channels, into a single channel, allowing the drainage to bypass approximately 90 miles of wetland water supply channels and Salt Slough. The drainage was redirected into the final 28 miles of the San Luis Drain for discharge into the lower nine miles of Mud Slough (north) and eventually into the San Joaquin River. Data presented in this report represents the water quality in selected water bodies within the Grassland Watershed one year prior to and one year after the advent of the Bypass project.

During Water Year 1996, water quality sampling was conducted at 17 sites within the Grassland Watershed and represented drainage from the DPA, internal wetland supply canals and overall discharge from the watershed. During Water Year 1997, the program was altered to reflect the changes in drainage water management resulting from the use of the Grassland Bypass. The remaining nine monitoring sites focused the program on providing data which could be used to evaluate the impact of the bypass. The primary constituents evaluated included electrical conductivity, boron and selenium, with more limited analyses of molybdenum, copper, chromium, lead, nickel, zinc, chloride and sulfate. Grab samples were collected on a weekly, monthly or quarterly schedule depending on the location and automated, composite samples were collected at selected sites to provide information on fluctuating concentrations and to provide a more complete data set for load calculations for salt, boron, and selenium.

The San Joaquin River Index is used to classify water year type in the river basin based on total runoff (SWRCB, 1995). Both Water Year 1996 and 1997 were classified as wet water years with periods of localized flooding occurring during February and March of 1996 and during the end of January and early February 1997. During the flooding in 1997, the Grassland Bypass could not handle the volume of drainage from the DPA and a portion of subsurface agricultural drainage was diverted through the wetland water supply channels and into Salt Slough between 27 January and 5 February.

During Water Year 1996, constituent concentrations followed trends observed during the previous years of study. The highest concentrations occurred in drains from the DPA, with elevated concentrations also apparent in Salt Slough. Internal channels had varying concentrations, depending on the routing of the subsurface agricultural drainage. Concentrations peaked in April 1996, as flood water receded and pre-irrigation began.

During Water Year 1997, all subsurface agricultural drainage from the DPA was removed from the internal wetland supply canals and Salt Slough and rerouted to the final nine miles of Mud Slough (north) through the San Luis Drain. Electrical conductivity, boron and selenium concentrations in the internal canals and Salt Slough dropped significantly over previous water years with the lowest mean monthly and annual concentrations recorded since 1985. A corresponding increase in constituent concentrations was noted in Mud Slough (north), reflecting discharge from the San Luis Drain which reached concentrations of 5460 µmhos/cm, 8.4 mg/L, and 107 µg/L for electrical conductivity, boron, and selenium, respectively.

[1] A Water Year covers the time period from 1 October through 30 September of the following year.

In October 1988, Central Valley Regional Board adopted water quality objectives for boron, molybdenum and selenium for Mud Slough (north) and Salt Slough and a selenium objective for water used to maintain wetland habitat (Resolution #88-195). The mean monthly boron objective (2.0 mg/L) depends on season and only applies from 15 March through 15 September, while the maximum objective applies year round.. In May 1996, the Regional Board adopted revised selenium water quality objectives for the two sloughs and for wetland water supply channels, as well as a compliance time schedule for Mud Slough (north). The selenium compliance time schedule does not require full compliance with the selenium objective until 1 October 2010. No water quality objectives have been adopted for the San Luis Drain.

During Water Year 1996, based on composite sampling data, the boron objective (2.0 mg/L) was not exceeded in Mud Slough (north), but was exceeded almost continuously from March through July in Salt Slough, with concentrations just below 2.0 mg/L in April. During Water Year 1997, the objective was exceeded in Mud Slough (north) both upstream and downstream of the San Luis Drain discharge. Upstream of the discharge, the exceedances were limited to March and April and may be due to a number of factors including localized elevated levels in groundwater seepage, releases from wetlands, and other surface drainage. Downstream of the discharge, the objective was exceeded continuously from March through September. No boron objective exceedances were observed in Salt Slough, during Water Year 1997. The improved water quality is most likely the result of the diversion of DPA subsurface agricultural drainage out of that water body.

During Water Year 1996, the applicable selenium water quality objective was only exceeded in Salt Slough, with monthly mean concentrations remaining above 10 μg/L from December through September. The selenium objectives changed during Water Year 1997, to a 2 μg/L monthly mean objective for Salt Slough and wetland water supply channels and a 5 μg/L 4-day average objective for Mud Slough (north) that is subject to a compliance time schedule. The revised objectives were not exceeded in Salt Slough, during Water Year 1997, but were exceeded sporadically in the wetland water supply channels. Exceedances in the supply channels may be due to a number of factors including elevated selenium levels in supply water, releases from the DPA (both in response to flood events and seepage from gates and canals), inflows from other agricultural subsurface drainage sources, and local sources such as groundwater seepage and surface return flows. Selenium concentrations in Mud Slough (north) above the drainage discharge remained below 5 μg/L, while monthly mean concentrations in the slough downstream of the drainage discharge remained above 5 μg/L, however, the slough is subject to a compliance time schedule.

Molybdenum concentrations remained consistent between the two water years for all sites except Mud Slough (north) downstream of the San Luis Drain discharge. Prior to Water Year 1997, the 19 μg/L monthly mean molybdenum objective was not exceeded in either Mud Slough (north) or Salt Slough. During Water Year 1997, the molybdenum objective was exceeded downstream of the drainage discharge five times; in February, April, June, August and September. Molybdenum concentrations in the drainage discharge ranged from 22 μg/L to 35 μg/L.

Salt, boron, and selenium loads for the DPA and the Grassland Watershed were calculated using the flow weighted monthly average of the available water quality data. In Water Year 1997, loads that previously had to be summed for individual sites in the DPA were consolidated into the San Luis Drain as part of the GBP. Discharge and loads from the DPA for Water Year 1997 are therefore based on discharge and loads from the GBP. Monthly discharge and monthly flow weighted average concentrations and loads for 1996 and 1997 for the Grassland Watershed are based on the combined discharge and loads for Mud Slough (north) and Salt Slough.

Annual discharge from the DPA dropped 30 percent between Water Years 1996 and 1997, from approximately 53,000 acre-feet to approximately 37,500 acre-feet. Annual salt load for the DPA also dropped 30 percent from just under 200,000 tons in 1996 to 140,000 tons in 1997. Boron loads were practically identical for both years at just over 700,000 pounds. Selenium loads from the DPA dropped 30 percent from approximately 10,000 pounds to under 7,000 pounds between 1996 and 1997.

Annual discharge from the Grassland Watershed to the San Joaquin River was similar in both years, increasing slightly from approximately 270,000 acre-feet in 1996 to approximately 290,000 acre-feet in 1997. Annual salt load for the watershed was similar for both years, dropping from just over 475,000 tons to just under 450,000 tons, while boron loads increased from approximately 1.3 million pounds to 1.4 million pounds. Selenium loads dropped almost 20 percent, from 9,500 pounds in 1996 to 7,700 pounds in 1997.

Although the DPA contributes large quantities of salt and boron, it is not the only source of these constituents in the basin. The DPA is, however, the primary source of selenium in the Grassland Watershed. In 1996, a higher selenium load was actually calculated in the DPA than in the watershed, which may be due to losses in the system or errors in the estimates used for calculating the loads. In 1997, the DPA accounted for 90 percent of the selenium load from the Grassland Watershed.

Monthly loading of constituents depended on the season and on the weather pattern. In the DPA, constituent loads tended to increase in January and stay at elevated levels throughout the irrigation season, dropping off by September. The Grassland Watershed followed a similar pattern, but was greatly influenced by storm events during both Water Years 1996 and 1997. During 1996, the highest monthly loads of all constituents leaving the watershed were recorded during February and March. During 1997, the highest loading leaving the watershed occurred during January, February and March and corresponded to major storms and flooding.

When compared to annual records since Water Year 1986, loads during wet Water Years 1996 and 1997 were comparable to loads for another wet water year (1986) but lower than loads during wet Water Year 1995. Water Year 1995 followed several years of dry and critically dry years. High loads of all constituents in 1995 likely resulted from the leaching of salts that had accumulated in the basin during previous years. Generally lower loads of all constituents in 1996 and 1997 were likely due to lower residual salt loads in the Grassland Watershed following a series of wet years and ongoing drainage management activities in the DPA.

Water quality monitoring in the Grassland Watershed will continue to allow evaluation of management practices on instream water quality and on constituent loads.

INTRODUCTION

The Agricultural Unit of the Central Valley Regional Water Quality Control Board (Regional Board) initiated a water quality monitoring program in May 1985 to evaluate the effects of subsurface agricultural drainage on the water quality of canals, drains, and sloughs in the Grassland Watershed in western Merced County. The Grassland Watershed is located west of the San Joaquin River between the Tulare Lake Basin and the Orestimba Creek alluvial fan. The purpose of this monitoring program was to compile an on-going database of selected inorganic constituents found in agricultural drains that discharge to and flow through wildlife areas before entering the San Joaquin River. This database has been and continues to be used to develop and evaluate agricultural drainage reduction programs in the San Joaquin River Basin.

This report contains laboratory results and a summary of water quality analyses for all constituents measured as part of the program during Water Years 1996 and 1997 (October 1995 through September 1997).[2] These two years represent conditions one year prior to and one year after a major change in the agricultural drainage water management in the Grassland Watershed: the advent of the Grassland Bypass Project. The Grassland Bypass began operation on 23 September 1996. The project consolidated subsurface agricultural drainage, which historically flowed through wetland water supply channels, into a single channel, allowing the drainage to bypass approximately 90 miles of wetland water supply channels. This report presents the data collected during both years, and compares salinity (measured as electrical conductivity), boron and selenium water quality at selected sites with respect to hydrology, change in water management, and applicable water quality objectives.

Water quality data collected during the previous years of study can be found in both a summary report presenting salinity, boron, and selenium information from May 1985 through September 1996 (Steensen et al., 1998) and in a series of annual reports presenting all water quality information collected (James et al., 1988; Chilcott et al., 1989; Westcot et al., 1990, 1991, and 1992; Karkoski and Tucker, 1993; Vargas et al., 1995; Chilcott et al., 1995; and Steensen et al., 1996).

STUDY AREA

The study area consists of the Grassland Watershed located west of the San Joaquin River between the towns of Newman and Mendota, in the San Joaquin River Basin in California. The watershed encompasses approximately 370,000 acres and includes the northern and southern divisions of Grassland Water District (GWD), and farmlands adjacent to the district. The watershed also contains a 90,000 acre area known as the Drainage Project Area (DPA), and approximately 100,000 acres of wetland habitat, including State and Federal wildlife refuges and private gun clubs (Figure 1).

Prior to October 1996, agricultural lands east, west, and south of the GWD discharged subsurface agricultural drainage water (tile drainage) and surface runoff (irrigation tailwater) through the GWD. Subsurface drainage from this area often contains high concentrations of salt, selenium and other trace elements. This regional drainage flowed north through the GWD, carried by a network of canals that could divert water in several possible ways before discharging into Mud Slough (north) or Salt Slough. These two sloughs are tributary to the San Joaquin River and serve as the primary drainage outlets for the Grassland Watershed.

After October 1996, all subsurface agricultural drainage from the DPA was rerouted into the Grassland Bypass which discharges into the final 28 miles of the San Luis Drain. The consolidated subsurface drainage is then released into the final nine miles of Mud Slough (north) for eventual discharge into the San Joaquin River. Consolidating the subsurface drainage removes the primary source of selenium in approximately 90 miles of canals which can supply water to wetland habitat. Reducing selenium in these water bodies is a primary goal of the project, since elevated concentrations of selenium have been documented to be hazardous to waterfowl (Skorupa, 1998).

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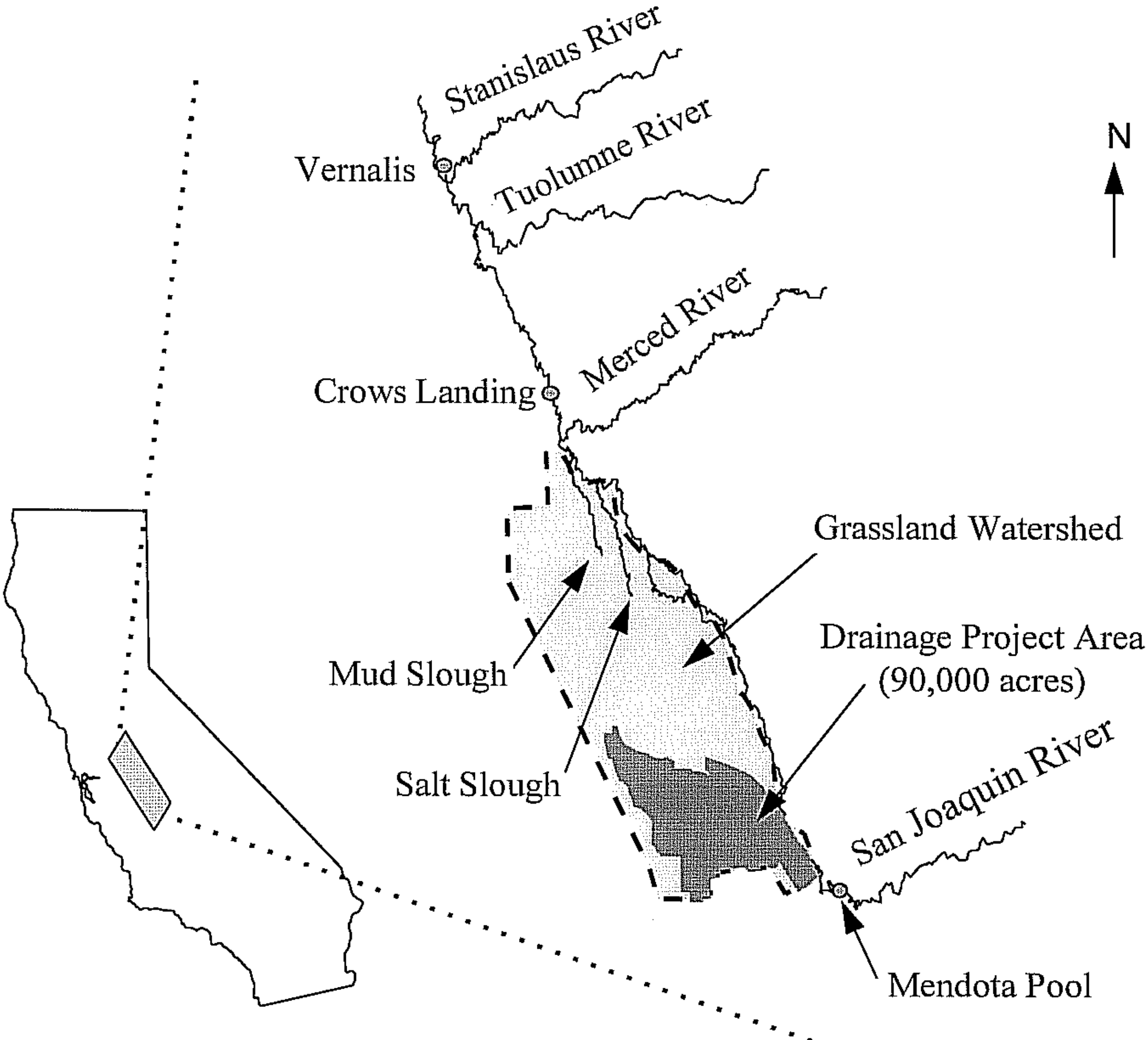
[2] A water year lasts from October 1st of one year through September 30th of the next year.

Figure 1. The Grassland Watershed Within the Lower San Joaquin River Basin.



SAMPLING PROGRAM

During Water Year 1996, water quality sampling was conducted at 17 sites within the Grassland Watershed: nine inflow sites to and four internal flow sites within the GWD and four outflow sites from the Grassland Watershed (Table 1). Inflow monitoring stations were located on drains that discharge into the GWD and are mainly situated at the southern end of the study area. Internal sites were located on canals within the GWD that carry or could carry subsurface tile drainage as it passes through, before discharging to the San Joaquin River. Outflow monitoring stations were located on water bodies which flow out of the Grassland Watershed.

Mud Slough (north) and Salt Slough are the primary tributaries to the San Joaquin River that drain the Grassland Watershed and are described in detail in previous reports (Pierson et al., 1989a and 1989b). Mud Slough (north) at the San Luis Drain (MER542) and Salt Slough at Lander Avenue (MER531) are located near flow monitoring stations operated by the U.S. Geologic Survey and are two principal stations in this monitoring program. These two sites best represent the water quality of the drainage leaving the Grassland Watershed. Los Banos Creek at Highway 140 (MER554) drains into Mud Slough (north) upstream of the San Joaquin River but downstream of the site near the San Luis Drain. Mud Slough (north) at Newman Gun Club (MER551) represents the combined quality of Mud Slough (north) and Los Banos Creek.

During Water Year 1997, the water quality monitoring program was altered to reflect the changes in drainage water management resulting from the use of the Grassland Bypass. With the consolidation of agricultural subsurface drainage, a majority of the inflow sites which historically contained the drainage, were eliminated from the sampling program. The remaining sites focused the monitoring program on providing data which could be used to evaluate the impact of the new bypass. Key sites which were maintained and provide comparison to pre-bypass conditions include: Camp 13 Slough and Agatha Canal (inflow); Santa Fe and San Luis Canals at Henry Miller Road (internal); and Mud Slough (north) at the San Luis Drain terminus and Salt Slough (outflow). In addition, three new sites were added to evaluate the discharge from the bypass itself: Mud Slough (north) upstream of the bypass discharge (MER536), discharge from the San Luis Drain (MER535), and inflow from the Grassland Bypass to the San Luis Drain at Check 17 (MER562). In total, water samples were collected at nine sites during Water Year 1997 (Table 2).

SAMPLE COLLECTION METHODS

Two distinct types of water samples were collected for this program: grab samples and automated composite samples. Although Regional Board staff collected all the water samples during Water Year 1996, staff from the Panoche Water District collected grab samples from five of the sites during Water Year 1997: Camp 13, Agatha Canal, Santa Fe Canal, San Luis Canal, and the Grassland Bypass inflow to the San Luis Drain. Field measurements for water temperature, electrical conductivity (EC), and pH were conducted at all sites monitored by Regional Board staff. Follow up EC measurements were made on all samples at the Regional Board office laboratory: within 24 hours for samples collected by Regional Board staff and within 24 hours of receipt of samples from Panoche Water District staff. The types of samples, methods for collection and quality control and assurance are discussed below.

Grab Samples

During both Water Year 1996 and 1997, grab samples were collected on either a weekly, monthly or quarterly basis depending on site and the constituent to be analyzed (Tables 3 and 4). Analyses for EC, total boron, and total selenium were conducted on all samples. Selected sites were also monitored for molybdenum, copper, chromium, nickel, lead, and zinc on a monthly or quarterly basis. During Water Year 1997, samples were also analyzed for dissolved selenium and total suspended solids at both the inflow to and outflow from the San Luis Drain.

Grab samples were collected in polyethylene bottles, usually within six feet of the bank. All sample bottles were rinsed with deionized water before use. All bottles were also rinsed three times with the water to be sampled prior to sample collection. All samples were kept on ice after collection and until

Table 1. Water Quality Monitoring Sites in the Grassland Watershed for Water Year 1996

Map Index*	RWQCB Site I.D.	Site Name	Site Type
I-1	MER556	Main (Firebaugh) Drain @ Russell Ave.	Inflow
I-2	MER501	Panoche Drain	Inflow
I-4	MER506	Agatha Canal @ Mallard Road	Inflow
I-6	MER504	Hamburg Drain	Inflow
I-7	MER505	Camp 13 Slough	Inflow
I-8	MER502	Charleston Drain	Inflow
I-9	MER555	Almond Drive Drain	Inflow
I-10	MER509	Rice Drain	Inflow
I-12	MER528	Salt Slough Ditch @ Hereford Road	Inflow
T-1	MER510	CCID Main @ Russell Avenue	Internal Flow
T-5	MER519	Sante Fe Canal @ Henry Miller Road	Internal Flow
T-7A	MER532	San Luis Canal @ Henry Miller Road	Internal Flow
T-13	MER548	Porter-Blake Bypass	Internal Flow
O-1	MER551	Mud Slough (N) @ Newman Gun Club	Outflow
O-2	MER542	Mud Slough (N) downstream of the San Luis Drain	Outflow
O-3	MER554	Los Banos Creek @ Highway 140	Outflow
O-4	MER531	Salt Slough @ Lander Avenue	Outflow

* Location Map in Appendix A

Table 2. Water Quality Monitoring Sites in the Grassland Watershed for Water Year 1997

Map Index*	RWQCB Site I.D.	Site Name	Site Type
I-4	MER506	Agatha Canal @ Mallard Road	Inflow
I-7	MER505	Camp 13 Slough	Inflow
T-5	MER519	Sante Fe Canal @ Henry Miller Road	Internal Flow
T-7A	MER532	San Luis Canal @ Henry Miller Road	Internal Flow
O-2	MER542	Mud Slough (N) downstream of the San Luis Drain	Outflow
O-4	MER531	Salt Slough @ Lander Avenue	Outflow
SLD-1	MER562	Inflow to San Luis Drain @ Check 17	Internal Flow
SLD-2	MER535	San Luis Drain @ Terminus	Outflow
O-8	MER536	Mud Slough (N) Upstream of SLD	Internal Flow

* Location Map in Appendix B

Table 3. Water Year 1996 Grassland Watershed Monitoring Sites, Sampling Frequencies, and Parameters Measured

Site ID	Site Description	Constituent									Dissolved Se	Auto-Samplers
		Temp	pH	EC	Se	Mo	TE's	B	Part Min	TSS		
MER501	Panoche Drain @ O'Banion Gauge Station	W	W	W	W	Q		W	M			b
MER502	Charleston Drain @ CCID Main Canal	W	W	W	W	Q		W	M			
MER504	Hamburg Drain near Camp 13 Slough	W	W	W	W	Q		W	M			
MER505	Camp 13 Slough @ Gauge Station	M	M	M	M			M	M			
MER506	Agatha Canal @ Mallard Road	M	M	M	M			M	M			
MER509	Rice Drain @ Mallard Road	M	M	M	Q			Q	Q			
MER528	Salt Slough Ditch @ Hereford Road	M	M	M	Q			Q	Q			
MER555	Almond Drive Drain	M	M	M	Q			Q	Q			
MER556	Main (Firebaugh) Drain @ Russell Ave.	W	W	W	W	Q		W	M			b
MER510	CCID Main @ Russell Ave.	M	M	M	Q			Q	Q			
MER519	Santa Fe Canal @ Henry Miller Road	M	M	M	M			M	M			
MER532	San Luis Canal @ Henry Miller Road	M	M	M	M			M	M			
MER548	Porter-Blake Bypass	M	M	M	M			M	M			
MER531	Salt Slough @ Lander Ave.	W	W	W	W	Q	Q	W	M			b
MER542	Mud Slough (N) Downstream of San Luis Drain	W	W	W	W	Q	Q	W	M			b
MER551	Mud Slough @ Newman Gun Club	M	M	M	M			M	M			
MER554	Los Banos Creek @ Hwy 140	M	M	M	Q			Q	Q			

W = weekly
M = monthly
Q = quarterly (October, January, April, and July)
b = Four day composite samples for Se and B

I= Inflow
T=Internal flow
O=Outflow

TE's: Trace Elements (Chromium, copper, lead, nickel, zinc)
Part Min = B, Cl, SO4, and Hardness
TSS=total suspended solids

Table 4. Water Year 1997 Monitoring Sites, Sampling Frequencies, and Parameters Measured: Grasslands Bypass Project

Site ID	Site Description	Constituents									Dissolved Se	Auto-Samplers
		Temp	pH	EC	Se	Mo	TE's	B	Part Min	TSS		
MER505	Camp 13 Slough @ Gauge Station			W	W			W				c
MER506	Agatha Canal @ Mallard Road			W	W			W				c
MER519	Santa Fe Canal @ Henry Miller Road			W	W			W				
MER532	San Luis Canal @ Henry Miller Road			W	W			W				
MER536	Mud Slough (N) Upstream of San Luis Drain	W	W	W	W	M	Q	W	Q			
MER562	Inflow at San Luis Drain: Check 17			W	W			W		W	W	
MER535	San Luis Drain @ Terminus	W	W	W	W	M	Q	W	Q	W	W	a
MER542	Mud Slough (N) Downstream of San Luis Drain	W	W	W	W	M	Q	W	Q			b*
MER531	Salt Slough @ Lander Ave.	W	W	W	W	M	Q	W	Q			b*

*discontinued 3/25/97 (See appendices for miscellaneous discontinued site data)

W = weekly
M = monthly
Q = quarterly (October, January, April, and July)
a = daily composite sample for Se and B
b = Four day composite samples for Se and B
c = used intermittently between January and April 1997

I= Inflow
T=Internal flow
O=Outflow

TE's: Trace Elements (Chromium, copper, lead, nickel, zinc)
Part Min = B, Cl, SO4, and Hardness
TSS=total suspended solids

processing. Selenium, boron, and trace element samples were preserved by lowering the pH to less than 2 within 24 hours of collection, using reagent grade nitric acid. Mineral samples were kept on ice until submittal to the laboratory for analysis.

Composite Automated Samples

In addition to grab samples, four-day composite and daily sampling was conducted at selected sites through the use of automated Sigma sampling devices. During Water Year 1996, Sigma samplers were located at Panoche Drain, Firebaugh (Main) Drain, Mud Slough (north) downstream of the terminus of the San Luis Drain, and Salt Slough at Lander Avenue. Samplers were also intermittently installed at Camp 13 and Agatha Canal to allow continuous data collection when access roads were inaccessible. These samplers were phased out during Water Year 1997, as more focus was placed on the impacts from the discharge from the Grassland Bypass Project. The Panoche Drain and Firebaugh (Main) Drain autosamplers were discontinued in January 1997, and the Salt Slough, Mud Slough (north), Camp 13 and Agatha Canal autosamplers were removed after 25 March 1997. In exchange, two autosamplers (one strictly backup) were installed on the San Luis Drain to collect daily composite samples. Each daily composite is made up of six 85 ml collections pulled at four hour intervals for a total sample volume of 510 ml. During both water years, autosamplers were serviced every two weeks. Both 4-day composite and daily samples were analyzed for EC, boron and selenium. Quality control and assurance methods for the autosamplers are discussed below.

QUALITY CONTROL AND QUALITY ASSURANCE

Standard

Potential contamination from the reagent grade nitric acid used to control pH was evaluated by submitting a deionized water matrix preserved with the normal amount of acid used (1 ml nitric acid per 500 ml of sample), to the analyzing laboratories at monthly intervals to be analyzed for the trace elements of concern. All reported recoveries for these acid check samples were below the analytical detection limit.

Field and handling contamination was evaluated by submitting a travel blank on a monthly basis. The travel blank consisted of a sample of deionized (DI) water which was collected at the Regional Board laboratory, traveled through the sampling run, and was then processed with the sample set. All results for travel blanks fell below the analytical detection limits for the elements of concern.

Additional quality control and quality assurance was conducted using blind split and spiked samples. Blind split samples were collected at a ten percent frequency for each sampling event by collecting the sample in a container double the normal sample volume and splitting that sample into two equal amounts for submittal to the analyzing laboratory. On a monthly basis, half of the blind split samples were spiked with known concentrations of constituents to be analyzed. Comparing the spiked splits to the background splits provided information on analytical accuracy. Comparing data from nonspiked splits provided information on analytical precision.

To evaluate the potential for contamination and evapo-concentration in samples collected using autosampler, a series of special checks were developed. First, whenever the sampler was serviced, a deionized blank sample, without a cap, was left in the collection base to be collected on the next servicing and analyzed for potential contamination. Second, during each servicing, replicate "grab" samples were collected through the autosampler mechanism, one was left in the sampler to be collected at the next servicing and the other was processed for immediate analyses. Final results of the two grabs were evaluated to determine concentration or dilution potentials.

During WY 97, samples for dissolved selenium were collected at two locations (MER535 and MER562). These samples required field filtration through an 0.45 μm cartridge system. To prevent and evaluate potential contamination, the equipment was soaked in a two percent nitric acid solution between usages, and rinsed three times in DI water. The new filters were conditioned at the time of sampling by allowing the first 10 ml of water passed through to be discarded before the remaining sample was collected. Approximately quarterly, filter blanks were collected using the Regional Board laboratory DI water and processing it through the standard equipment used in the field.

Only data from sample sets whose blind-QA/QC met specifications outlined in Table 5 have been included in this report.

Special Studies

With the advent of the Grassland Bypass Project, a number of State and Federal agencies (US Bureau of Reclamation, US Geological Survey, US Fish and Wildlife Service, California Regional Water Quality Control Board, and California Department of Fish and Game) became involved in monitoring potential environmental impacts from the Grassland Bypass Project. A Data Collection and Reporting Team (DCRT) was formed and chaired by the US Bureau of Reclamation to coordinate activities. This team intends to utilize information presented by the Regional Board to evaluate water quality impacts from the project and raised concerns on the following issues:

--complete mixing at Mud Slough (north) downstream of the San Luis Drain discharge;
--field preservation versus laboratory preservation within 24 hours; and
--field versus laboratory filtration for dissolved selenium analyses.

<u>Complete Mixing at Mud Slough (north) Downstream of the San Luis Drain Discharge</u>

Prior to the initiation of the project, there was concern by some members of the DCRT, that the proposed sampling location for Mud Slough (north) downstream of the San Luis Drain (the bridge over Mud Slough [north]) may be too close to the point of discharge to ensure sufficient mixing of the two flows. To assess the extent of mixing, the Regional Board divided the width of the Mud Slough (north) into five intervals. On four separate occasions depth integrated samples were collected from the bridge at each of the intervals and at mid channel; grab samples were also collected from the stream banks. The four sampling events included the range of seasonal flow conditions. Results from the sampling are presented in Table 6.

Visual observation of the data shows almost no variability between samples within a sampling event. Coefficient of variations varied from 1.2 to 5.6 percent. This variation is well within analytical error. Also, there are no apparent trends in the distribution of selenium concentrations within a stream cross section. Statistical analysis of the data was not attempted because of the small sample size. From these results, it is concluded that the flow is sufficiently mixed at this location.

<u>Field versus Laboratory Preservation</u>

Samples collected for selenium require preservation with acid to a pH of 2. The Regional Board staff generally acidify samples in the laboratory within 12 hours of sample collection and not more that 24 hours after collection. Field acidification of samples, immediately after sample collection, is not routinely conducted by Regional Board staff due to safety concerns.

A special study was conducted to assess the impacts of delaying sample preservation on sample integrity. Two paired samplings were conducted in which samples were collected and immediately split into two containers by incremental pouring of small volumes and agitating between pourings. One of the splits was immediately acidified in the field and the other was acidified at a later time as per standard sample handling protocol. A set of samples was collected along the San Luis Drain (Table 7) to represent a high selenium environment. Another set of samples was collected from the San Joaquin River at Crows Landing (Table 8) to represent a low selenium environment.

Statistical analysis of the differences of the paired data was conducted. A test for normality according to the method of Shapiro and Wik (W test) (Gilber, 1987) demonstrated that the data were not normally distributed. Thus, a non-parametric technique, the sign test (Helseland Hirsch, 1997) was used to test the null hypothesis that the probability of $x>y$ is equal to 0.5, where x and y are paired results. The

Table 5. Quality Assurance Tolerance Guidelines Used in the Regional Water Quality Control Board Agricultural Drainage Monitoring Program.

Constituent	Recovery Range at Low Levels (µg/L)*	Acceptable Split/Spike Recovery Range
Copper	1-20 ± 5	>20 70-130%
Chromium	1-20 ± 5	>20 70-130%
Lead	5-25 ± 8	>25 60-140%
Molybdenum	1-10 ± 2	>10 90-110%
Nickel	5-25 ± 6	>25 65-135%
Selenium	0.4-10 ± 0.8	>10 90-110%
Zinc	1-20 ± 6	>20 70-130%
Boron	50	85-115%
Chloride	5000	85-115%

* For certain constituents, recovery is expressed as an absolute value rather than a percentage at low levels. For example, if the result of copper analysis for a particular sample is 10 µg/L, a split analysis must fall between 5 µg/L and 15 µg/L. If the sample is greater than 20 µg/L, recovery is expressed as a percent and must be between 70 and 130%. If a recovery range is not shown at low levels, the detection limit is given.

Table 6. Assessment of Cross-Channel Mixing at Mud Slough (north) Downstream of the San Luis Drain

	Selenium Concentration (ug/L)							coefficient of
Date	west bank grab	7-8'	14-15'	mid-channel	23-28'	30-35'	east bank grab	variation
10/1/96	49.2	49.2	49.5	48.9	49.1	48.9	–	1.2
3/20/97	–	32.8	32.2	32.7	32.4	32.4	–	1.2
6/27/97	54.6	54.6	54.2	55.8	55.8	56.1	54.6	3.4
9/12/97	20.1	20.0	19.3	20.4	19.6	19.3	–	5.6

Table 7. Study: Lab vs Field Preservation
Paired Sampling at San Luis Drain Terminus

Miles below Check 19	Selenium (ug/L) Preserved in Lab	Preserved in Field	Diff.
0.50	62.9	63.0	0.1
1.00	69.1	69.4	0.3
1.65	63.6	62.7	-0.9
3.33	62.5	61.7	-0.8
5.63	63.6	64.3	0.7
7.00	61.1	60.2	-0.9
9.50	54.1	54.2	0.1
10.96	65.1	65.2	0.1
14.16	55.4	55.1	-0.3
14.70	55.2	55.4	0.2
15.20	55.0	55.5	0.5
15.90	57.6	57.2	-0.4
18.00	53.1	52.8	-0.3
19.77	64.5	67.4	2.9
22.47	116	108	-8.0
22.62	112	112	0.0
24.44	91.7	82	-9.7
27.07	83.5	82.2	-1.3
		Mean:	-1.0
		Standard deviation:	3.0

Table 8. Study: Lab vs Field Preservation
Paired Sampling at San Joaquin River, Crows Landing

Feet from East Bank	Time Collected	Selenium (ug/L) Preserved in Lab	Preserved in Field	Diff.
east bank	930	2.41	2.40	-0.01
10	1110	2.48	2.42	-0.06
20	1120	2.42	2.44	0.02
30	1126	2.51	2.62	0.11
40	1131	2.53	2.66	0.13
50	1135	2.58	2.60	0.02
60	1141	2.58	2.61	0.03
70	1146	2.58	2.54	-0.04
80	1151	2.64	2.62	-0.02
90	1157	2.67	2.63	-0.04
100	1201	2.64	2.56	-0.08
110	1207	2.48	2.58	0.10
west pier	1246	2.66	2.63	-0.03
center pier	1247	2.63	2.58	-0.05
east pier	1248	2.58	2.64	0.06
Sigma*	1305	2.65	2.62	-0.03
west bank	1415	2.60	2.86	0.26
			Mean:	0.0
			Standard deviation:	0.1

* = composite sampler

Table 9. Study: Field vs Lab Filtering

Date	Dissolved Selenium (µg/L) Inflow to SLD Field filt.	Inflow to SLD Lab filt.	Discharge from SLD Field filt.	Discharge from SLD Lab filt.
11/8/96	61.1	61.8	42.1	43.4
11/19/96	57.0	58.8	75.2	77.3
11/26/96	39.6	42.8	56.4	58.2
12/5/96	–	–	31.0	28.8
12/10/96	56.3	54.3	39.0	36.2
12/20/96	80.2	81.0	49.0	51.1
12/27/96	91.9	92.0	61.6	63.5
1/9/97	76.6	72.4	34.2	32.4
2/4/97	70.5	70.2	61.8	61.8
2/11/97	96.6	94.2	78.4	78.4
2/18/97	78.6	89.4	83.2	76.5

SLD = San Luis Drain

analysis failed to reject the null hypothesis at α equal to 0.01. The conclusion is that there is no difference in selenium concentrations between field and laboratory preserved samples.

Field versus Laboratory Filtration

The DCRT developed a coordinated monitoring plan which called for assessing dissolved selenium at the inflow and outflow of the San Luis Drain. This assessment requires filtering of samples through a 0.45 µm filter and analyzing the filtrate. Generally, this procedure is conducted in the field using a vacuum system or a peristaltic pump which draws sample through inert tubing into a filter apparatus. Due to resource limitations and logistical difficulties, the Regional Board did not immediately implement the collection of this sample. The Regional Board instead submitted the sample to a contract laboratory for filtration within 24 hours of collection.

A revised filtration method was later suggested. In this revised procedure, a syringe and filter cartridge apparatus is used to quickly and inexpensively filter samples in the field. This procedure overcame the resource and logistical limitations and was subsequently implemented by Regional Board staff. The revised filtration method was evaluated as follows.

To test the hypothesis of no difference in dissolved selenium concentration between samples filtered in the field and those filtered in the laboratory within 24-hours of sample collection, results for dissolved selenium were compared for paired samples filtered in the field and in the laboratory. Results of the paired results are presented on Table 9.

The difference between the paired samples was tested for normality by the W test. The null hypothesis that the difference of the paired samples are normally distributed could not be rejected. Thus, the t-test was used to test the hypothesis that there is no difference between the means. The null hypothesis could not be rejected and thus, it is concluded that there is no difference between field versus laboratory (delayed) filtration.

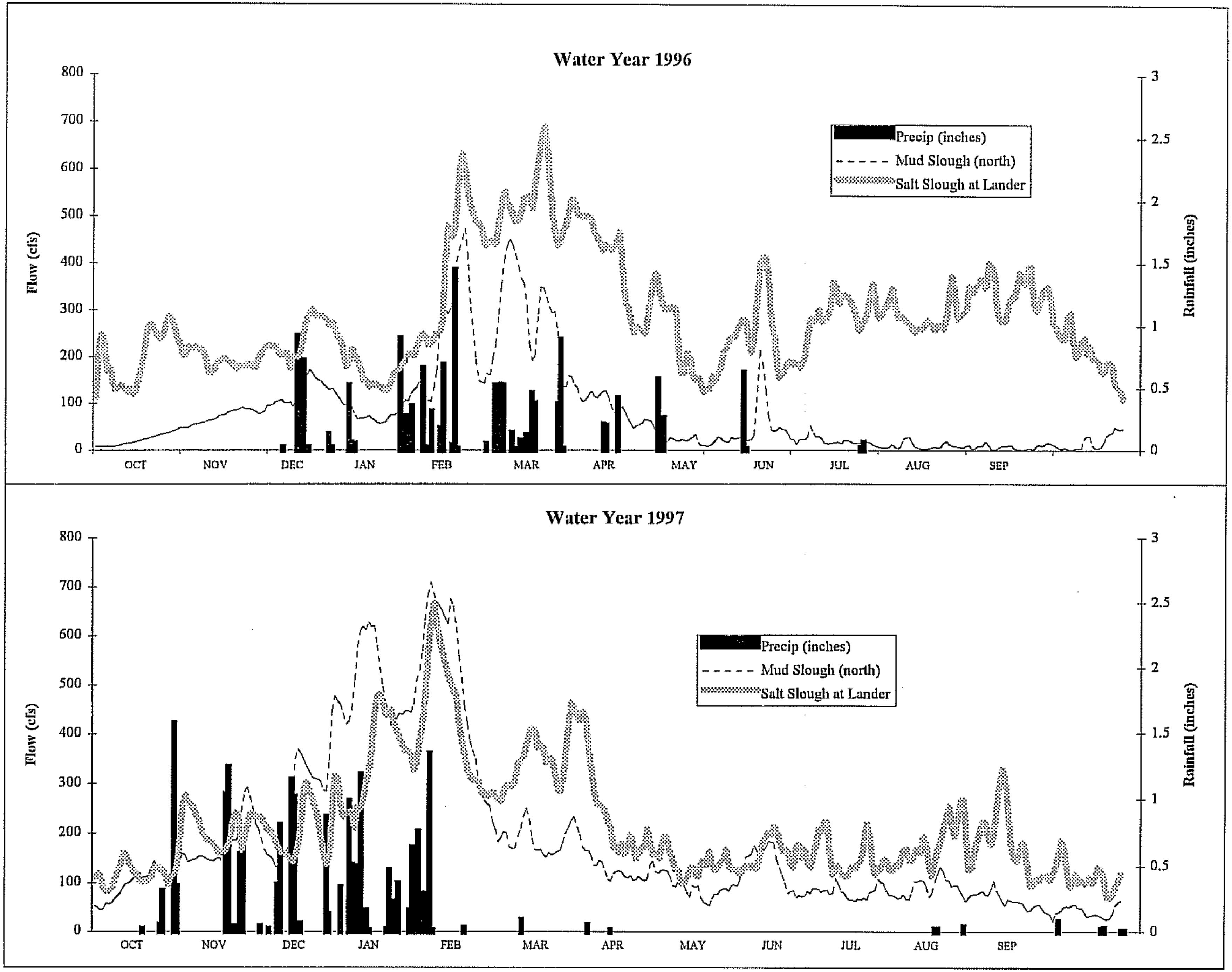
RAINFALL AND DISCHARGE PATTERNS

The San Joaquin River Index, as described in the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (SWRCB, 1995) is used to classify water year type in the river basin based on runoff. The 60-20-20 Index includes one "wet" classification, two "normal" classifications (above and below normal), and two "dry" classifications (dry and critical), for a total of five water year types. Water years 1996 and 1997 were both classified as "wet" based on runoff exceeding 3.8 million acre feet.

Mud Slough (north) and Salt Slough are the main water bodies that drain the Grassland Watershed. Daily flows in both sloughs are compared to the monthly rainfall at Friant Dam for Water Years 1996 and 1997 (Figure 2). Water Year 1996 saw flows peak in February and March, while Water Year 1997 saw the flows peak in late January due to an unusual 4.60 inches of rain for the month. The peaks and sustained highs which do not correspond to rainfall events are generally a result of groundwater, wetland discharges, and surface return flows. In addition, between 3 and 17 April 1996, groundwater which had accumulated in the San Luis Drain during years of disuse, was released into Mud Slough (north) under the provisions of the National Pollutant Discharge Elimination System (NPDES), Permit No. CA0083917. The permitted discharge of the groundwater was a regulatory necessity prior to the use of the drain to transport agricultural subsurface drainage. A total of 461 acre-feet of water was discharged over the 15-day period.

The effects of the opening of the Bypass channel in September 1996, can be clearly seen in the comparison of flows from May through August in Water Years 1996 and 1997. The bulk of the subsurface drainage discharges went through Salt Slough in WY 96, whereas in WY 97, much of the discharge was rerouted through Mud Slough (north) via the San Luis Drain. High rainfall during WY 97 resulted in localized flooding which in turn resulted in the diversion of commingled agricultural subsurface and storm drainage flows from the DPA into water bodies flowing through the Grassland

Figure 2. Flows in Mud Slough (north) and Salt Slough as Compared to Rainfall at Friant Dam: Water Years 1996 and 1997



Watershed between 27 January and 5 February 1997. An extensive summary of the hydrology of the Grassland Watershed can be found in Steensen, *et al.*, (1998).

RESULTS

Grab sample water quality results for minerals and trace elements, as well as EC, pH, and temperature at time of sampling, are listed by site in Appendices A through C. Appendix A includes sites sampled in Water Year 1996 and Appendix B contains data for the sites sampled throughout Water Year 1997. All information collected using automated Sigma samplers is presented in Appendix C. The number of sampling events and the ranges, mean and median values for each measured constituent at each site are shown in these appendices. Results are presented below by water year. Water Year 1996 has been divided into results for the inflow, internal flow and outflow sites. Data for Water Year 1997 has been divided into results for the San Luis Drain and Mud Slough (north), and wetland water supply channels and Salt Slough. Also presented is data from the autosamplers which collected either four day or daily composites depending on the location (refer to Tables 3 and 4). Tables 10 and 11 list the median constituent concentrations for all water bodies monitored in the Grassland Watershed for Water Years 1996 and 1997, respectively. Table 12 summarizes annual minimum, mean and maximum EC, boron and selenium concentrations at locations sampled in the watershed during Water Years 1996 and 1997 and compares those values to the average range in concentration during the previous ten water years of record. The previous ten years of record contained seven critically dry years and three wet years as determined using the San Joaquin River Index (SWRCB, 1995). Since both Water Years 1996 and 1997 were classified as wet water years, the previous data record's summary information, although presented in full, has also been separated into critically dry years and wet years.

Water Year 1996

Inflow Monitoring Stations

The inflow monitoring stations represent the quality of water entering the grasslands area and include the following stations: Charleston Drain, Hamburg Drain, Firebaugh (Main) Drain, Panoche Drain, Almond Drive Drain, Rice Drain, Camp 13 Slough, Agatha Canal, and Salt Slough Ditch. Salt Slough Ditch at Hereford Road flows into the North Grassland area; the others flow into the South Grassland area.

The highest combined levels of salinity (based on EC), boron, and selenium were found at the Panoche, Hamburg, Firebaugh and Charleston Drains (Table 10). These drains primarily carry subsurface agriculture drainage from the DPA. Lower concentrations were recorded for the remaining inflow sites which are not as strongly dominated by subsurface agriculture drainage. The highest EC was recorded in the Hamburg Drain on 1 March 1996 (6890 µmhos/cm) and the highest selenium concentration in the Firebaugh Drain (162 µg/L), also on 1 March 1996. The highest boron concentrations were found in the Rice Drain. The Rice Drain, sampled on a quarterly basis in WY 96, had levels of boron ranging from 5.5 mg/L to 15 mg/L, with the maximum occurring on 25 January 1996, and variable levels of selenium (3.4 to 28.4 µg/L). Data is too limited to determine if the concentrations at this site followed seasonal trends.

Camp 13 and the Agatha Canal (sampled on a monthly basis) may carry a combination of supply water and/or agricultural drainage, therefore water quality fluctuated greatly during Water Year 1996. Concentrations at the Agatha Canal at Mallard were high in December, January, February and August (peaking in December with the EC at 4490 µmhos/cm, selenium at 100 µg/L, and boron at 6.3 mg/L). Low concentrations in the Agatha Canal were observed in September and October with the EC at 324 µmhos/cm, selenium at 0.9 µg/L, and boron at 0.12 mg/L. During this time period the Agatha Canal is used exclusively for wetland water deliveries. At Camp 13 Slough, EC, boron and selenium levels were elevated from November through July; particularly in November, January and April. The peak EC occurred in January at 4660 µmhos/cm, while boron peaked in November and January at 6.9 mg/L. The maximum selenium concentration occurred in April at 88.8 µg/L. The lowest concentrations in Camp 13 occurred in September with the EC dropping to 338 µmhos/cm, boron to 0.13 mg/L, and selenium to 0.8 µg/L.

Table 10. Median Constituent Concentrations for Waterways within the Grassland Watershed: Water Year 1996.

Type	Station	EC	B	Cl	SO4	Se	Mo	Cr	Cu	Ni	Pb	Zn	Hardness
		(umhos/cm)	mg/L			ug/L							mg/L
I	*Main (Firebaugh) Drain	2870	3.4	285	1100	48.8	26	—	—	—	—	—	720
I	*Panoche Drain	4555	7.0	605	1450	76.5	13	—	—	—	—	—	1100
I	Agatha Canal	588	2.3	66	97	3.6	—	—	—	—	—	—	120
I	Hamburg Drain	4435	4.7	630	1550	57.8	6	—	—	—	—	—	1600
I	Camp 13	3760	5.7	435	1100	57.4	—	—	—	—	—	—	915
I	Charleston Drain	3940	3.5	470	1300	59.8	5	—	—	—	—	—	1000
I	Almond Drain	925	0.47	63	98	1.5	—	—	—	—	—	—	155
I	Rice Drain	2590	6.0	290	960	10.1	—	—	—	—	—	—	600
I	Salt Slough @ Hereford	744	0.27	114	103	0.8	—	—	—	—	—	—	200
T	CCID Main Canal	558	0.42	23	23	0.9	—	—	—	—	—	—	86
T	Santa Fe Canal @ Henry Miller Rd.	608	0.42	67	96	1.8	—	—	—	—	—	—	120
T	San Luis Canal @ Henry Miller Rd.	653	0.52	74	100	1.8	—	—	—	—	—	—	140
T	Porter-Blake Bypass	3155	4.4	330	920	37.8	—	—	—	—	—	—	730
O	Salt Slough @ Lander*	2060	2.0	290	520	16.0	9	12	8	14	<5	26	450
O	Mud Slough @ Newman Gun Club	1787	1.4	270	330	1.2	—	—	—	—	—	—	360
O	Los Banos Creek	1297	1.2	205	220	0.6	—	—	—	—	—	—	305
O	Mud Slough @ San Luis Drain*	1660	1.2	235	305	1.0	9	7	5	10	<5	14	370

—: Not analyzed   I = Inflow   O = Outflow
*Autosampler 4-day Composite Data for EC, B, and Se only.   T = Internal flow

Table 11. Median Constituent Concentrations for Waterways within the Grassland Watershed: Water Year 1997.

Type	Station	EC	B	Cl	SO4	Se	Mo	Cr	Cu	Ni	Pb	Zn	Hardness
		(umhos/cm)	mg/L			ug/L							mg/L
I	Agatha Canal	432	0.2	55	43	1.2	—	—	—	—	—	—	87
I	Camp 13	520	0.4	64	49	1.6	—	—	—	—	—	—	30
T	Santa Fe Canal @ Henry Miller Rd.	833	0.83	59	54	2.1	—	—	—	—	—	—	110
T	San Luis Canal @ Henry Miller Rd.	886	0.87	—	—	2.0	—	—	—	—	—	—	—
O	Salt Slough @ Lander	1320	0.7	190	200	1.0	7	—	—	—	—	—	290
D	Inflow to San Luis Drain @ Ck 17	4390	7.5	—	—	66.4	22	—	—	—	—	—	—
D	San Luis Drain @ Terminus	4330	7.1	460	1300	60.4	26	—	—	—	—	—	1000
B	Mud Slough (N) Upstream of SLD	1160	1.0	130	130	0.8	6	—	—	—	—	—	200
O	Mud Slough dwnstrm of SLD	3100	4.4	195	330	32.4	17	—	—	—	—	—	340
D	San Luis Drain @ Terminus*	4420	7.2	—	—	61.5	—	—	—	—	—	—	—

—: Not analyzed   I = Inflow   O = Outflow   D = agricultural drainage
*Autosampler Daily Composite Data for EC, B, and Se only.   T = Internal flow   B = background

Table 12. Annual Minimum, Mean, and Maximum Electrical Conductivity, Boron, and Selenium at Monitoring Sites Within the Grassland Watershed: Water Years 86-95, 96 and 97.

Site	Count	EC (umhos/cm)			Boron (mg/L)			Selenium (ug/L)		
		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Firebaugh (Main) Drain @ Russell Ave.										
WYs 86-95	334	255	3770	9090	0.12	5.3	23	1.0	65.0	286
WYs 86-95 (critical)	212	2050	3770	9090	1.2	5.3	23	4.0	62.3	286
WYs 86-95 (wet)	115	255	3940	8740	0.12	5.3	18	1.0	71.0	224
WY 96	50	1910	3310	6590	2.4	4.0	9.4	23.0	64.0	162
Panoche Drain										
WYs 86-95	296	2600	4560	5990	3.9	7.5	10	14.0	75.0	156
WYs 86-95 (critical)	197	2700	4580	5860	3.9	7.5	10	14.0	73.6	156
WYs 86-95 (wet)	92	3000	4640	5990	4.5	7.5	10	22.6	79.9	146
WY 96	48	3440	4520	5380	3.8	7.1	9.4	19.7	79.1	137
Hamburg Drain										
WYs 86-95	318	366	7880	7480	0.19	5.5	9.4	3.8	82.0	201
WYs 86-95 (critical)	205	2900	5070	7100	2.1	5.5	9.0	17.1	88.9	201
WYs 86-95 (wet)	107	366	4610	7480	0.6	5.5	9.4	3.8	72.6	200
WY 96	49	383	4250	6890	0.24	4.7	9.7	1.5	59.5	129
Agatha Canal										
WYs 86-95	234	162	3120	8100	0.07	5.0	20	0.8	36.0	116
WYs 86-95 (critical)	153	430	3310	8100	0.10	5.4	20	0.8	37.6	114
WYs 86-95 (wet)	74	162	2770	6600	0.12	4.3	15	1.0	34.0	120
WY 96	12	200	1940	4730	0.12	3.0	6.6	0.9	28.2	100
WY 97	43	187	518	4240	0.11	0.25	0.46	0.5	1.3	3.4
Camp 13 Slough										
WYs 86-95	264	266	3550	6700	0.18	5.0	10	0.9	52.0	144
WYs 86-95 (critical)	185	390	3690	6700	0.22	5.1	10	1.0	53.1	123
WYs 86-95 (wet)	72	266	3320	6510	0.18	4.7	9.3	0.9	50.8	144
WY 96	11	338	3410	4660	0.13	4.9	6.9	0.8	55.9	88.8
WY 97	42	172	822	3760	0.15	1.1	7.1	0.6	2.6	23.4
Charleston Drain										
WYs 86-95	246	304	4140	10200	0.15	4.0	24	1.3	65.0	129
WYs 86-95 (critical)	166	590	4170	10220	0.74	4.0	24	1.9	64.6	125
WYs 86-95 (wet)	75	304	4110	6010	0.15	3.9	7.7	1.3	66.8	129
WY 96	46	553	3600	6370	0.48	3.2	5.4	4.2	53.8	103
Almond Drive Drain										
WYs 86-95	149	70	1560	3530	<0.05	1.4	4.4	0.4	3.4	17
WYs 86-95 (critical)	128	448	1670	3530	0.16	1.5	3.9	0.4	3.5	17
WYs 86-95 (wet)	20	70	1050	3230	0.04	1.0	4.4	0.6	2.4	6.1
WY 96	4	220	1110	2700	0.10	0.68	1.7	0.7	3.0	8.4
Rice Drain										
WYs 86-95	216	1070	2980	7700	0.85	5.9	19	1.0	3.2	36.0
WYs 86-95 (critical)	172	1090	3000	7700	1.6	5.9	18	1.1	3.3	36.0
WYs 86-95 (wet)	36	1070	2950	6900	0.85	5.8	19	1.0	3.0	10.0
WY 96	4	2050	3100	6300	5.5	8.1	15	3.4	13.0	28.4
Salt Slough Ditch @ Hereford Rd.										
WYs 86-95	222	430	1040	1950	0.10	0.35	1.1	<0.4	1.1	22.0
WYs 86-95 (critical)	177	680	1090	1950	0.15	0.35	0.99	0.4	1.1	22.3
WYs 86-95 (wet)	42	430	907	1600	0.10	0.34	1.1	<0.4	1.0	4.0
WY 96	4	515	836	1260	0.20	0.3	0.34	0.6	1.0	1.7

Table 12 continued:

Site	Count	EC (umhos/cm) Min	EC Mean	EC Max	Boron (mg/L) Min	Boron Mean	Boron Max	Selenium (ug/L) Min	Selenium Mean	Selenium Max
CCID Main Canal										
WYs 86-95	213	50	719	4280	<0.05	0.45	5.8	<0.4	2.2	76.0
WYs 86-95 (critical)	180	55	734	4280	0.10	0.42	5.2	0.4	2.3	76.0
WYs 86-95 (wet)	33	50	584	2100	<0.05	0.41	2.7	0.6	1.9	16.0
WY 96	3	56	526	1300	<0.05	0.61	1.3	<0.4	2.3	5.2
Santa Fe Canal										
WYs 86-95	105	318	1440	4090	0.19	1.7	5.5	<0.4	10.0	60.0
WYs 86-95 (critical)	41	410	1210	4090	0.22	1.2	5.3	0.3	7.4	59.8
WYs 86-95 (wet)	58	318	1580	3930	0.19	2.0	5.5	1.0	11.0	44.0
WY 96	12	188	675	1450	0.10	0.5	1.3	0.6	2.1	4.7
WY 97	42	339	941	1870	0.24	1.0	2.9	0.8	2.1	3.9
San Luis Canal										
WYs 86-95	114	330	1690	4850	0.19	2.1	7.4	0.7	15.0	74.0
WYs 86-95 (critical)	50	486	1220	4010	0.30	1.2	4.9	0.7	7.0	56.6
WYs 86-95 (wet)	64	330	2050	4850	0.19	2.7	7.4	0.8	20.8	74.0
WY 96	12	196	918	3560	0.10	0.82	4.4	0.8	6.5	40.8
WY 97	41	501	973	1840	0.36	1.1	3.3	1.0	2.1	6.2
Porter-Blake Bypass										
WYs 86-95	110	348	3110	4820	0.30	4.4	7.1	1.7	40.6	88.0
WYs 86-95 (critical)	66	348	3100	4630	1.06	4.4	7.1	3.4	39.4	77.8
WYs 86-95 (wet)	43	786	3120	4820	0.30	4.5	6.9	1.7	42.4	88.0
WY 96	12	532	2830	3800	0.32	3.8	5.3	2.1	36.7	66.3
Mud Slough (N) @ Newman Gun Club										
WYs 86-95	241	230	3120	7570	0.10	2.8	7.0	0.5	8.4	48.0
WYs 86-95 (critical)	206	909	3300	7570	0.30	2.9	7.0	0.5	9.0	48.0
WYs 86-95 (wet)	35	230	2040	4850	0.10	1.7	4.7	1.0	5.0	34.0
WY 96	12	758	2260	5280	0.50	1.9	8.4	0.6	2.3	15.6
Mud Slough (N) @ San Luis Drain										
WYs 86-95	288	616	3320	10900	0.06	2.8	7.9	<0.4	7.8	59.0
WYs 86-95 (critical)	340	660	3510	10860	0.20	3.1	7.9	0.4	9.4	50.0
WYs 86-95 (wet)	114	616	2250	7250	0.27	2.0	6.4	0.4	4.1	59.0
WY 96	50	588	1900	5530	0.45	1.5	8.7	<0.4	1.4	11.8
WY 97	46	1150	2870	4930	1.1	4.1	6.8	5.0	30.7	79.6
Los Banos Creek @ Highway 140										
WYs 86-95	124	641	2030	7450	0.30	1.6	6.6	<0.4	2.1	30.0
WYs 86-95 (critical)	98	669	2140	7450	0.30	1.6	6.6	0.3	2.3	30.0
WYs 86-95 (wet)	25	641	1000	3600	0.33	1.3	2.9	<0.4	1.0	2.0
WY 96	3	509	1260	3350	0.60	1.5	3.0	<0.4	0.6	1.2
Salt Slough @ Lander Ave.										
WYs 86-95	472	780	2220	4050	0.30	2.1	5.0	1.0	15.0	44.0
WYs 86-95 (critical)	351	1020	2230	4050	0.30	2.0	4.7	0.6	14.6	44.0
WYs 86-95 (wet)	115	780	2240	3970	0.43	2.2	5.0	1.0	16.0	42.0
WY 96	49	1010	2010	3000	0.47	2.0	3.5	1.0	16.0	33.5
WY 97	48	922	1370	2000	0.40	0.77	1.8	0.5	1.0	3.4
Inflow to San Luis Drain @ Check 17										
WY 97	48	2620	4460	5600	4.2	7.3	9.0	17.9	65.9	108.0
San Luis Drain @ Terminus										
WY 97	48	2720	4270	5460	4.4	6.8	8.4	17.0	59.3	107.0
Mud Slough (N) upstream of SLD										
WY 97	48	744	1390	2960	0.56	1.2	2.9	<0.4	0.8	1.7

Table 12 continued:

Site	Count	EC (umhos/cm)			Boron (mg/L)			Selenium (ug/L)		
		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Autosampler Data (1)										
Camp 13 Slough										
WY 97	*	122	1030	4630	0.34	3.8	7.7	<0.4	12.4	33.0
Agatha Canal										
WY 97	†	116	225	809	0.37	0.62	1.0	0.5	1.7	6.8
Panoche Drain										
WY 96	85	3050	4530	5580	3.4	7.0	9.2	23.4	79.9	149
WY 97	29	3830	4750	5320	–	–	–	35.0	72.8	116
Firebaugh (Main) Drain										
WY 96	82	1830	3190	5520	2.1	3.8	7.6	25.2	59.7	136
WY 97	25	2290	4110	5550	–	–	–	28.8	72.7	125
Mud Slough (N) @ SLD										
WY 96	79	610	1880	5150	0.45	1.4	5.6	0.5	1.7	19.4
WY 97	42	1170	2130	3760	1.3	2.5	6.2	4.5	17.1	50.6
Salt Slough at Lander Avenue										
WY 96	95	886	2020	3170	0.47	2.0	3.0	1.2	16.0	37.8
WY 97	43	960	1440	2070	0.47	1.0	1.9	0.5	1.3	6.3
San Luis Drain @ Terminus										
WY 97	344	2620	4390	5880	4.1	7.0	9.3	15.2	62.4	116

Count = the minimum number of analyses out of the three constituents

(1) = All autosamplers except at the San Luis Drain site were removed by April 1997. The San Luis Drain sampler was installed in September 1996. The Camp 13 and Agatha samplers were operated intermittently between January and March 1997.

* = 75 EC, 20 selenium and 8 boron analyses were conducted

† = 67 EC, 9 selenium and 4 boron analyses were conducted

Water year type is based on the San Joaquin 60-20-20 River Index as follows:

Critical Water Year: Runoff < 2.1 million ac-ft (WYS 87-92 and 94)
Wet Water Year: Runoff > 3.81 million ac-ft (WYs 86, 93, 95, 96, and 97)

The Almond Drive Drain, as in previous years, contained low levels of the constituents of concern, as did Salt Slough Ditch at Hereford Road. These sites were sampled on a quarterly schedule and normally carry either surface tailwater or supply water.

Internal Flow Monitoring Sites

Four internal flow sites were monitored in WY 96: Santa Fe Canal at Henry Miller Road, San Luis Canal at Henry Miller Road, and Porter-Blake Bypass on a monthly basis; and CCID Main at Russell on a quarterly basis. These channels can carry supply water for both agriculture lands and wetland habitat, as well as transport agricultural tailwater and subsurface drainage. During Water Year 1996, EC in these water bodies ranged from 56 µmhos/cm to 3800 µmhos/cm, while boron ranged from <0.05 mg/L to 5.3 mg/L (Table 12). Selenium concentration ranged from <0.4 µg/L to 66.3 µg/L. The lowest concentrations occurred in the CCID Main at Russell which primarily carries supply water, while the highest concentrations occurred in the Porter-Blake Bypass, which served as a conduit when subsurface agricultural drainage was discharged into Salt Slough.

When compared to the previous ten years of available data, the Santa Fe and San Luis sites showed significant decreases for the constituents of concern, CCID Main remained at approximately the same level, and Porter-Blake concentrations increased.

Outflow Monitoring Stations

Four outflow stations were sampled during Water Year 1996. Salt Slough at Lander Avenue and Mud Slough (north) downstream of the San Luis Drain were monitored on a weekly basis. Mud Slough (north) at Newman Gun Club was sampled on a monthly basis, and Los Banos Creek at Highway 140 was sampled on a monthly basis, with boron and selenium analyses only conducted on a quarterly basis.

During Water Year 1996, the majority of subsurface drainage flowed through Salt Slough prior to discharge into the San Joaquin River. EC, boron, and selenium concentrations ranged from 1010 to 3000 µmhos/cm, 0.47 to 9.3 mg/L, and 1.0 to 33.5 µg/L, respectively (Table 12). The highest concentrations occurred on 5 May 1996, while lowest occurred the first two weeks in November. Mud Slough (north) at the San Luis Drain and Mud Slough (north) at Newman Gun Club had lower concentrations of boron and selenium than Salt Slough, but higher overall ECs. A short term spike in selenium concentrations occurred in Mud Slough (north) downstream of the San Luis Drain between 14 and 17 April 1996, during the dewatering of groundwater from the drain in preparation for the Grassland Bypass Project. During those four days, selenium concentrations in Mud Slough (north) ranged from 10 µg/L to 21 µg/L. Once the discharge ceased, selenium concentration in Mud Slough (north) dropped back below 2 ug/L.

Los Banos Creek contained consistently low concentrations of EC, boron and selenium, ranging from 509 to 3350 µmhos/cm, 0.60 to 3.0 mg/L, and <0.4 to 1.2 µg/L, respectively.

Composite Samples

Four autosamplers were in place during Water Year 1996, collecting 4-day composite samples at Panoche Drain, Firebaugh (Main) Drain, Mud Slough (north) and Salt Slough (Figures 3 and 4). Autosamplers were also installed intermittently on Camp 13 Slough and the Agatha Canal when flooding made the site inaccessible (Data presented in Appendix C).

The 4-day composite information collected at the Panoche and Firebaugh (Main) Drain, demonstrates not only the overall elevated constituent concentrations at these sites (minimum EC, boron, and selenium concentrations above 2,000 µmhos/cm, 2.5 mg/L, and 25 µg/L, respectively), but also the variability of the concentrations over the season and even within a 4-day period. Even with the few data gaps that occurred during flood events when the sites could not be accessed for maintenance, the composite record provides a more continuous data base than the weekly grab samples for water year 1996.

Figure 3. Electrical Conductivity, Boron and Selenium Concentrations in Panoche and Firebaugh Drains (Sigma Data): Water Year 1996

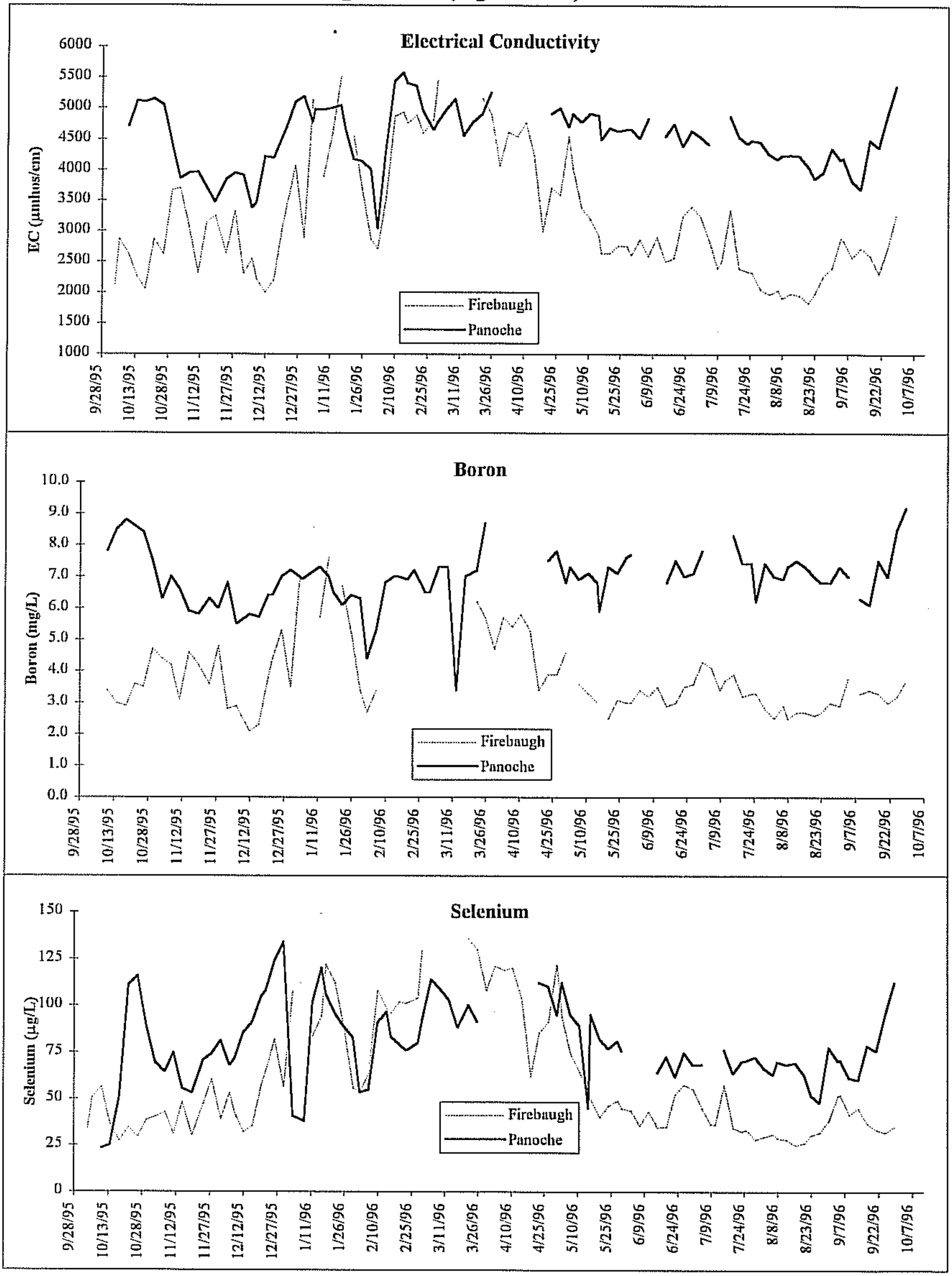
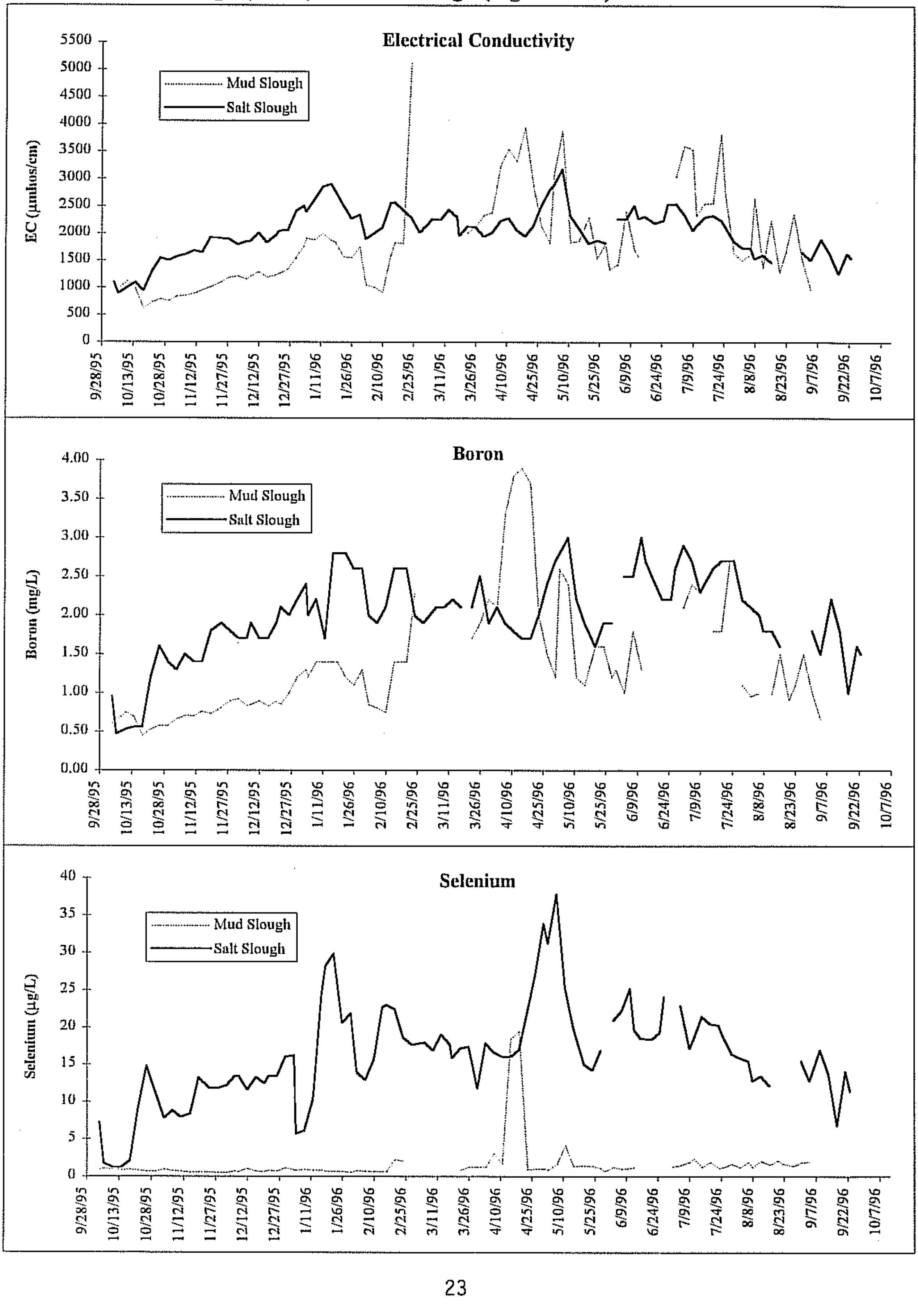


Figure 4. Electrical Conductivity, Boron and Selenium Concentrations Mud Slough (north) and Salt Slough (Sigma Data): Water Year 1996



The composite samplers installed at both Mud Slough (north) and Salt Slough, also provide an almost continuous record of EC, boron and selenium concentrations at the two sites. The Mud Slough (north) sampler was removed for a short period between the end of February and early March, when high flows in the slough threatened to submerge the device which was attached to the bridge. EC and boron concentrations in the two sloughs are comparable with rapid concentration shifts over 4-day periods. Selenium concentrations in Salt Slough remain quite elevated over Mud Slough (north) concentrations during the entire water year except for a peak evident in Mud Slough (north) during mid-April which corresponds to the dewatering of groundwater from the San Luis Drain.

Water Year 1997

With the advent of the Grassland Bypass on 26 September 1996, the focus of the monitoring program shifted from general evaluation of impacts of agricultural drainage on inflow, internal flow and outflow water bodies within the Grassland Watershed, to impacts from consolidating discharge of subsurface drainage into Mud Slough (north) and resulting water quality in wetland water supply channels.

Three new monitoring sites were added in Water Year 1997, due to the opening of the Grassland Bypass Project. One was the inflow to the San Luis Drain which represents the water quality in the Grasslands Bypass. The samples at this site were collected by Panoche Water District on a weekly schedule at a point on the San Luis Drain downstream of the Grassland Bypass inflow. The second addition was the San Luis Drain at its terminus prior to discharge into Mud Slough (north). The final addition, Mud Slough (north) upstream of the San Luis Drain, was added to furnish background data for the Mud Slough (north) site prior to the inflow from the San Luis Drain.

Several of the inflow sites monitored during Water Year 1996, were discontinued in Water Year 1997. The exceptions were Camp 13 Slough and Agatha Canal. Grab samples at these sites were collected by Panoche Water District. The frequency of sampling was increased from monthly to weekly on 3 November 1996, and automated composite samples were collected from 10 January 1997 to 25 March 1997 due to limited direct access.

Two internal sites were continued in WY 97: Santa Fe and San Luis Canals at Henry Miller Road. Weekly sampling by Panoche Water District staff began in November 1996. No data is available for January 1997.

Both the Salt Slough at Lander Avenue and the Mud Slough (north) at the San Luis Drain sites were continued during Water Year 1997. The outflow sites on Los Banos Creek and Mud Slough (north) at Newman Gun Club were discontinued.

Electrical conductivity, boron, and selenium data have been summarized in Tables 11 and 12. Remaining water quality information collected during Water Year 1997, is listed in Appendix B.

<u>San Luis Drain and Mud Slough (north)</u>

Grab samples were collected both from the inflow to and discharge from the San Luis Drain and also from Mud Slough (north) upstream and downstream of the discharge from the San Luis Drain. In addition to EC, boron, and total selenium, dissolved selenium and total suspended solids were analyzed at both San Luis Drain sites.

Concentrations at the inflow to and discharge from the San Luis Drain were similar (Figure 5). The discharge's impact on Mud Slough (north) was pronounced (Figure 6), particularly after February 1997. Elevated background concentrations of EC and boron in Mud Slough (north) upstream of the San Luis Drain discharge (reaching 2960 μmhos/cm and 2.9 mg/L, respectively) are further exacerbated by the drainage discharge, with EC and boron concentrations reaching 4930 μmhos/cm and 6.8 mg/L, respectively. The greatest impact on Mud Slough from the San Luis Drain discharge was on selenium concentrations. Selenium concentrations in Mud Slough (north) upstream of the discharge were below

Figure 5. Electrical Conductivity, Boron and Selenium Concentrations in the Inflow to and Discharge from the San Luis Drain (Grab Data): Water Year 1997.

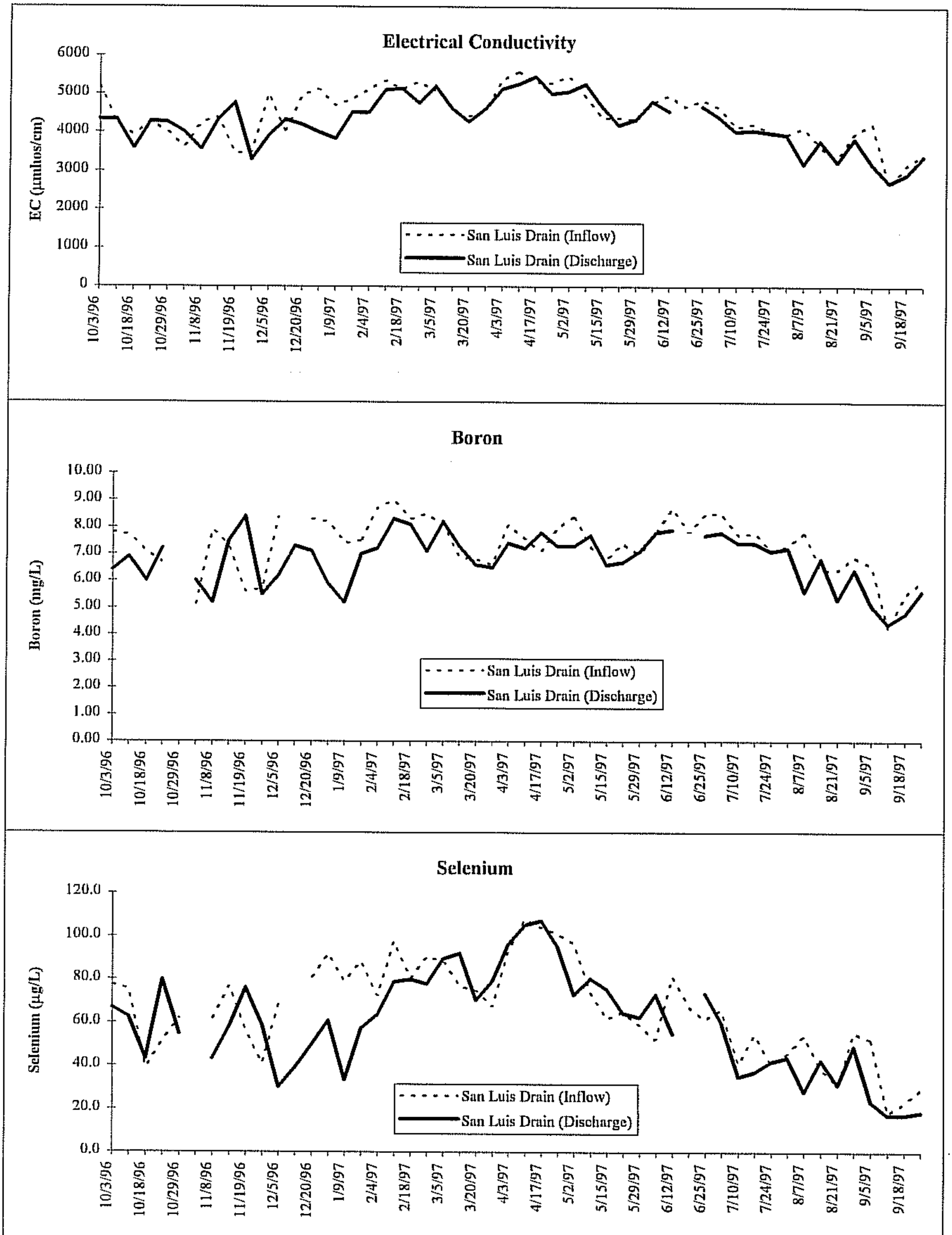
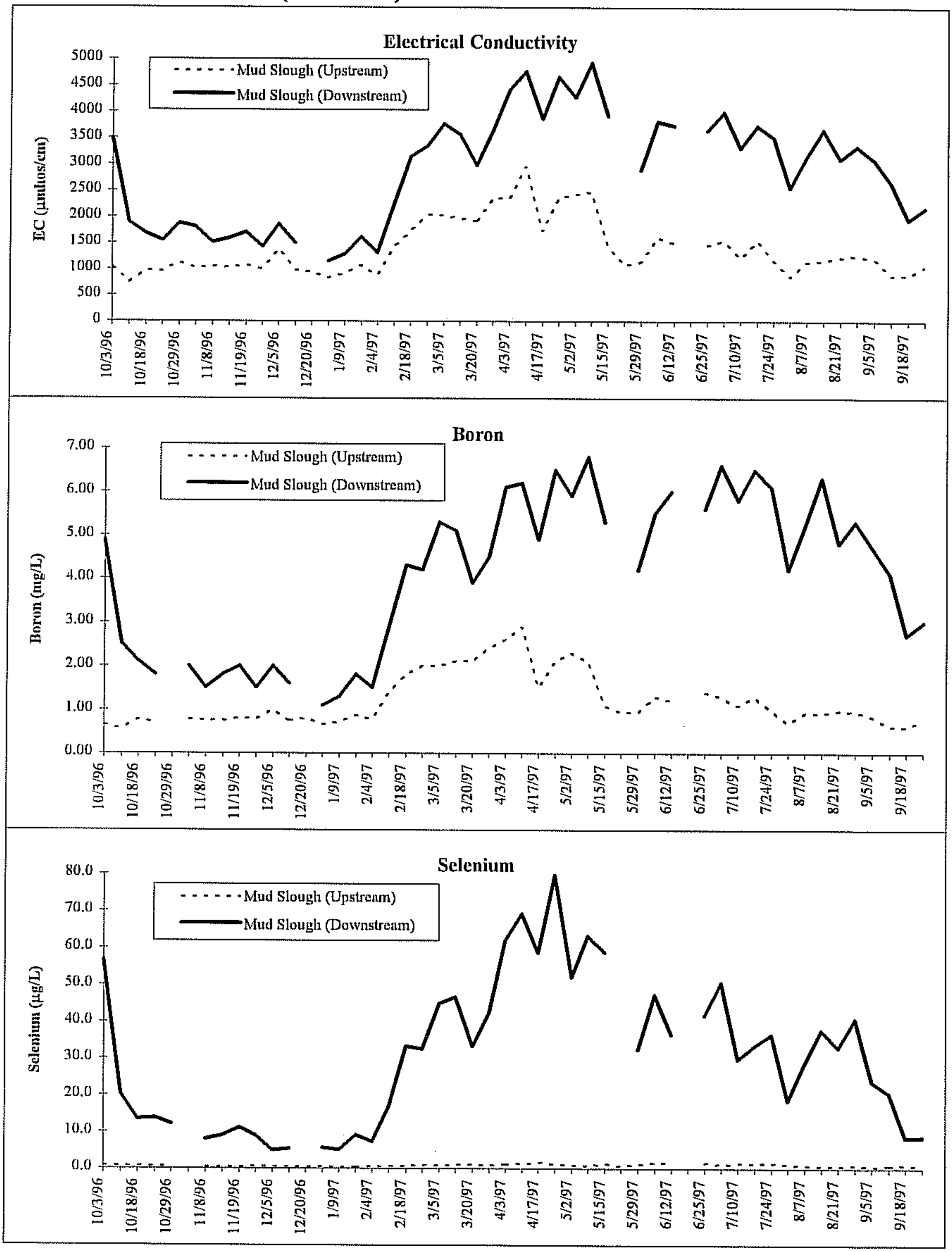


Figure 6. Electrical Conductivity, Boron and Selenium Concentrations in Mud Slough (north) Upstream and Downstream of the Discharge from the San Luis Drain (Grab Data): Water Year 1997.



1.7 µg/L; downstream of the discharge, the mean selenium concentration was 30.7 µg/L with a maximum of 79.6 µg/L.

A comparison of total versus dissolved selenium concentrations at the two San Luis Drain sites is presented in Table 13. Concentrations of each sample pair fall within the analytical criteria of acceptable split samples, indicating that selenium in the drain is in the dissolved (aqueous) form.

Total suspended sediment was analysed on a weekly basis in the inflow to and discharge from the San Luis Drain. Summary results from the analyses are presented in Table 14 and Figure 7. Complete analytical results are listed in Appendix B. Total suspended sediment concentrations were consistently higher in the inflow to the drain than in the discharge from the drain, although actual weekly concentrations varied widely. Median concentrations in the inflow and discharge were 96 mg/L and 25 mg/L, respectively.

Wetland Water Supply Channels and Salt Slough

Weekly grab samples were collected at: Camp 13 Ditch and the Agatha Canal, major supply canals for wetlands within Grassland Water District; the San Luis Canal and Santa Fe Canal at Henry Miller Road, two internal distribution canals for wetland habitat; and at Salt Slough, a tributary of the San Joaquin River. During a brief period, between 27 January and 5 February 1997, subsurface agricultural drainage was diverted into these channels in response to a flood event. Data for this time period have been presented and discussed in a previous report (USBR, 1997) and are not included in the discussion below.

EC, boron and selenium data for Camp 13 Slough and Agatha Canal are presented in Figure 8. Concentrations were consistently higher at Camp 13 than at the Agatha, except for an EC spike recorded on 4 February 1997, during the tail end of the flood event. EC and boron levels reached their maximum in early April, reaching 3760 µmhos/cm and 7.1 mg/L, respectively, at Camp 13. Selenium showed a peak of 13.5 µg/L on 7 May 1997, at Camp 13, while the median selenium level was 1.6 µg/L. On a number of occasions, Camp 13 Slough exceeded 2.0 µg/L selenium, while the Agatha Canal reached a maximum of 3.4 µg/L and only exceeded 2.0 µg/L on five separate occasions.

Concentrations in the internal supply channels, the San Luis and Santa Fe Canals, fluctuated during Water Year 1997, as depicted in Figure 9. Aside from the storm event, the highest EC and boron concentrations occurred between the end of February and April, a primary period of wetland releases and pre-irrigation. Selenium levels did not demonstrate the same spike; however, concentrations remained above 2.0 µg/L for the majority of samples collected from February through September 1997.

The cause of the elevated selenium levels for that time period is not readily apparent but may be due to a number of different factors. Some potential sources include elevated selenium levels in supply water, releases from the DPA (both in response to flood events and seepage from gates and canals), inflows from other sources such as the Rice Drain and Almond Drive Drain, and local sources such as groundwater seepage and surface return flows.

To evaluate the potential for elevated selenium concentrations in irrigation supply water, all available selenium data since October 1996, for the Delta Mendota Canal, Mendota Pool, and the Central California Irrigation District (CCID) Main Canal, major water supplies for the Grassland Watershed, were compiled and listed in Table 15. Although the data set is extremely limited, on a number of occasions, these sources of supply water have exceeded 2.0 µg/L selenium.

During March and early April, 1997, elevated constituent concentrations were noted at Camp 13 Slough. Regional Board staff observation and discussion with Grassland Water District staff confirmed that water from the Main Drain, which contained drainage from adjacent flooded farm land, was being diverted into Camp 13 ditch during this time period. This water was not from farmland participating in the Grassland Bypass Project and staff from the water district assumed that the flood water was of good quality. Review of data collected using an automated sampler which was in place at Camp 13 Slough, until 25 March 1997, indicated that the diverted water contained elevated levels of all three constituents

Table 13. Total vs Dissolved Selenium Concentrations at the Inflow to and Discharge from the San Luis Drain.

	Selenium Concentration (µg/L)			
	Inflow		Outflow	
Date	Total	Dissolved	Total	Dissolved
9/26/96	44.8	46.0L	20.2	19.5L
10/3/96	77.4	79.1L	66.8	65.8L
10/18/96	38.6	37.5L	43.0	41.8L
10/25/96	51.4	49.5	79.8	77.2
10/29/96	62.0	61.6	54.6	54.8
11/8/96	61.3	61.1	43.2	42.1
11/19/96	56.2	57.0	75.8	75.2
11/26/96	40.6	39.6	58.9	56.4
12/5/96	68.4	69.9L	30.1	31.0
12/10/96			38.9	39.0
12/20/96	80.4	80.2	49.8	49.0
12/27/96	91.7	91.9	60.8	61.6
1/9/97	78.7	76.6	33.3	34.2
1/21/97	88.2	84.8	57.0	56.4
2/4/97	72.0	70.5	63.6	61.8
2/11/97	97.5	96.6	78.4	78.4
2/18/97	80.3	78.6	79.7	83.2
2/28/97	90.3	86.4	77.6	73.4
3/5/97	88.4	91.1	89.3	87.1
3/12/97	76.6	77.2		
3/13/97			91.8	84.4
3/19/97	74.5	71.1		
3/20/97			70.2	70.4
3/26/97	67.0	61.0		
3/27/97			78.9	78.1
4/2/97	93.0	95.8		
4/3/97			96.2	93.7
4/9/97	108	117		
4/10/97			105	102
4/16/97	104	104		
4/17/97			107	110
4/23/97	101	97.6		
4/24/97			95.2	93.6
5/1/97	96.8	96.6		
5/2/97			72.6	73.7
5/7/97	73.6	73.0		
5/8/97			80.3	78.3
5/14/97	61.6	57.6		
5/15/97			75.2	75.7
5/21/97	65.0	63.6		
5/23/97			64.2	64.6
5/28/97	58.5	60.6		
5/29/97			62.3	60.9
6/4/97	52.1	50.6		
6/5/97			72.8	70.4
6/11/97	81.0	78.9		
6/12/97			54.6	55.0
6/18/97	67.5	63.1		
6/25/97	61.5	60.5	73.3	73.6
7/2/97	65.8	64.1	59.9	59.8
7/9/97	40.6	40.5		
7/10/97			34.9	35.0
7/16/97	54.5	53.0		
7/17/97			37.0	37.0
7/23/97	40.5	43.5		
7/24/97			41.8	39.5
7/30/97	45.5	44.6		
7/31/97			43.7	42.4
8/6/97	53.8	50.4		
8/7/97			27.9	27.7
8/13/97	38.4	39		
8/14/97			42.3	41.7
8/20/97	30.8	30.4		
8/21/97			31.2	31.0
8/27/97	55.4	53.7	48.9	47.2
9/3/97	52.1	49.4		
9/5/97			23.4	23.3
9/10/97	17.9	16.6		
9/12/97			17.0	16.4
9/17/97	22.8	21.8		
9/18/97			17.1	17.0
9/24/97	29.0	28.0		
9/25/97			18.3	18.4

L = Lab filtered

Table 14. Summarized Total Suspended Sediment Data for the Inflow to and Discharge from the San Luis Drain: Water Year 1997

Location	Total Suspended Sediment (mg/L)					
	Count	Min	Max	Mean	Geo Mean	Median
Inflow to San Luis Drain	43	38	190	100	92	96
Discharge from San Luis Drain	44	8	140	28	23	25

Figure 7. Total Suspended Sediment Concentration in the Inflow to and Discharge from the San Luis Drain: Water Year 1997.

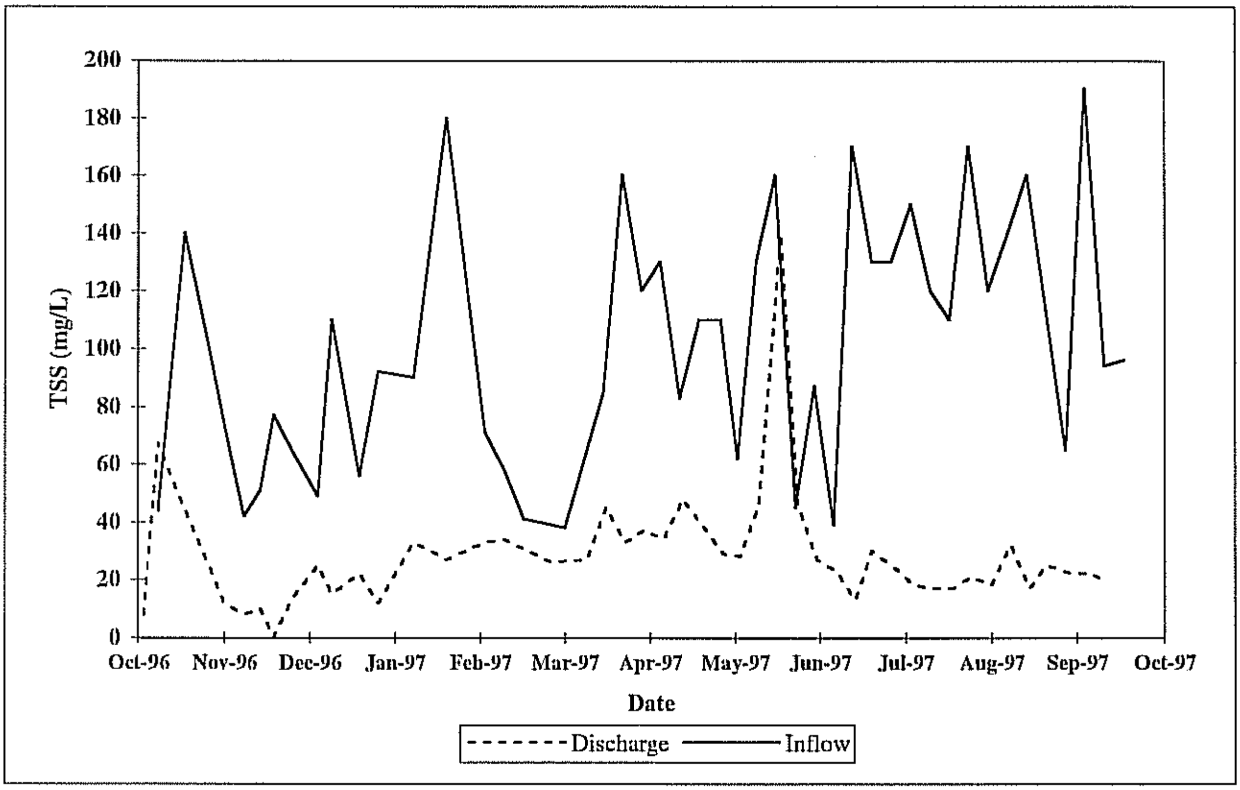


Figure 8. Electrical Conductivity, Boron and Selenium Concentrations in Camp 13 Slough and Agatha Canal (Grab Data): Water Year 1997.

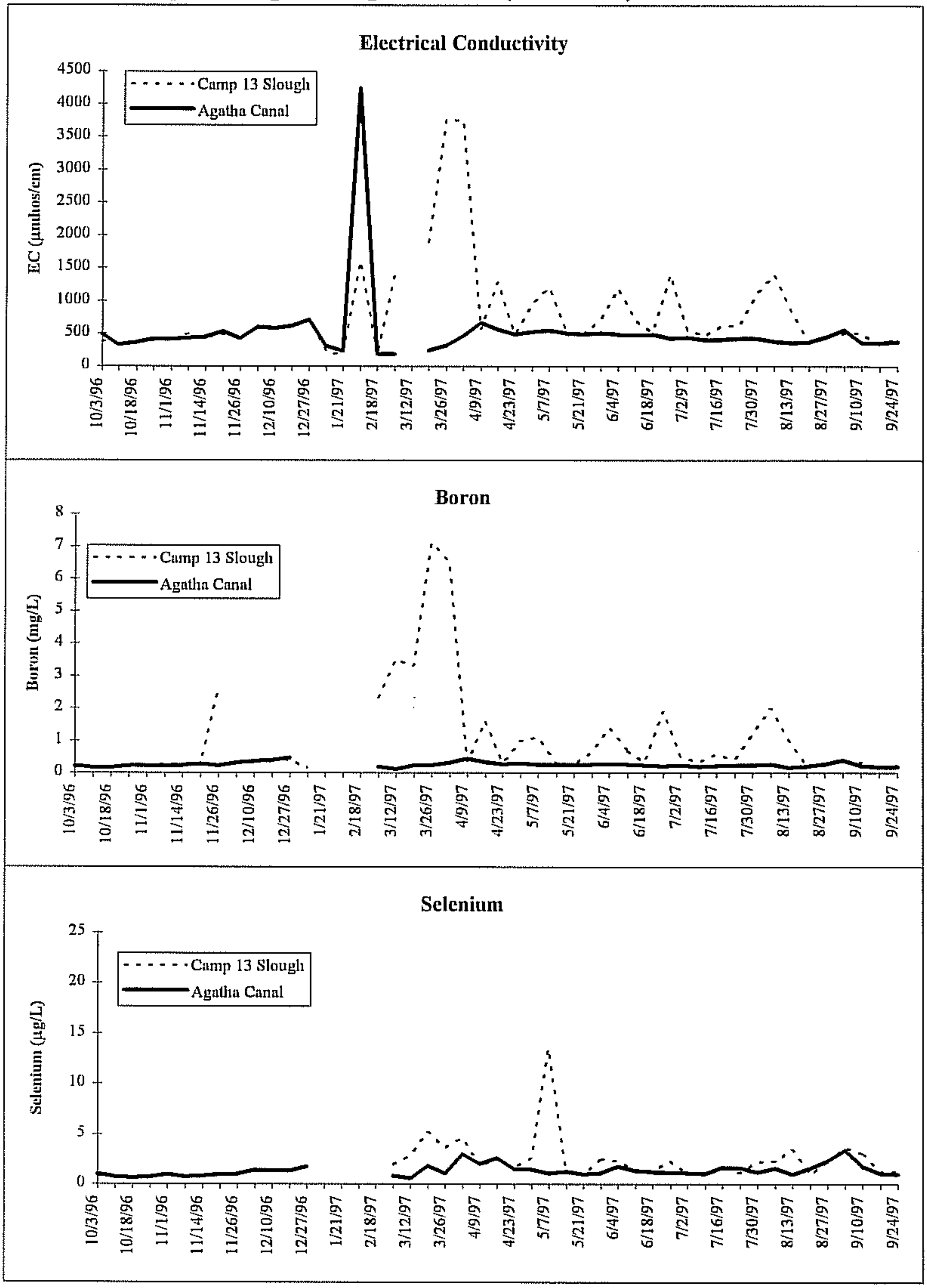


Figure 9. Electrical Conductivity, Boron and Selenium Concentrations in the San Luis Canal and Santa Fe Canal (Grab Data): Water Year 1997.

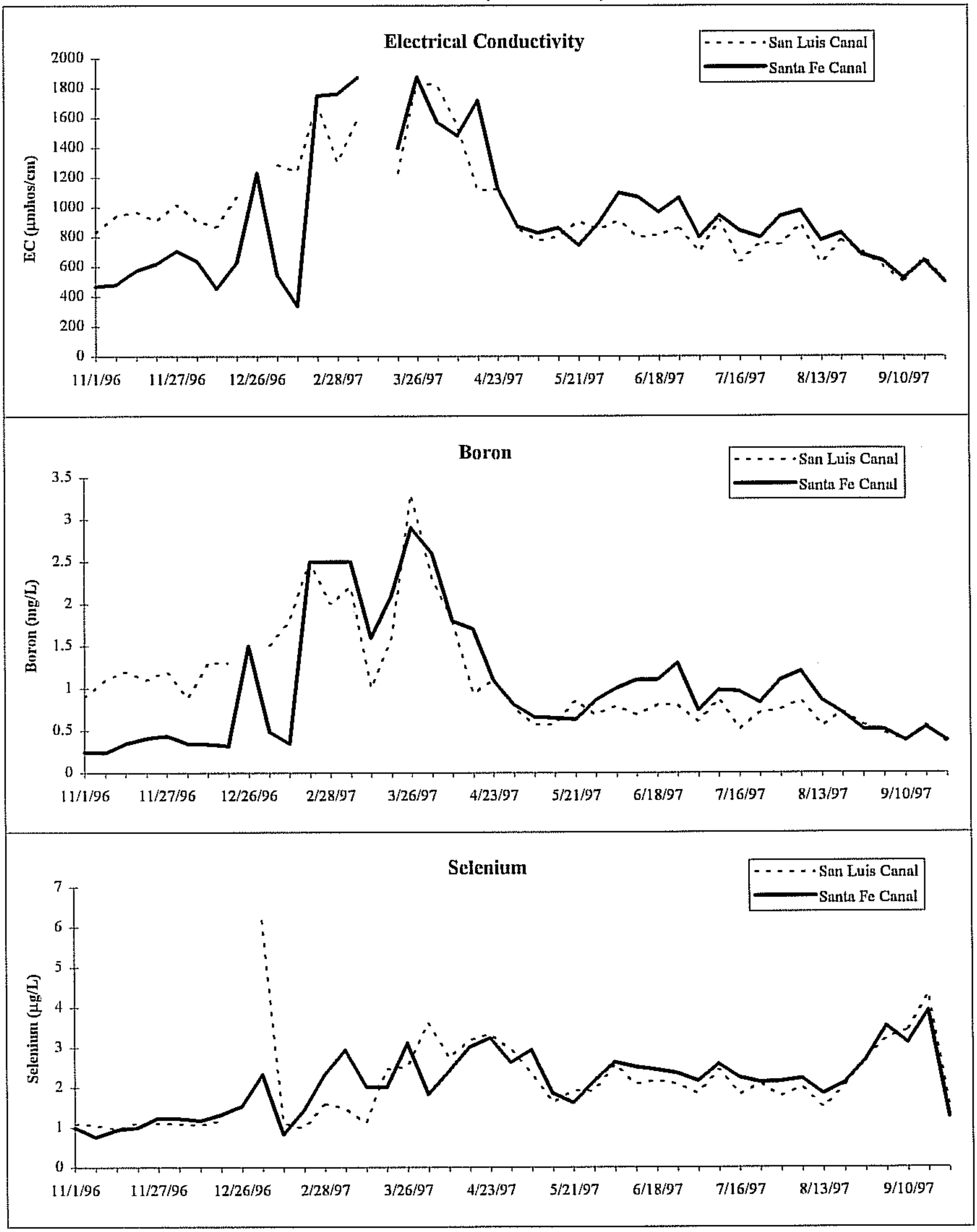


Table 15. Selenium Concentrations in Supply Water to the Grassland Watershed: October 1996 through September 1997.*

Date	Selenium Concentration (µg/L)		
	Delta Mendota Canal MP 110.12	Mendota Pool at Mowry Bridge	CCID Main Canal @ Head of San Luis Canal
10/2/96	<1	—	—
10/14/96		<2	—
11/13/96	<1	—	—
11/15/96	—	2.9	—
12/18/96	—	2.4	—
1/8/97	3	—	—
1/15/97	—	<2	<2
2/11/97	18	—	—
2/18/97	—	<2	—
3/12/97	13	—	—
3/13/97	—	<2	—
4/2/97	2	—	—
4/16/97	—	4	—
5/9/97	<2	—	—
5/15/97	—	4.8	—
6/13/97	<2	—	—
7/9/97	<2	—	—
7/11/97	—	2.2	4
8/14/97	<2	—	—
9/16/97	4	—	—

* = Data provided by Summers Engineering and the Central California Irrigation District based on internal monitoring and sampling conducted by the U.S. Bureau of Reclamation.

of concern. Electrical conductivities reached 4600 μmhos/cm while selenium concentrations peaked at 21.2 μg/L. The automated data confirms the peaks seen during the program's weekly grab samples (Figure 10). The diversion of the ponded water ceased on 28 March 1997. Additional periods of elevated concentrations also occurred between April and September 1997. These elevated concentrations corresponded to a period of very low flow in Camp 13 Slough. Little, if any supply water was being delivered and the majority of flow was from leaks in the gates separating the slough from the main supply canal and from major drains. Reports from the San Luis Delta Mendota Water Authority (SLDMWA, 1997) indicate that between 5 and 10 gpm will leak from the Main Drain into Camp 13 Slough through the closed gates.

Another potential selenium source to the internal wetland supply canals includes elevated concentrations in the Rice Drain, which receives drainage from lands in the eastern portion of the watershed, and the Almond Drive Drain, which receives drainage from lands in the western portion of the watershed. Although these drains were not monitored during Water Year 1997, historical data indicates that both drains have contained selenium concentrations in excess of 2.0 μg/L on many occasions (Figure 11). Sources of drainage into these water bodies needs to be determined.

Other factors such as elevated concentrations in groundwater seepage and in surface drainage may also impact the quality of water in the internal canals. Further review of all factors related to the elevated selenium levels in the internal canals within the Grassland Watershed and possible source flows, is necessary.

Concentrations of electrical conductivity, boron and selenium have all decreased dramatically in Salt Slough as compared to values recorded prior to the operation of the Grassland Bypass Project (Steensen et al., 1998). Concentrations of these three constituents in Salt Slough during Water Year 1997, are depicted in Figure 12. Electrical conductivity and boron remained below 2,000 μmhos/cm and 1.8 mg/L, respectively, throughout the water year. Selenium concentration remained below 2.0 μg/L except for one spike recorded in the first part of February 1997, during the flood event, when concentrations reached 3.4 μg/L.

Daily Composite Samples

Daily composite samples were collected at the discharge from the San Luis Drain. Some inconsistencies in the quality control samples for the discharge were noted for the time period of 10 through 21 January 1997. Although the information collected was graphed, the data were not used in the summary calculations presented in Tables 11 and 12. Daily electrical conductivity (EC), boron and selenium results are presented in Figure 13 along with grab sample data.

At the San Luis Drain discharge, EC and boron concentrations can vary widely on a daily basis. Daily EC values vary up to 1,000 μmhos/cm in a day, while boron concentrations vary up to 2 mg/L per day. Some seasonality is evident with concentrations peaking between February and April and tapering off from June through September. The results obtained from the grab and autosampler show similar means and medians of 4390 μmhos/cm and 4420 μmhos/cm, respectively for EC and 7.0 and 7.2 mg/l, respectively for boron (Tables 11 and 12).

Selenium showed greater seasonal fluctuations than EC or boron, with concentrations peaking in April at 116 μg/L and dropping off to 15.2 μg/L in September. Daily concentration fluctuations could also be high, with a 40 μg/L shift occurring between 2 and 3 October 1996. Although weekly grab samples appear to document the seasonal trends and shifting concentrations, they are unable to detect the potentially large changes in daily concentrations.

DISCUSSION

Comparison of Water Year 1996 with Water Year 1997

When the Grassland Bypass became operational at the end of September 1997, it effectively consolidated agricultural subsurface drainage from the DPA into a single channel for discharge into the

Figure 10. Corroboration of Grab Sample Data by Use of Automated Collection (Sigma) Sampler at Camp 13 Slough: Water Year 1997.

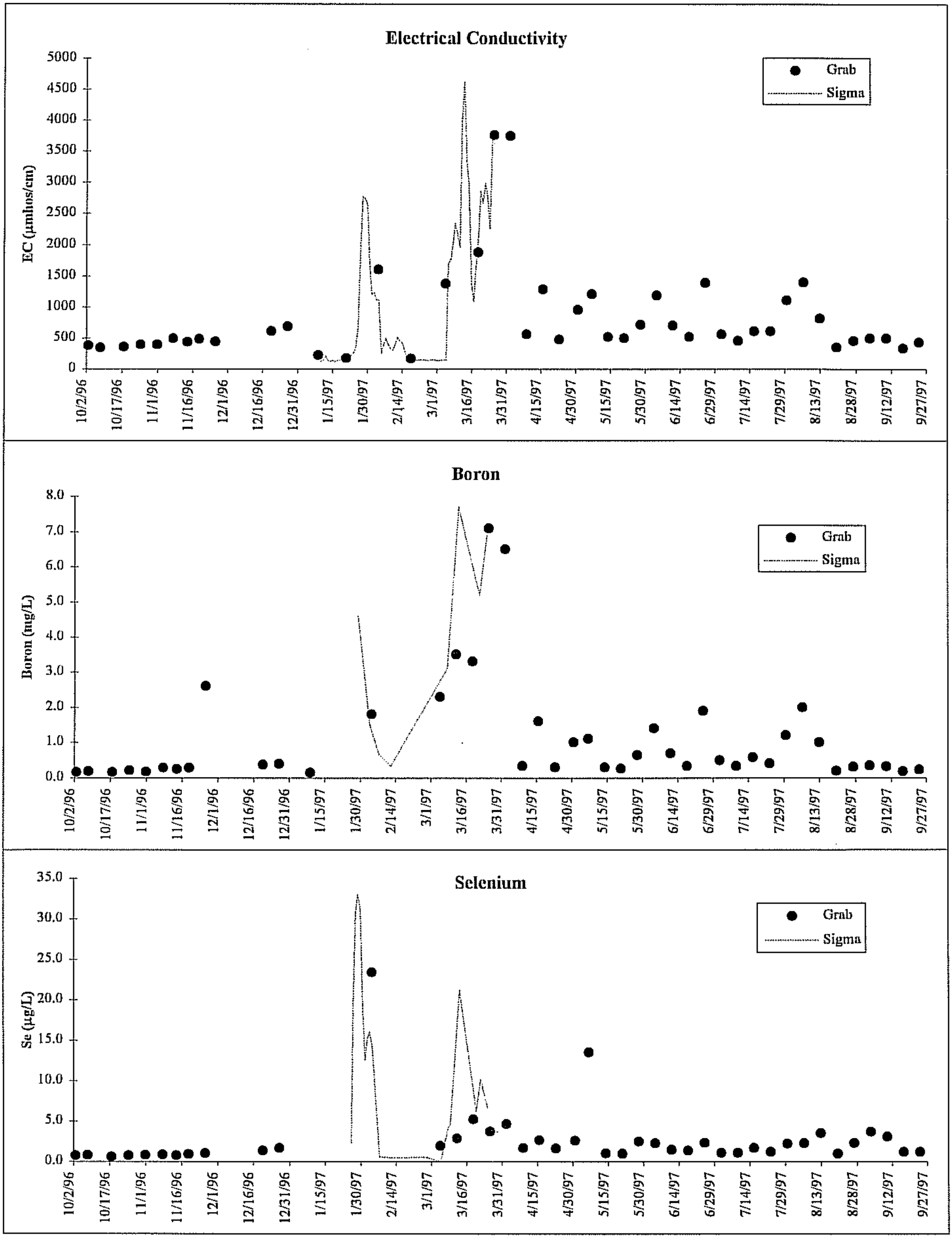
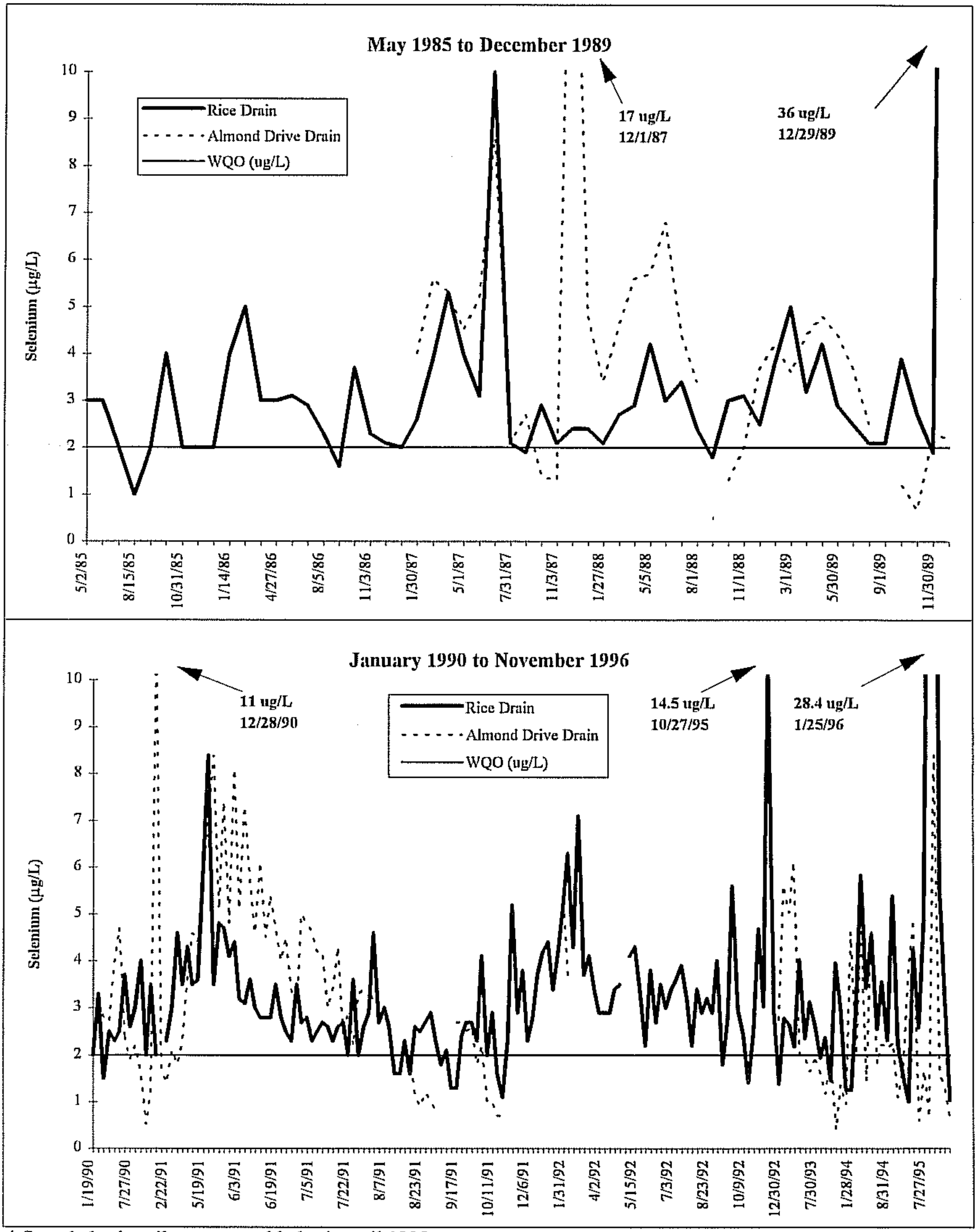


Figure 11. Selenium Concentrations in Almond Drive and Rice Drain: May 1985 to November 1996*



* Sampled primarily on a monthly basis until 1995
1991: special study (frequent sampling)
1995 and 1996: sampled quarterly

Figure 12. Electrical Conductivity, Boron and Selenium Concentrations in Salt Slough (Grab Data): Water Year 1997

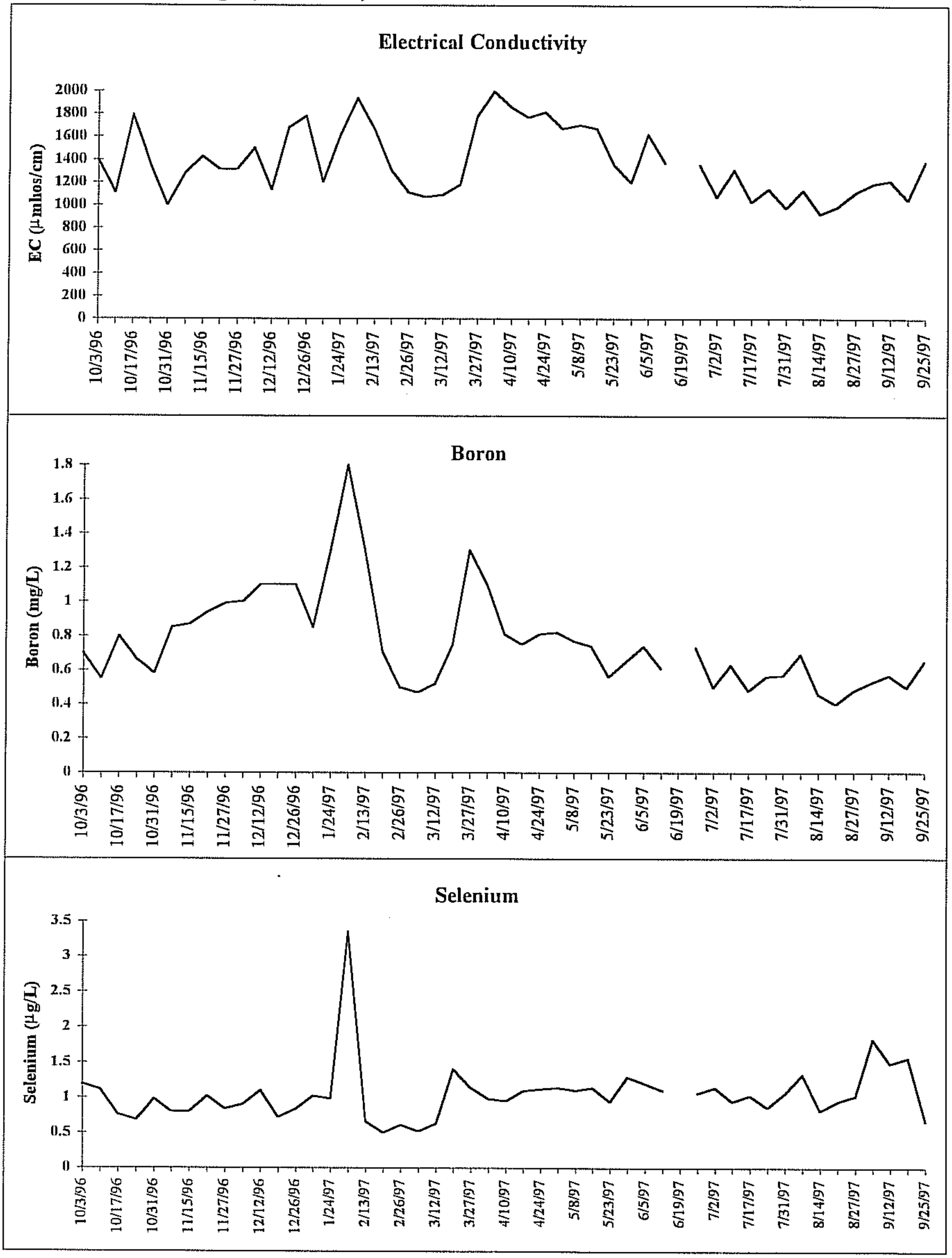
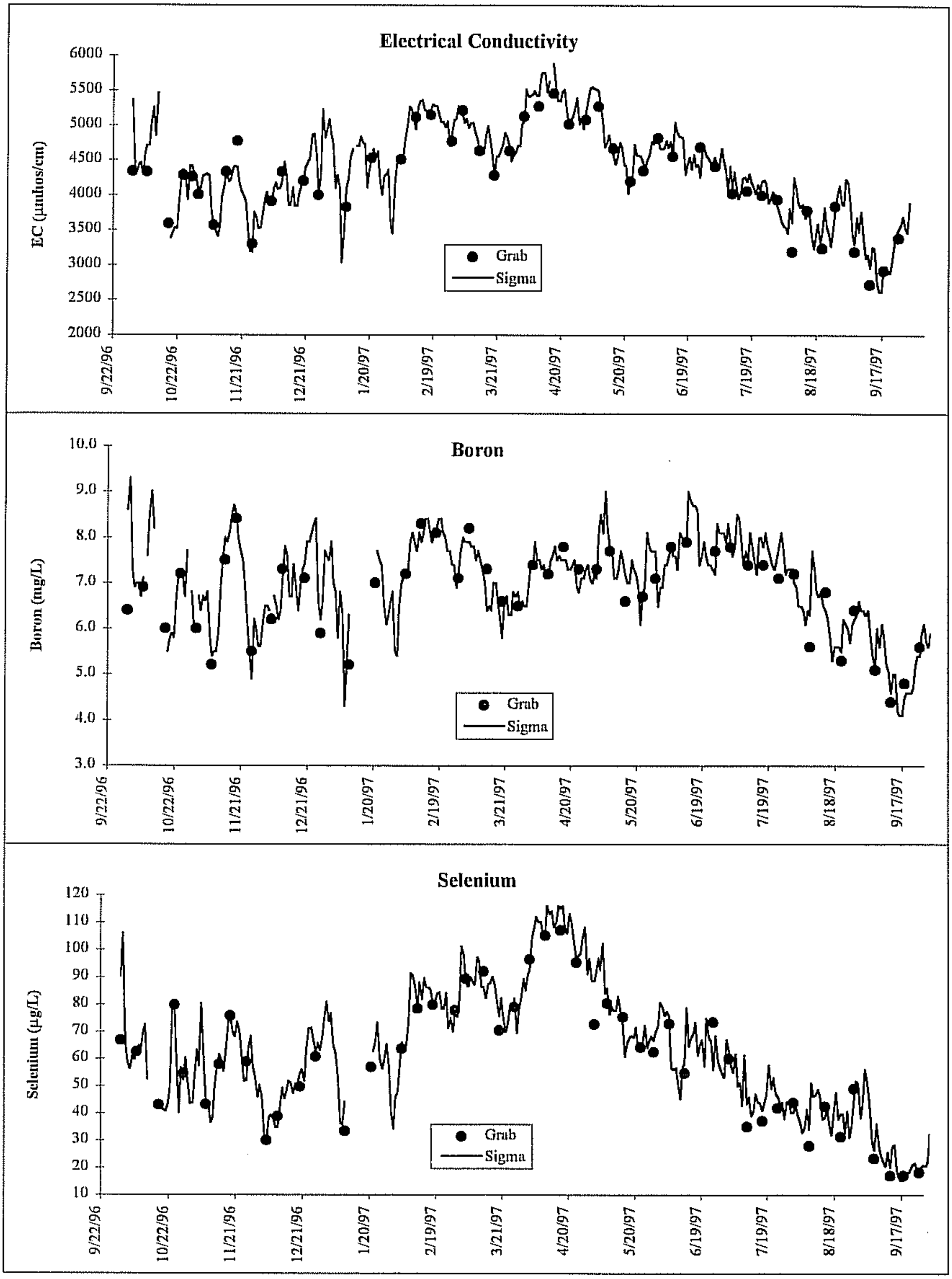


Figure 13. Comparison of Selenium, Boron and Electrical Conductivity at the San Luis Drain Using Grab Sample Data and Autosampler (Sigma) Data: Water Year 1997.



final nine miles of Mud Slough (north). This consolidation removed the subsurface drainage from approximately 90 miles of internal wetland water supply channels and from Salt Slough.

Figure 14 depicts the changes in EC, boron, and selenium concentrations in Mud Slough (north) and Salt Slough for the period prior to the Bypass (Water Year 1996) and the first year following the Bypass operation (Water Year 1997). Both EC and boron concentration declined in Salt Slough and increased in Mud Slough (north) once the Bypass began operation. The most dramatic change, however, occurred with selenium concentrations. Removing the agricultural subsurface drainage from Salt Slough, reduced the selenium concentration to below 2.0 µg/L during Water Year 1997 as opposed to a range of 1.0 to 33.5 µg/L during Water Year 1996. A corresponding increase was seen in Mud Slough (north) with selenium concentrations ranging from 5.0 to 79.6 µg/L during Water Year 1997. When subsurface agricultural drainage is present, the higher overall selenium concentrations observed in Mud Slough (north), as compared to Salt Slough, is due to limited dilution potential. Mud Slough (north) has a lower baseline flow and therefore provides less dilution for agricultural subsurface drainage than Salt Slough.

Concentrations in the wetland water supply channels was more variable. Overall concentrations in Camp 13 Slough and the Agatha Canal decreased dramatically after the Bypass began operation, however, a number of concentration spikes were apparent throughout Water Year 1997 (Figure 15). Potential reasons for the concentration spikes include elevated selenium levels in supply water, releases from the DPA (seepage and flood flows), inflows from other sources such as the Rice Drain and Almond Drive Drain, and other internal sources such as groundwater seepage and surface return flows. These potential sources were discussed in more detail in the section on wetland water supply channels and Salt Slough under the results for Water Year 1997.

Concentrations in the San Luis Canal and Santa Fe Canal do not appear to have changed, with similar values recorded both prior to and after Bypass operation (Figure 16). Most subsurface agricultural drainage was diverted out of these canals and into Salt Slough through the Porter-Blake Bypass, upstream of the sampling locations, during water year 1996. Only when subsurface agricultural drainage was diverted to Mud Slough (north) or continued downstream in the San Luis Canal to the City Ditch diversion to Salt Slough, would the drainage be measured in these canals at these sampling locations. By water year 1997, the majority of subsurface drainage had been consolidated into the Grassland Bypass and lower portion of the San Luis Drain, and did not reach the two canals except during flood flows.

Comparison to Applicable Water Quality Objectives

In October 1988, the Regional Board adopted water quality objectives for boron, molybdenum and selenium for Mud Slough (north), Salt Slough and water used to maintain wetland habitat. In May 1996, the Regional Board adopted revised selenium water quality objectives for the two sloughs and for wetland water supply channels, as well as a compliance time schedule for Mud Slough (north). Water quality objectives which applied during each water year are listed in Table 16. The selenium compliance time schedule which applies to Mud Slough (north), does not require full compliance with the selenium objective until 1 October 2010. No water quality objectives have been adopted for the San Luis Drain.

Tables 17 and 18 list the exceedances of boron and selenium water quality objectives, respectively, for both Water Year 1996 and 1997. All potential selenium exceedances have been shown, whether or not they may be subject to the compliance time schedule.

Boron

The boron water quality objective remained unchanged for both water years and only applied to two water bodies, Mud Slough (north) and Salt Slough. In addition, the objective (2.0 mg/L) is applied as a monthly mean for a set time period: 15 March through 15 September. A maximum objective of 5.8 mg/L boron applies year round.

Figure 14. Comparison of Selenium, Boron and Electrical Conductivity at Salt Slough and Mud Slough (North) Downstream of the San Luis Drain: Water Years 1996 and 1997.

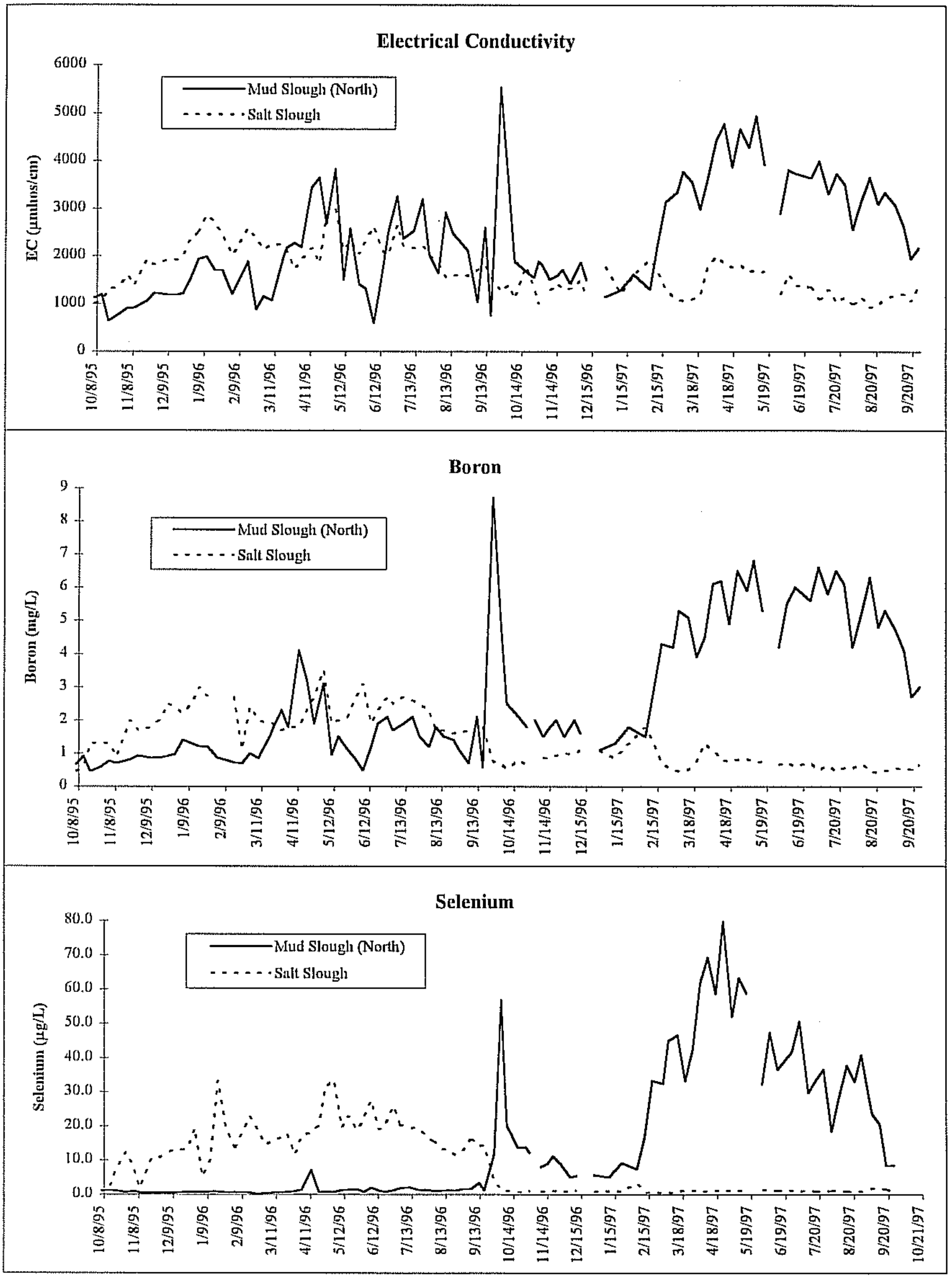


Figure 15. Comparison of Selenium, Boron and Electrical Conductivity at Agatha Canal and Camp 13 Slough: Water Years 1996 and 1997.

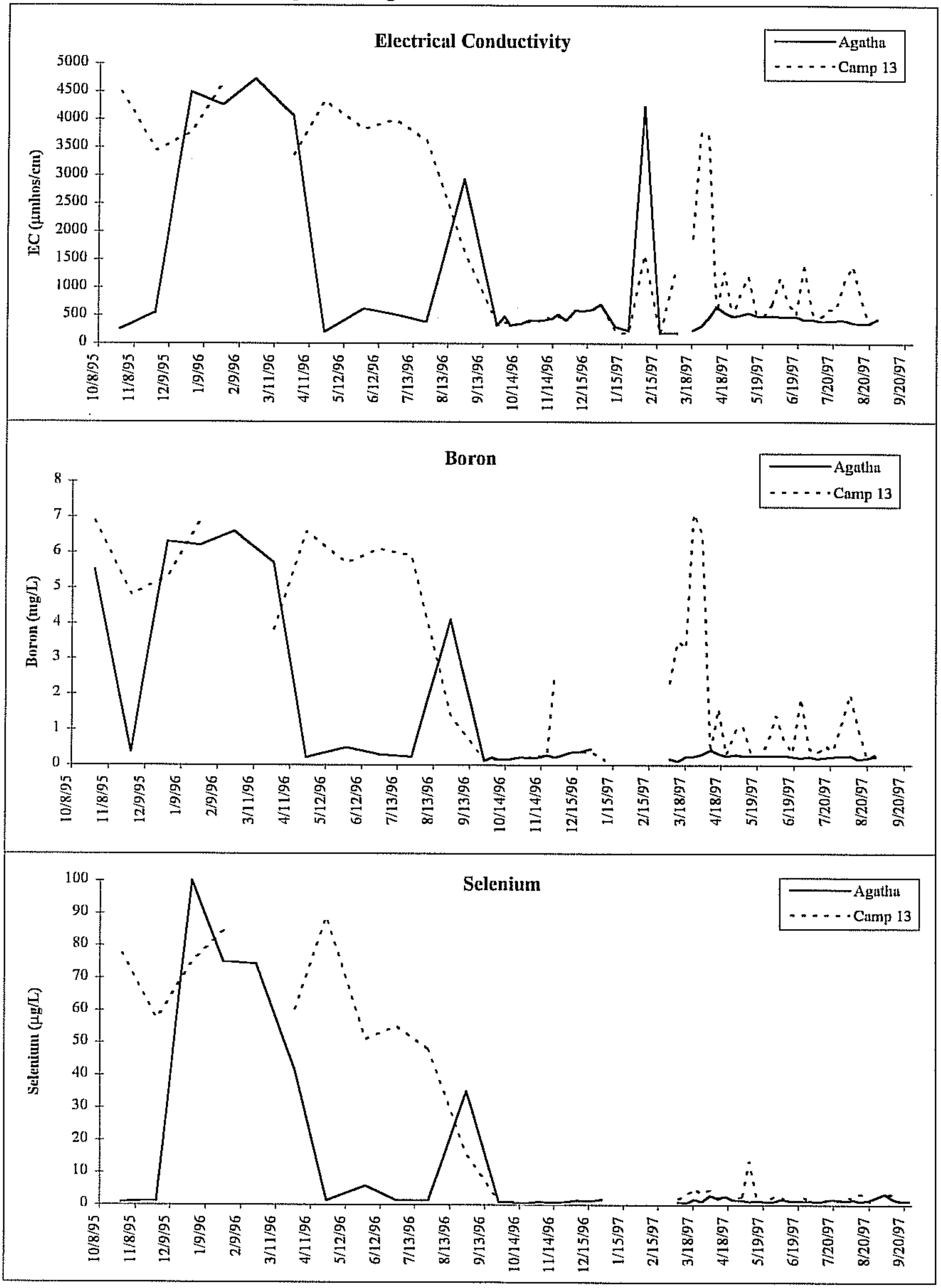


Figure 16. Comparison of Selenium, Boron and Electrical Conductivity at San Luis Canal and Santa Fe Canal at Henry Miller Road: Water Years 1996 and 1997.

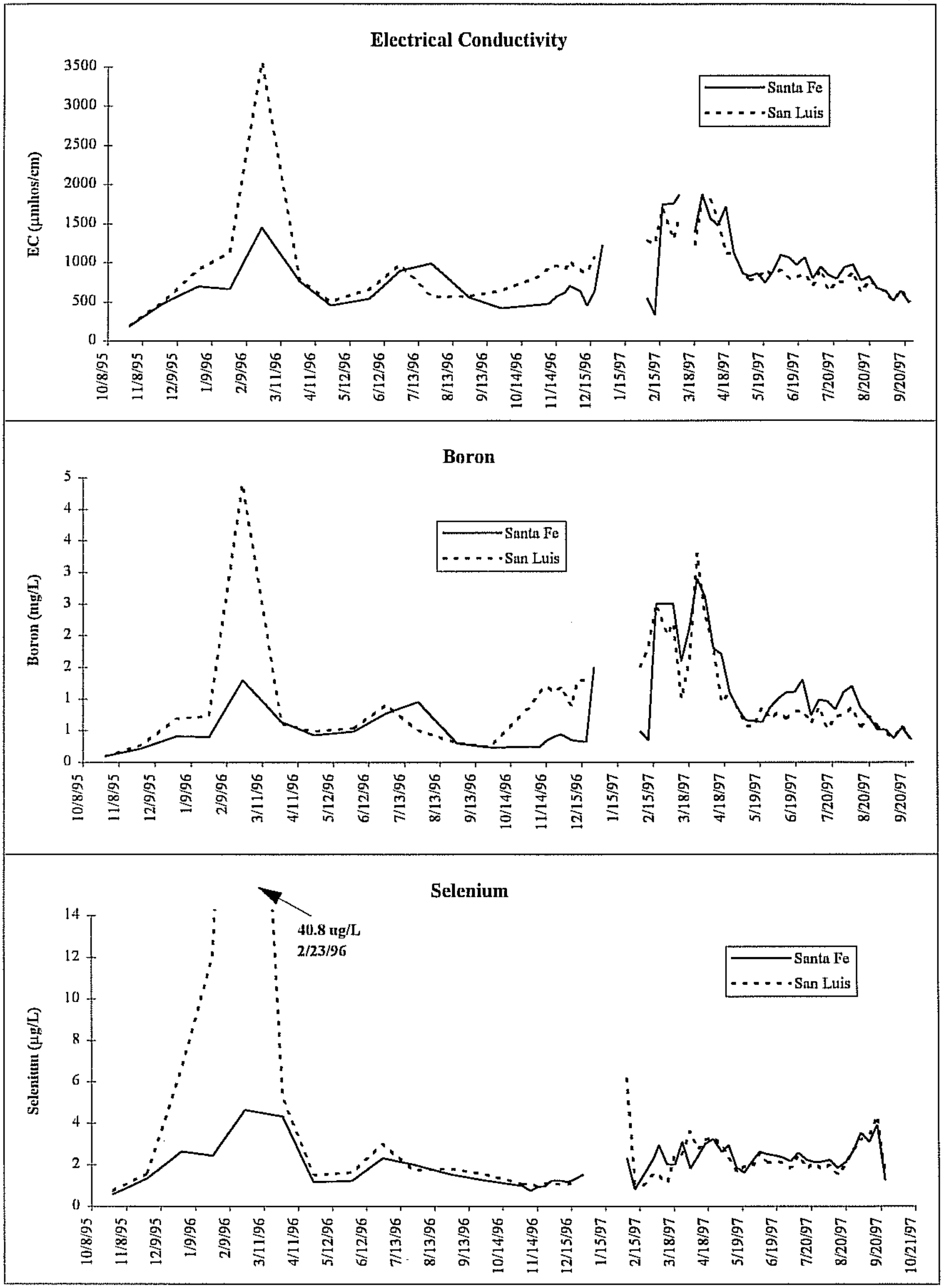


Table 16. Boron, Selenium and Molybdenum Water Quality Objectives for Water Bodies Within the Grassland Watershed. Water Years 1996 and 1997.

Water Body	Boron (mg/L)		Selenium (µg/L)		Molybdenum (µg/L)	
	Continuous	Maximum	Continuous	Maximum	Continuous	Maximum
Mud Slough (north)						
WY 1996	2.0 (monthly mean)†	5.8	10 (monthly mean)	26	19 (monthly mean)	50
WY 1997	2.0 (monthly mean)†	5.8	5 (4-day average)*	20	19 (monthly mean)	50
Salt Slough						
WY 1996	2.0 (monthly mean)†	5.8	10 (monthly mean)	26	19 (monthly mean)	50
WY 1997	2.0 (monthly mean)†	5.8	2 (monthly mean)	20	19 (monthly mean)	50
Wetland Water Supply Channels						
WY 1996	—	—	2 (monthly mean)††	—	—	—
WY 1997	—	—	2 (monthly mean)	20	—	—

† = The water quality objective only applies from 15 March through 15 September
* = Compliance time schedule adopted and in effect until October 2010
†† = as measured in water used for wetland habitat maintenance

Table 17. Boron Water Quality Objective Exceedances in the Grassland Watershed: Water Years 1996 and 1997.

Station ID	Description	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Monthly WQO
Water Year 1996														
MER542	Mud Slough (N) downstream of the SLD	a	a	a	a	a								2.0
MER531	Salt Slough at Lander Ave.	a	a	a	a	a								2.0
MER542	Mud Slough (N) at SLD autosampler	a	a	a	a	a								2.0
MER531	Salt Slough at Lander Avenue autosampler	a	a	a	a	a								2.0
Water Year 1997														
MER536	Mud Slough (N) upstrm of the Drainage Discharge	a	a	a	a	a								2.0
MER542	Mud Slough (N) dwnstrm of the Drainage Discharge	a	a	a	a	a								2.0
MER531	Salt Slough at Lander Avenue	a	a	a	a	a								2.0

[shaded box] = water quality objective exceedance

a = objective only applies 15 March through 15 September

WQO = water quality objective in mg/L

Table 18. Selenium Water Quality Objective Exceedances in the Grassland Watershed: Water Years 1996 and 1997.

Station ID	Description	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Monthly WQO
Water Year 1996														
MER505	Camp 13 Slough			b	b	b	b	b	b	b	b	b		2
MER506	Agatha Canal			b	b	b	b	b	b	b	b	b		2
MER543	San Luis Canal at Henry Miller Road			b	b	b	b	b	b	b	b	b		2
MER519	Santa Fe Canal at Henry Miller Road			b	b	b	b	b	b	b	b	b		2
MER551	Mud Slough (N) at Newman Gun Club													10
MER542	Mud Slough (N) at San Luis Drain													10
MER531	Salt Slough at Lander Avenue													10
MER542	Mud Slough (N) at SLD autosampler													10
MER531	Salt Slough at Lander Avenue autosampler													10
Water Year 1997														
MER505	Camp 13 Ditch				ND									2
MER506	Agatha Canal				ND	ND								2
MER543	San Luis Canal at Henry Miller Road	ND			ND									2
MER519	Santa Fe Canal at Henry Miller Road	ND			ND									2
MER551	Mud Slough (N) upstrm of the Drainage Discharge													5
MER542	Mud Slough (N) dwnstrm of the Drainage Discharge													5
MER531	Salt Slough at Lander Avenue													2

[shaded box] = water quality objective exceedance ND = no data available WQO = water quality objective in μg/L

b = the 2 ug/L objective only applied to wetland water supply so applied to wetland floodup (Sept. through Nov.)

Note that Table 17 is for discussion only as a compliance time schedule applies to the 5 μg/L 4-day average Se water quality objective
Beginning WY97, *the 2 ug/L objective applied to stations MER531, MER505, MER506, MER543, and MER519*

Table 19. Monthly Molybdenum Concentrations and Water Quality Objective Exceedances in the Grassland Watershed: Water Years 1996 and 1997

Station ID	Description	Molybdenum Concentration (ug/L) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Monthly WQO
Water Year 1996														
MER556	Main (Firebaugh) Drain at Russell Ave.	45	—	—	31	—	—	20	—	—	7	—	—	na
MER501	Panoche Drain at O'Banion Gauge Station	13	—	—	8	—	—	12	—	—	15	—	—	na
MER504	Hamburg Drain near Camp 13 Slough	7	—	—	7	—	—	5	—	—	4	—	—	na
MER502	Charleston Drain at CCID Main Canal	2	—	—	5	—	—	6	—	—	5	—	—	na
MER542	Mud Slough (N) downstream of the SLD	7	—	—	6	—	—	10	—	—	11	—	—	19
MER531	Salt Slough at Lander Ave.	6	—	—	9	—	—	9	—	—	10	—	—	19
Water Year 1997														
MER536	Mud Slough (N) upstrm of the Drainage Discharge	7	—	3	3	—	7	11	5	7	3	5	10	19
MER535	San Luis Drain at the Terminus	35	30	23	22	27	29	26	23	26	25	25	35	na
MER542	Mud Slough (N) dwnstrm of the Drainage Discharge	11	8	3	6	*19*	17	*24*	17	*21*	16	*23*	*20*	19
MER531	Salt Slough at Lander Avenue	4	4	7	7	7	7	10	6	9	5	5	9	19

[shaded box] = water quality objective exceedance — = no data available na = no water quality objective (WQO) for this site

During Water Year 1996, the mean monthly boron water quality objective was exceeded during April and September in Mud Slough (north) based on weekly grab samples. However, when evaluated using 4-day composite data for the same site, monthly mean boron concentrations remained below the 2.0 mg/L objective. In contrast, the boron objective was exceeded continuously from April through July in Salt Slough, based on the weekly grab samples. Review of the 4-day composite information indicates that the objective was also exceeded in March 1996, but concentrations fell just below 2.0 mg/L in April. Maximum boron concentrations remained below 5.8 mg/L in both sloughs.

During Water Year 1997, the mean monthly boron objective was exceeded in Mud Slough (north) both upstream and downstream of the San Luis Drain discharge. The exceedances upstream of the discharge may be due to a number of factors including localized elevated levels in groundwater seepage, releases from wetlands, and other surface drainage. Exceedances in the slough downstream of the discharge increased substantially over both background and previous year concentrations, with exceedances during each month that the water quality objective applied. Maximum boron concentrations in Mud Slough (north) downstream of the San Luis Drain discharge exceeded 5.8 mg/L on nine separate occasions between April and August 1997. Only one mean monthly boron exceedance was recorded in Salt Slough which may reflect the diversion of subsurface agricultural drainage out of that water body. This exceedance was related to the storm event previously discussed. All measured concentrations in Salt Slough remained below 5.8 mg/L during Water Year 1997.

Selenium

Selenium water quality objectives for water bodies within the Grassland Watershed changed between water years 1996 and 1997 with the adoption of the 1996 Basin Plan Amendment. During Water Year 1996, a 10 µg/L monthly mean selenium objective applied to both Mud Slough (north) and Salt Slough, while a 2 µg/L objective applied to water which was used to maintain wetland habitat. The new objectives, which were adopted in May 1996 and went into effect during Water Year 1997, included a 2 µg/L monthly mean selenium objective for all wetland water supply channels (not just the supply water) and Salt Slough. A 5 µg/L, 4-day average objective was adopted for Mud Slough (north) along with a compliance time schedule which requires that the objective be met by 1 October 2010.

During Water Year 1996, the 2 µg/L selenium objective applied primarily from September through November, the normal period of wetland floodup. Of the supply waters sampled, only Camp 13 exceeded the 2 µg/L objective. The exceedances occurred during October and November and were likely due to the use of the channel to convey subsurface agricultural drainage through the Grassland Watershed. Most of the subsurface drainage was routed to Salt Slough during Water Year 1996, which resulted in continuous exceedances of the 10 µg/L selenium objective in that water body from December through September. Available 4-day composite data for Salt Slough confirmed the exceedances. In contrast, Mud Slough (north) remained below the 10 µg/L selenium objective throughout Water Year 1996.

During Water Year 1997, the 2.0 µg/L monthly mean selenium water quality objective was exceeded repeatedly in the supply channels (Camp 13, Agatha, San Luis Canal and Santa Fe Canal), but not in Salt Slough. As discussed earlier, a number of factors may have led to these exceedances and each must be further evaluated to determine a means of meeting the water quality objective.

Although subject to the adopted compliance time schedule, Mud Slough (north) was evaluated against the 5 µg/L, 4-day average selenium water quality objective. Mud Slough (north) downstream of the San Luis Drain Discharge continuously exceeded the objective in Water Year 1997, while there were no exceedances upstream of the discharge.

Molybdenum

Molybdenum analyses in water bodies within the Grassland Watershed were restricted to quarterly analyses in selected drains, Mud Slough (north) and Salt Slough during Water Year 1996. During Water Year 1997, molybdenum monitoring was focused on sites which would likely be influenced by the Grassland Bypass Project and included monthly analyses in Mud Slough (north) upstream and downstream of the San Luis Drain discharge, the San Luis Drain itself, and Salt Slough. Available data is presented in Table 19.

During Water Year 1996, the monthly mean molybdenum objective (19 µg/L) only applied to Mud Slough (north) and Salt Slough, and was not exceeded based on limited, quarterly grab samples. Although the objective did not apply to upstream water bodies, information collected from the four major discharge points for the Drainage Project Area indicated elevated molybdenum concentrations in the Main (Firebaugh) Drain.

During Water Year 1997, molybdenum concentrations in Mud Slough (north) upstream of the San Luis Drain discharge and in Salt Slough resembled those recorded in Water Year 1996 and did not exceed the 19 µg/L objective. While no objective applied to the drain itself, molybdenum concentrations in the discharge were elevated, ranging from 22 µg/L to 35 µg/L. This discharge did impact the water quality in the downstream segment of Mud Slough (north), elevating molybdenum concentrations over background (upstream) concentrations. The 19 µg/L molybdenum objective was exceeded on five separate occasions at the downstream location: in February, April, June, August and September.

LOADS OF SALT, BORON AND SELENIUM

Salt, boron, and selenium loads for the Drainage Project Area (DPA), Grassland Bypass Project (GBP), and the Grassland Watershed were estimated based upon the flow weighted monthly average of the available water quality data. In Water Year 1997, loads that previously had to be summed for individual sites in the DPA were consolidated into the San Luis Drain as part of the GBP. Discharge and loads from the DPA for Water Year 1997 are therefore based on discharge and loads from the GBP. Discharge data for the DPA obtained for the individual water districts was provided by Joe McGahan (personal communication). Discharge and electrical conductivity data for the Grassland Bypass Project was obtained from the USBR (Nigel Quinn, personal communication). Preliminary daily discharge data and daily electrical conductivity for the two Grassland Watershed outflow sites, Mud Slough (north) and Salt Slough, were obtained from the USGS (Pat Shiffer, personal communication). Salt loads for the GBP and the Grassland Watershed sites are based upon daily electrical conductivity and flow measurements. Salt loads for the DPA are based upon laboratory measurement of electrical conductivity for grab samples and automatic Sigma(tm) samples collected by Regional Board staff. Boron and selenium loads are also based upon combined grab and automatic Sigma(tm) automatic sample data for the DPA and GBP sites. Only grab samples were collected and used for the Grassland Watershed sites, during Water Year 1997. The methodology used to calculate loads can be found in Grober et al., 1998. Raw data used to present loads have been tabulated and are available in hard copy from the Regional Board's Sacramento office. This information can also be found at the Regional Board web site. Follow the links to view or download files from:

http://www.swrcb.ca.gov/ ~rwqcb5/home.html

The tabulated flow and water quality data used to compute loads for Water Years 1986 through 1997 are presented chronologically. Each year of data is comprised of four data tables; the first table contains mean daily flow data; the second, third and fourth contain electrical conductivity (EC), boron and selenium data, respectively. Additionally, EC, boron, and selenium data are presented for five Sigma™ automatic sampler sites for Water Years 1995, 1996 and 1997. Matrices are sparsely filled for some water quality data.

For Water Year 1996, mean daily flow data is available for Panoche Drain and Firebaugh Main Drain. Only mean monthly flow data is available for Pacheco Drain, Charleston Drain, and CCID diversions. Full matrices of mean daily flows for these sites are based on mean monthly flow estimates (Summers Engineering, Inc., 1996). Flow data for the Grassland Bypass Project for Water Year 1997 was obtained from the USBR (Nigel Quinn, personal communication). Mean daily flow for Mud Slough (north), and Salt Slough for Water Years 1996 and 1997 were obtained from the United States Geological Survey (Pat Shiffer, personal communication, 1997).

EC data for drains in the DPA are based on water quality samples collected by the Regional Board and by districts in the DPA. Mean daily EC data for the GBP was obtained from continuous EC recorders maintained by the USBR (Nigel Quinn, personal communication). EC data for Mud Slough (north), and Salt Slough are mean daily values obtained from continuous EC recorders maintained by the USGS (Pat Shiffer, personal communication, 1997). Consolidated boron and selenium concentration data presented here are from samples collected and analyzed by the Regional Board.

Monthly discharge and monthly flow weighted average concentrations and loads for the DPA were calculated for Water Year 1996 and 1997 (Table 20). High rainfall in January and early February 1997 (see Figure 2), led to rates of surface runoff in the DPA that exceeded the capacity of the GBP channels. Excess flows from the DPA were discharged to wetland channels in the Grassland Watershed during these flood events. Table 20 does not include flows and loads discharged to wetland channels. Daily flows, electrical conductivities, and selenium concentrations in two major wetland water supply channels from 21 January to 10 February 1997 (the period associated with the flood flows), are listed in Appendix D. Total selenium load to these channels during this time period was 137 pounds (USBR et al., 1997).

Monthly discharge and monthly flow weighted average concentrations and loads for 1996 and 1997 for the Grassland Watershed are based on the combined discharge and loads for Mud Slough (north) and Salt Slough (Table 21). Annual discharge from the DPA dropped 30 percent from approximately 53,000 acre-feet in 1996 to approximately 37,500 acre-feet in 1997. Annual salt load for the DPA also dropped 30 percent from just under 200,000 tons in 1996 to 140,000 tons in 1997. Boron loads were practically identical for both years at just over 700,000 pounds. Selenium loads from the DPA dropped 30 percent from approximately 10,000 pounds in Water Year 1996, to under 7,000 pounds in Water Year 1997.

Annual discharge in the Grassland Watershed was similar in both years, increasing slightly from approximately 270,000 acre-feet in 1996 to approximately 290,000 acre-feet in 1997. Annual salt load for the Grassland Watershed was similar for both years, dropping from just over 475,000 tons to just under 450,000 tons, while boron loads increased from approximately 1.3 million pounds to 1.4 million pounds between 1996 and 1997. Selenium loads dropped almost 20 percent, from 9,500 pounds in 1996 to 7,700 pounds in 1997. Although the DPA contributes large quantities of salt and boron, it is not the only source of these constituents in the basin. The DPA is, however, the primary source of selenium in the Grassland Watershed. A higher selenium load was in fact calculated for the DPA than the Grassland Watershed in Water Year 1996. This discrepancy may be due to losses in the system or an overestimate of loads from the DPA or underestimates for the Grassland Watershed. For a full discussion of possible calculation errors or system losses see Grober et al, 1998. In 1997, the DPA accounted for 90 percent of the selenium load in the Grassland Watershed.

Monthly loads of salt for the DPA and Grassland Watershed are shown in Figure 17. Figures 18 and 19 show the monthly loads of boron and selenium, respectively. The overall pattern of loading for each area was similar in Water Years 1996 to 1997. Monthly salt loads from the DPA were higher in 1996 than 1997 for all months except January. Similarly, salt loads were also higher for the February through September period of 1996 than 1997 in the Grassland Watershed. Salt loads in the Grassland Watershed were higher during the October through January period of 1997 than 1996, particularly in January. This January peak in salt loads in the Grassland Watershed is attributable to extremely high flood flows. January to May boron loads from the GBP were slightly higher in 1997 than 1996. From June through September, boron loads were slightly lower in 1997. A similar trend is evident downstream for the Grassland Watershed, although boron loads were slightly higher in the October to December period of 1997. Once again there was markedly higher boron loading during the extremely wet January of 1997 when compared to 1996. Selenium loads from the DPA were higher for all months of 1996 than 1997 except for April. Selenium loads in the Grassland Watershed were also higher for all months of 1996 than 1997 except for October, January, April, and May.

Figure 20 shows the annual discharge for the combined Grassland Watershed outflow sites, Mud Slough (north) and Salt Slough, and for the DPA, for Water Years 1985 through 1997. Figures 21 through 23 depict the annual salt, boron, and selenium loads from the two areas for the same time

Table 20. Monthly and Annual Discharge and Salt, Boron and Selenium Loads and Flow Weighted Concentrations for the Drainage Project Area: Water Years 1996 and 1997.

Water Year 1996		Loads			Flow Weighted Conc.		
Month	Flow (af)	Se (lbs)	B (1000 lbs)	TDS (tons)	Se (ppb)	B (ppm)	TDS (ppm)
Oct-95	1,911	313	27	6,346	60.2	5.12	2,442
Nov-95	2,192	324	29	7,017	54.3	4.87	2,354
Dec-95	2,586	578	35	9,053	82.2	4.98	2,575
Jan-96	2,647	687	44	11,148	95.4	6.10	3,097
Feb-96	5,664	1,247	78	25,872	80.9	5.09	3,359
Mar-96	4,620	1,324	67	21,107	105.4	5.32	3,359
Apr-96	4,641	1,243	73	19,431	98.5	5.81	3,079
May-96	5,626	1,145	76	22,050	74.8	4.98	2,882
Jun-96	6,825	977	89	23,387	52.6	4.78	2,520
Jul-96	6,671	992	90	23,147	54.7	4.96	2,551
Aug-96	6,339	747	74	18,758	43.3	4.32	2,176
Sep-96	3,255	459	41	10,210	51.8	4.63	2,307
WY 96 Total	52,978	10,034	723	197,526	69.6	5.02	2,742

Water Year 1997		Loads			Flow Weighted Conc.		
Month	Flow (af)	Se (lbs)	B (1000 lbs)	TDS (tons)	Se (ppb)	B (ppm)	TDS (ppm)
Oct-96	1,276	202	25	4,247	58.3	7.10	2,448
Nov-96	1,569	252	29	5,066	59.0	6.73	2,375
Dec-96	1,946	285	38	6,718	53.9	7.18	2,539
Jan-97 *	3,702	599	65	12,926	59.5	6.47	2,568
Feb-97 *	4,172	878	89	17,139	77.3	7.80	3,021
Mar-97	4,875	1,119	93	19,191	84.4	6.98	2,895
Apr-97	4,452	1,280	89	18,886	105.7	7.35	3,120
May-97	4,214	849	85	16,804	74.1	7.39	2,932
Jun-97	3,457	611	74	13,529	65.0	7.85	2,878
Jul-97	3,276	428	69	11,619	48.0	7.71	2,608
Aug-97	3,158	348	54	9,807	40.5	6.30	2,283
Sep-97	1,444	109	21	4,132	27.7	5.33	2,103
WY 97 Total	37,541	6,959	729	140,063	68.2	7.14	2,744

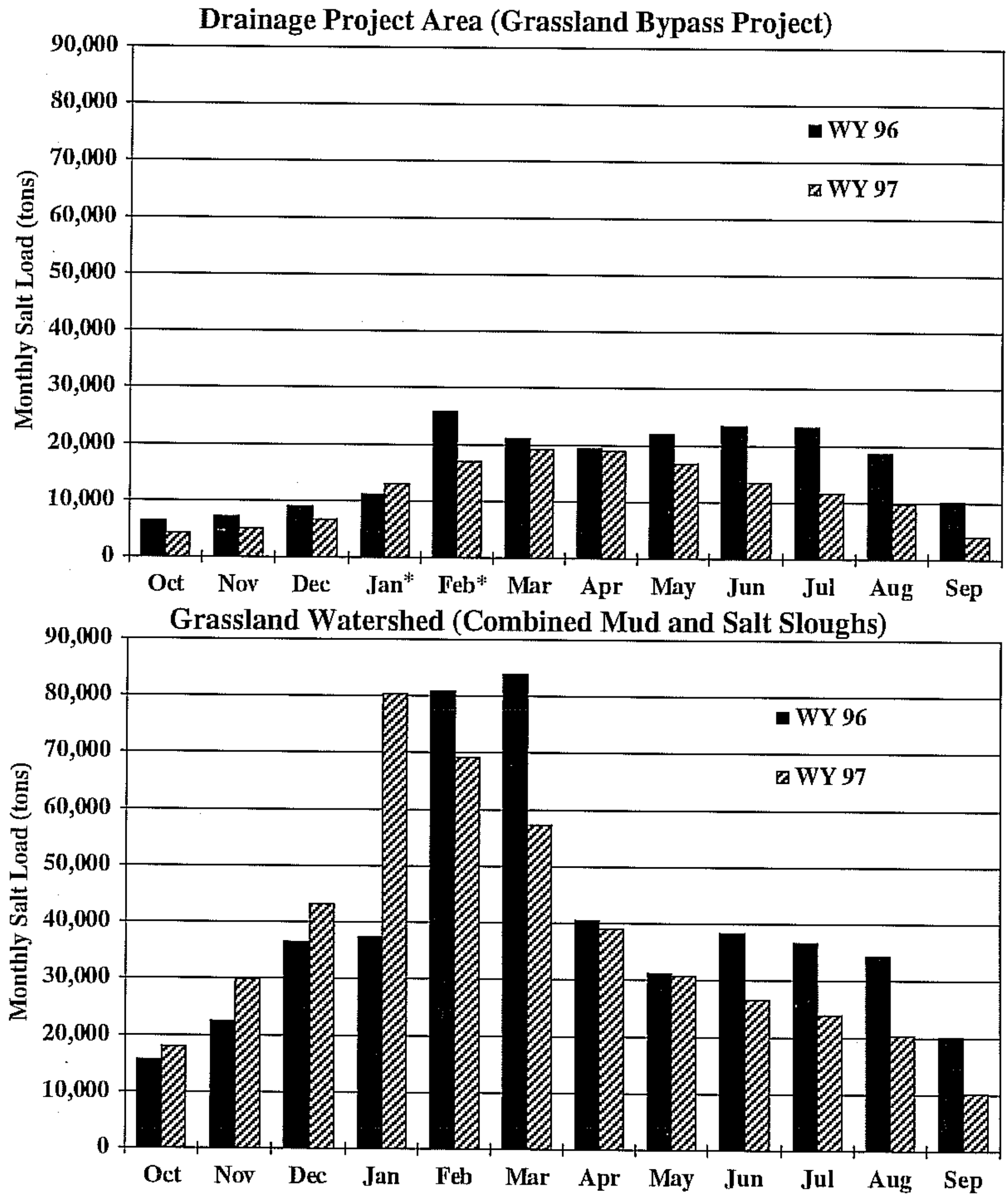
* Data presented does not include flood flows and loads discharged to wetland channels in the Grassland Watershed during a late January and early February 1997 flood event (see text and Appendix D)

Table 21. Monthly and Annual Discharge and Salt, Boron and Selenium Loads and Flow Weighted Concentrations for the Grassland Watershed: Water Years 1996 and 1997.

Water Year 1996 Month	Flow (af)	Loads Se (lbs)	Loads B (1000 lbs)	Loads TDS (tons)	Flow Weighted Conc. Se (ppb)	Flow Weighted Conc. B (ppm)	Flow Weighted Conc. TDS (ppm)
Oct-95	13821	248	40	15696	6.6	1.05	835
Nov-95	15894	319	56	22450	7.4	1.30	1039
Dec-95	22033	538	94	36391	9.0	1.56	1215
Jan-96	17621	625	97	37333	13.0	2.03	1558
Feb-96	47067	1466	210	80753	11.5	1.64	1262
Mar-96	43499	1451	215	83854	12.3	1.81	1418
Apr-96	19991	911	109	40429	16.7	2.00	1487
May-96	17007	851	88	31194	18.4	1.91	1349
Jun-96	17365	906	109	38354	19.2	2.30	1624
Jul-96	18650	956	123	36708	18.8	2.42	1447
Aug-96	21074	749	94	34444	13.1	1.65	1202
Sep-96	13927	470	66	20120	12.4	1.74	1062
WY 96 Total	267948	9491	1299	477725	13.0	1.78	1311

Water Year 1997 Month	Flow (af)	Loads Se (lbs)	Loads B (1000 lbs)	Loads TDS (tons)	Flow Weighted Conc. Se (ppb)	Flow Weighted Conc. B (ppm)	Flow Weighted Conc. TDS (ppm)
Oct-96	13566	279	52	18084	7.6	1.42	980
Nov-96	23296	302	82	29742	4.8	1.30	939
Dec-96	31885	355	112	43003	4.1	1.30	992
Jan-97	59661	833	214	80247	5.1	1.32	989
Feb-97	40336	1055	211	69194	9.6	1.92	1261
Mar-97	32632	1169	180	57205	13.2	2.03	1289
Apr-97	15999	1205	126	39133	27.7	2.91	1799
May-97	16225	859	110	30740	19.5	2.49	1393
Jun-97	14030	586	93	26449	15.4	2.44	1386
Jul-97	15410	504	99	23926	12.0	2.37	1142
Aug-97	16021	437	80	20405	10.0	1.83	937
Sep-97	9193	138	35	10219	5.5	1.41	817
WY 97 Total	288253	7722	1396	448347	9.8	1.78	1144

Figure 17. Monthly Salt Loads Discharged from the Drainage Project Area and the Grassland Watershed, Water Years 1996 and 1997



* Data presented does not include flood flows and loads discharged to wetland channels in the Grassland Watershed during a late January and early February 1997 flood event (see text and Appendix D)

Figure 18. Monthly Boron Loads Discharged from the Drainage Project Area and the Grassland Watershed, Water Years 1996 and 1997

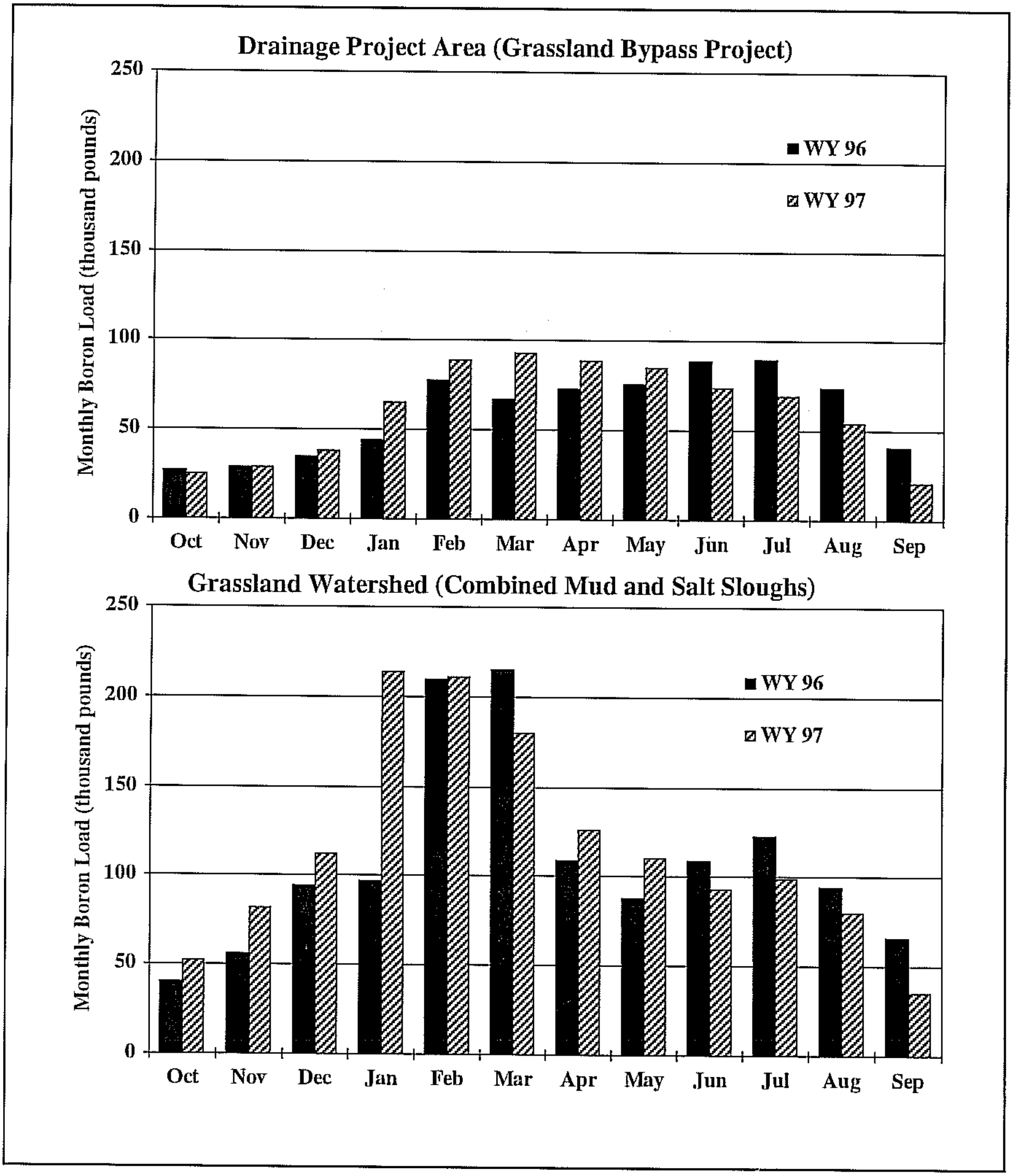


Figure 19. Monthly Selenium Loads Discharged from the Drainage Project Area and the Grassland Watershed, Water Years 1996 and 1997

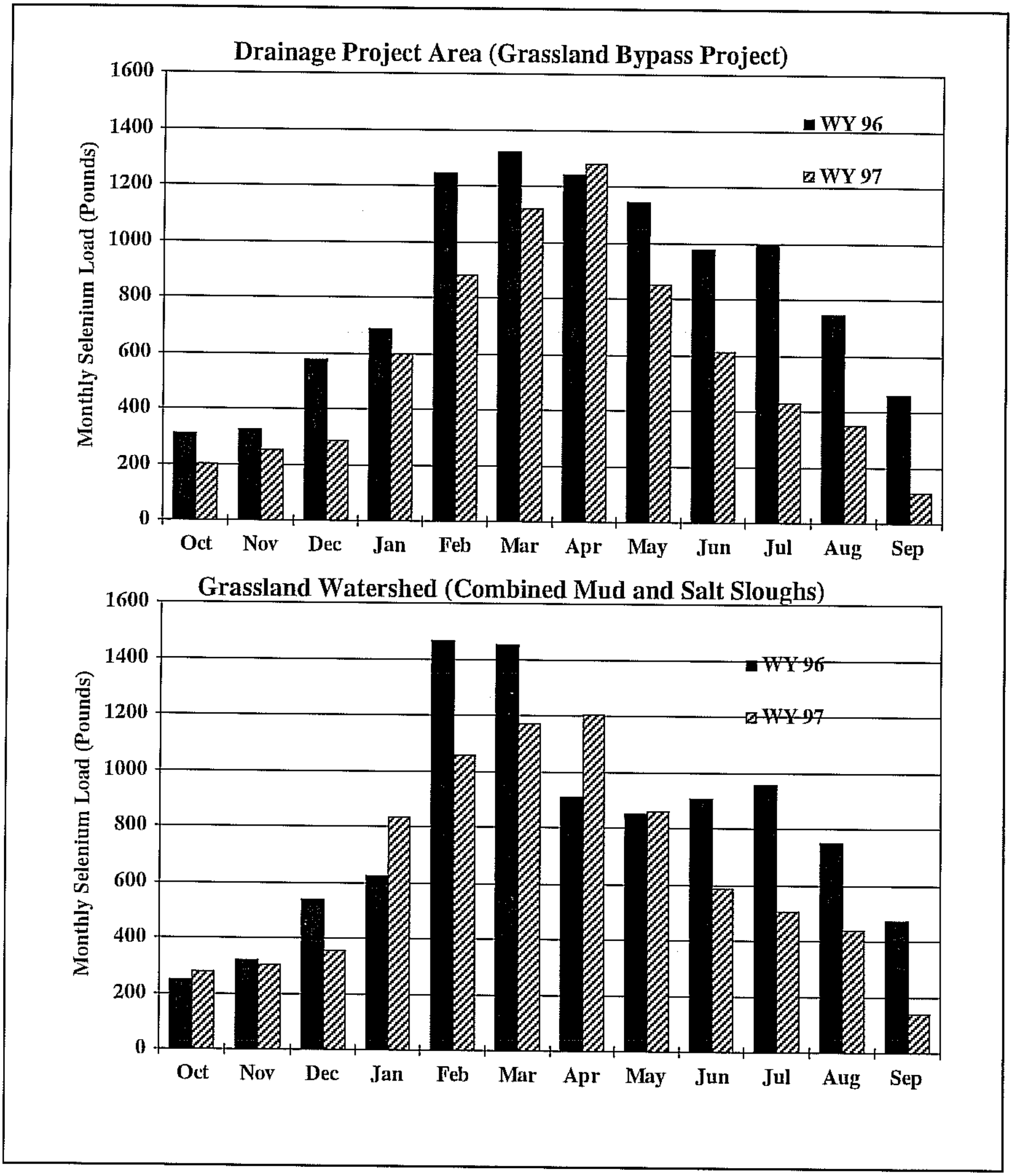


Figure 20. Annual Discharge from the Drainage Project Area and the Grassland Watershed, Water Years 1986 through 1997

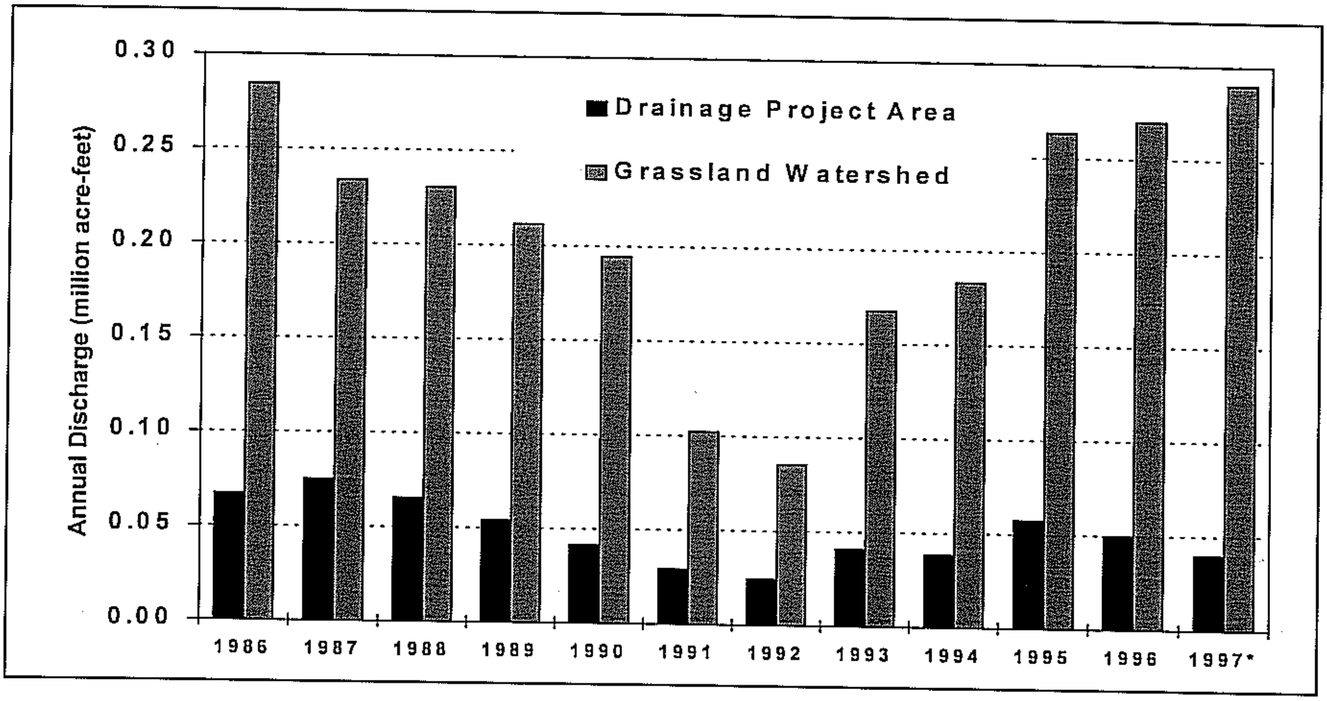


Figure 21. Annual Salt Load from the Drainage Project Area and the Grassland Watershed, Water Years 1986 through 1997

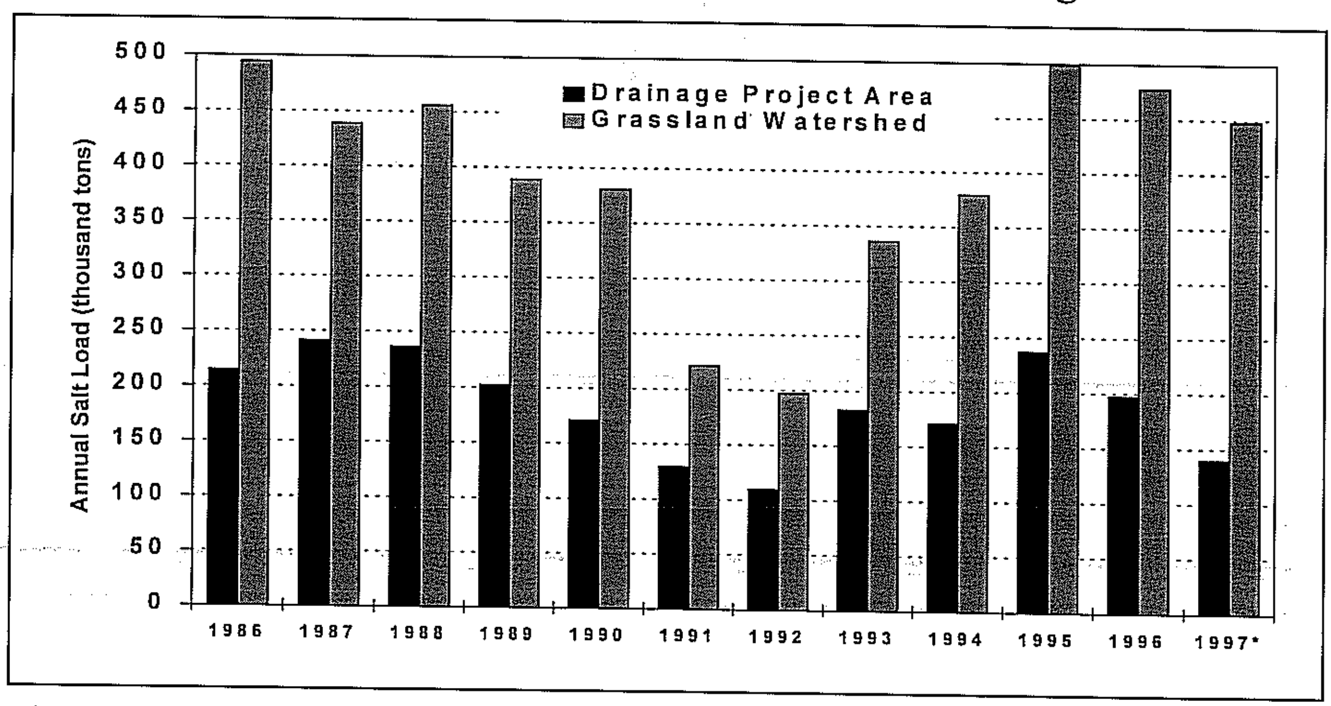


Figure 22. Annual Boron Load from the Drainage Project Area and the Grassland Watershed, Water Years 1986 through 1997

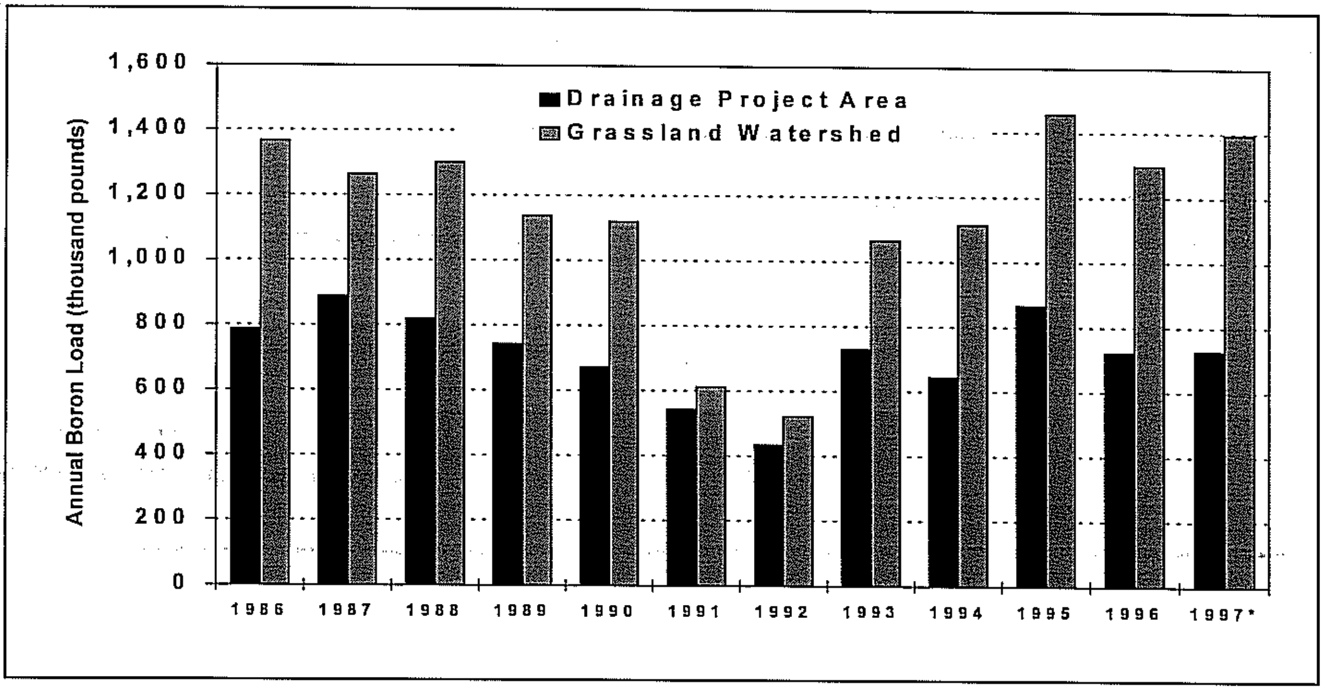
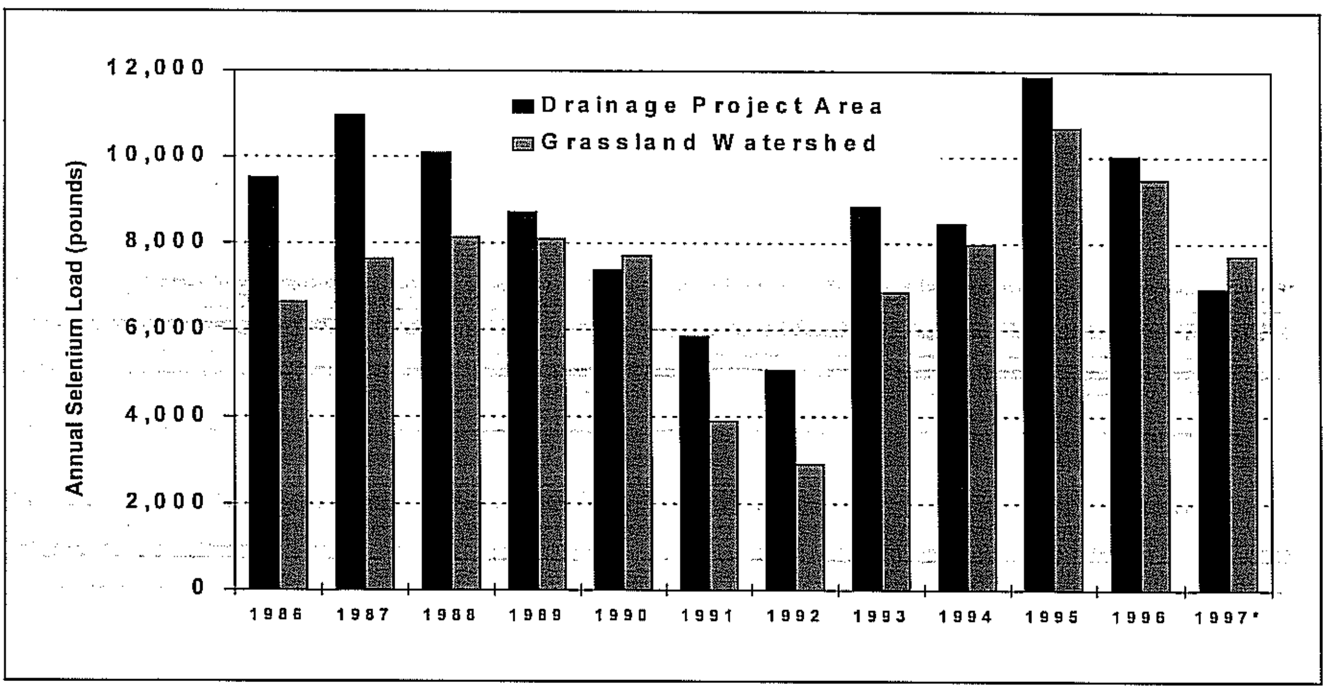


Figure 23. Annual Selenium Load from the Drainage Project Area and the Grassland Watershed, Water Years 1986 through 1997



period. Discharge for the DPA and Grassland Watershed for Water Years 1996 and 1997 was similar to Water Year 1995, another wet year, but significantly higher than 1991 through 1994. Water Year 1995 was the first wet year following several dry and critically dry years. High loads of all constituents in 1995 likely resulted from the leaching of salts that had accumulated in the basin during previous years. Generally lower loads of all constituents in 1996 and 1997 were likely due to lower residual salt loads in the Grassland Watershed following a series of wet years. Markedly lower selenium loads from the DPA are also attributable to district recycling and other water conservation and drainage reduction methods that were initiated in 1997 to reduce selenium loads as part of the Grassland Bypass Project.

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