Grassland Bypass Project

Annual Report 2010 - 2011

PUBLISHED NOVEMBER 2013

Grassland Bypass Project

GBP

PREPARED BY

THE SAN FRANCISCO ESTUARY INSTITUTE FOR THE GRASSLAND BYPASS PROJECT OVERSIGHT COMMITTEE

U.S. Bureau of Reclamation

U.S. Environmental Protection Agency

U.S. Fish and Wildlife

U.S. Geological Survey

Central Valley Regional Water Quality Control Board

California Department of Fish and Game

San Luis & Delta-Mendota Water Authority

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GBP

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CHAPTER 1
Introduction

January 1, 2010 – December 31, 2011

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INTRODUCTION

The Grassland Bypass Project (GBP) completed its fifteenth year of operation on December 31, 2011. The Grassland Area Farmers continued to reduce the amount of agricultural drainage water produced in the Grassland Drainage Area (GDA), preventing the discharge of this water into local Grassland wetland water supply channels, and improved the quality of water in the San Joaquin River.

This report has been prepared by the multi-agency Data Collection and Review Team as a review and evaluation of the monitoring program that was conducted through December 2011. It builds upon prior reports to discern changes in environmental conditions since the GBP began in October 1996.

BACKGROUND

The GBP is based upon an agreement[3] between the U.S. Bureau of Reclamation (Reclamation) and the San Luis and Delta-Mendota Water Authority (Authority) to use a 28-mile segment of the San Luis Drain to convey agricultural subsurface drainage water from the GDA to Mud Slough (North), a tributary of the San Joaquin River.

The purposes of the GBP are:

1. to continue the separation of unusable agricultural drainage water discharged from the GDA from wetland water supply conveyance channels for the period 2010 - 2019; and,

2. to facilitate drainage management that maintains the viability of agriculture in the GDA and promotes continuous improvement in water quality in the San Joaquin River.

The GBP has removed agricultural drainage water from channels that supply water to more than 160,000 acres of wetlands and wildlife areas in the Grasslands Watershed. **Figure 1** is a map that shows the location of the GDA and monitoring stations along tributaries of the San Joaquin River. **Figure 2** is a schematic diagram of the Project with the location of monitoring sites discussed in this report. **Figure 1 in Chapter 2** is a map that shows the location of the GDA in relation to the State and Federal wildlife areas.

The first Use Agreement was signed November 3, 1995, and the Authority conveyed drainage water in the San Luis Drain from September 27, 1996 to September 30, 2001. The second Use Agreement, executed on September 27, 2001, allowed the Authority to use the San Luis Drain and continue the Project through December 31, 2009. The third use agreement, signed on December 22, 2009, allows the Authority to continue to use the San Luis Drain through December 31, 2019.

All three Use Agreements have many conditions, including the assessment of "Drainage Incentive Fees" to be imposed when monthly or annual selenium or salt loads are exceeded. The fees are to be used for programs or actions that will assist in meeting selenium load values, salinity load values and discharge goals, water quality objectives in the drainage area, and/or will enhance wildlife values in the GDA or adjacent areas.

3 U.S Bureau of Reclamation and the San Luis and Delta-Mendota Water Authority, December 22, 2009. Agreement for Continued Use of the San Luis Drain for the Period of January 1, 2010 to December 31, 2019. Agreement No. 10-WC-20-3975

The 2009 Use Agreement provides "Incentive Fee Credits" when annual and monthly discharges are more than 10 percent below the respective load values specified in Appendix C (Selenium) and Appendix E (Salinity). **Tables 3a** and **4a** list the monthly incentive credits that have been accrued in 2010 and 2011; **Tables 3c** and **4c** list the annual incentive credits. Note that the Authority has accrued more than 15,700 selenium incentive credits and more than 186,700 salinity incentive credits that may be applied against future monthly or annual exceedances though December 2017.

The California Regional Water Quality Control Board, Central Valley Region (Regional Board), issued Waste Discharge Requirements (WDR)[4] in 2001 to Reclamation and the Authority that specify further conditions for discharging drainage water into Mud Slough (North). The monitoring requirements for the WDR are the basis for the monitoring program discussed in this report. After July 2011, Reclamation took over the collection and analysis of samples from many sites previously handled by the Regional Board. (**Tables 1a and 1b**).

This report summarizes Project activities and accomplishments for 2010-2011 and compares annual averages and totals for the entire fifteen years of the Project.

2010 HIGHLIGHTS

This year was "above normal" according to the San Joaquin River Index. Total rainfall varied from 8.1 to 14.1 inches measured at five weather stations located across the Grasslands Watershed (**Table 2c**). **Figure 3a** shows the pattern of daily rainfall and flow from the GDA. Storms in late January 2010 resulted in a brief peak flow of 27 cfs. Storms in March 2010 resulted in the year's highest flow of 50 cfs. The Grassland Area Farmers controlled drainage and met the annual selenium load value for 2010 (**Figure 4**).

The loads of selenium discharged each month from the GDA met the Selenium Load Values specified in the 2009 Use Agreement (**Table 3a** and **Figure 5**). The annual load of selenium discharged from the GDA in 2010 was 1,555 pounds, sixty-three percent below the Annual Load Value of 4,162 pounds (**Table 3c**).

The loads of salts discharged each month met the Load Values specified in the 2009 Use Agreement (**Table 4a** and **Figure 6**), except for November 2010, when the discharge was 95 tons over the Load Value. This exceedance was offset by application of Incentive Credits[5] for the significant reductions in salt loads through the project, and did not result in a Drainage Incentive Fee. The Project discharged about 88,460 tons of salts in 2010, which was 47 percent below the Annual Salinity Load Value of 167,883 tons (**Table 4c**).

2011 HIGHLIGHTS

This year was "wet" according to the San Joaquin River Index. Total rainfall varied from 6.6 to 8.8 inches measured at five weather stations located across the Grasslands Watershed (**Table 2c**).

4 California Regional Water Quality Control Board, Central Valley Region, September 21, 2001. Waste Discharge Requirements No. 5-01-234 for the San Luis & Delta-Mendota Water Authority and the United States Department of the Interior, Grassland Bypass Channel Project (Phase II), Fresno and Merced Counties.

5 Appendix J, 2009 Use Agreement

Figure 3b shows the pattern of daily rainfall and flow from the GDA during 2011. Storms in late February and early June resulted in peak flows of 78 and 61 cfs. A storm in late March resulted in the year's highest flow of 97 cfs. The Grasslands Are Farmer controlled drainage and met the annual selenium load value for 2011 (**Figure 4**).

The load of selenium discharged each month were less than the Selenium Load Values specified in the 2009 Use Agreement (**Table 3a** and **Figure 5**). The annual load of selenium discharged from the GDA was 1,997 pounds, fifty-five percent below the Annual Load Value of 4,480 pounds (**Table 3c**).

The loads of salts discharged each month met the Load Values specified in the 2009 Use Agreement (**Table 4a** and **Figure 6**). The project discharged about 83,600 tons of salt in 2011, which was 50 percent below the Annual Salinity Load Value of 167,847 tons (**Table 4c**).

CURRENT LOADS AND CONCENTRATIONS COMPARED TO PRE-PROJECT CONDITIONS

Table 5 presents the concentrations and loads of selenium, boron, and salt in water discharged from the GDA for Water Years[6] 1986 through 2011. The volume of drainwater and loads of selenium, boron, and salts discharged from the GDA in Water Year 2011 were much less than the pre-project years.

Table 6 lists the annual loads of selenium, boron, and salt discharged from the Grasslands watershed (Mud and Salt Sloughs) for Water Years 1986 through 2011. The volume of water in the streams has increased since 1993, mainly due to larger deliveries of CVP water to local refuges under federal law[7].

Table 7 lists the annual loads of selenium, boron, and salt in the San Joaquin River below the Merced River for Water Years 1986 through 2011. The annual average concentration of selenium in the river in 2010 was 1.2 and in 2011 was 0.5, which is considerably less than the pre-project average of 4.1 µg/L. The annual load of selenium in the river was 2,280 pounds in 2010 and 4,102 pounds in 2011, much less than the pre-project average of 8,129 pounds.

ADDITIONAL REPORTS AND STUDIES

Delta-Mendota Canal Water Quality Monitoring

Reclamation continued to measure selenium and salinity in water in the Delta-Mendota Canal and Mendota Pool. These facilities convey water to the farms and wetlands in the Grasslands Basin. Daily composite samples are collected from four sites to study the temporal and local changes in water quality due to the operation of the canal, drainage sumps, and tail water inlet structures. These data are published in monthly reports and are available upon request from Reclamation.

6 Water Year = October 1 – September 30

7 Title XXXIV, Central Valley Project Improvement Act, Reclamation Projects Authorization and Adjustments Act of 1992 (Public Law 102-575 – Oct. 30, 1992)

San Joaquin River Restoration Program (SJRRP)

In 1988, a coalition of environmental groups, led by the Natural Resources Defense Council (NRDC), filed a lawsuit challenging the renewal of long-term water service contracts between the United States and the Central Valley Project Friant Division contractors. After more than 18 years of litigation of this lawsuit, known as NRDC et al. v. Kirk Rodgers et al., a Stipulation of Settlement (Settlement) was reached. On September 13, 2006, the Settling Parties, including NRDC, Friant Water Users Authority, and the U.S. Departments of the Interior and Commerce, agreed on the terms and conditions of the Settlement, which was subsequently approved by the U.S. Eastern District Court of California on October 23, 2006.

The SJRRP is a comprehensive long-term effort to restore flows in the San Joaquin River from Friant Dam to the confluence of the Merced River, ensure irrigation supplies to Friant water users, and restore a self-sustaining fishery in the river. The SJRRP has two primary goals:

- Restoration Goal – To restore and maintain fish populations in "good condition" in the main stem San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.
- Water Management Goal – To reduce or avoid adverse water supply impacts on all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

Reclamation and other agencies are conducting environmental monitoring along the river between Friant Dam and the confluence with the Merced River at Hills Ferry. The two-mile portion of the river between Mud Slough and Hills Ferry conveys water from the GBP. GBP data are being used for baseline studies and future monitoring will be coordinated by both programs.

Water Quality Monitoring in the San Joaquin River at Hills Ferry

The Grassland Area Farmers collected water samples from the San Joaquin River above the Merced River at Hills Ferry each week. The concentration of selenium in weekly grab samples of water collected at this point ranged from 0.3 µg/L to 33 µg/L (**Table 8a**). The source of these high levels of selenium in the river has not been determined and was studied by Reclamation, the Regional Board, and the Grassland Area Farmers.

The monthly average concentration of boron ranged from 0.3 mg/L to 2.6 mg/L. The concentrations of salt and boron did not increase with the observed spikes in selenium.

Water samples were also collected each month at this site for the SJRRP.

PROJECT ORGANIZATION

The GBP involves the coordination and cooperation of the US Bureau of Reclamation (Reclamation), US Fish and Wildlife Service (USFWS), the US Geological Survey (USGS), the US Environmental Protection Agency (USEPA), the California Regional Water Quality Control Board - Central Valley Region (Regional Board), California Department of Fish and Game (CDFG), and the San Luis and Delta-Mendota Water Authority (Authority).

Oversight Committee

The Oversight Committee reviews progress and operation of the project including drainage reduction goals, progress in achieving water quality objectives, monitoring data, etc. It makes recommendations to the Draining Parties, Reclamation, and/or the Regional Board, as appropriate, regarding all aspects of the project, including modifications to project operation, appropriate mitigation, and termination of the Agreement if necessary. It carries out other functions required of it under this Agreement, which include determining the occurrence and extent of load exceedances, the Drainage Incentive Fees that are payable and actions or projects to be funded with Drainage Incentive Fees.

The Oversight Committee is comprised of senior level representatives from Reclamation, USEPA, USFWS, CDFG, and the Regional Board. Its role is to review process and assure performance of all operations of the Project as specified in the 2009 Use Agreement, including monitoring data, compliance with selenium load reduction goals, and other relevant information.

The Oversight Committee did not meet in 2010 or 2011.

Technical and Policy Review Team (TPRT)

The TPRT consists of representatives of the Reclamation, USEPA, USGS, USFWS, CDFG, and the Regional Board. The Team did not meet during 2010. The team met informally during 2011 to review a proposal to use the 2005 Drainage Incentive Fees for a source control project in Pacheco Water District.

Data Collection and Reporting Team (DCRT)

The DCRT is made up of representatives of agencies that collect the monitoring data: Reclamation, USEPA, USFWS, USGS, CDFG, the Regional Board, the Authority, and Block Environmental Services. The Team reviewed monthly and quarterly data reports. The DCRT completed the 2008-2009 report. The DCRT met in November of 2011.

Data Management

Each agency collecting data is responsible for its own internal data quality and data management procedures. Each agency submits its data to the San Francisco Estuary Institute for compilation of data and information from all sampling sites in a timely manner.

Reporting

The San Francisco Estuary Institute publishes monthly, quarterly and annual reports of data from the 14 monitoring stations depicted on **Figure 2**. The monthly reports present daily and weekly water quality data, including the calculated selenium load discharged at Site B, the terminus of the San Luis Drain. Quarterly data reports consist of all available data from all stations during a 3-month period.

All of the GBP data reports are available at the Institute's Website:

http://www.sfei.org/gbp/reports/

Annual reports are available on the SFEI website.

http://www.sfei.org/gbp/reports/Annual-Reports

Many other GBP documents are posted on the website of the Bureau of Reclamation, Mid-Pacific Region:

http://www.usbr.gov/mp/grassland/documents/index.html

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Tables

Table 1a. Grassland Bypass Project - Current Water Quality Monitoring Program - Stations, Parameters, and Sampling Frequencies (Through June 2011)

Table 1b. Grassland Bypass Project - Interim Water Quality Monitoring Program - Stations, Parameters, and Sampling Frequencies (After July 2011)

Table 2a. Monthly Rainfall on the Grasslands Watershed

Table 2b. Annual Rainfall on the Grasslands Watershed - Water Years 1997 – 2011

Table 2c. Annual Rainfall on the Grasslands Watershed - Calendar Years 1997 – 2011

Table 3a. Monthly Loads of Selenium Discharged from the San Luis Drain (Station B2)

Table 3b. Annual Loads of Selenium Discharged from the San Luis Drain (Station B/B2)

Table 3c. Annual Loads of Selenium Discharged from the San Luis Drain (Station B/B2)

into Mud Slough Compared to Load Values - Calendar Years 1997 – 2011

Table 4a. Monthly Loads of Salt Discharged from the Grassland Drainage Area Compared to Salinity Load

Table 4b. Annual Loads of Salt Discharged from the Grassland Drainage Area Compared to Salinity Load Values - Calendar Years 1997 – 2011

Table 4c. Annual Loads of Salt Discharged from the Grassland Drainage Area Compared to Salinity Load Values – Calendar Years 1997 – 2011

Table 5. Grassland Drainage Area - Water Years 1986 – 2011

Table 6. Grassland Watershed (Mud and Salt Sloughs) - Water Years 1986 – 2011

Table 7. San Joaquin River at Patterson and Crows Landing - Water Years 1986 - 2011

Table 8a. Water Quality in the San Joaquin River at Hills Ferry (Station H)

Table 8b. Summary Statistics, October 1995 - December 2011

Figures

Figure 1. Map of the Grassland Bypass Project

Figure 2. Grassland Bypass Project - Schematic Diagram Showing Locations of GBP Monitoring Sites Relative to Major Hydrologic Features of the Study Area

Figure 3a. Comparison of Rainfall and Flow from the Grassland Drainage Area 2010

Figure 3b. Comparison of Rainfall and Flow from the Grassland Drainage Area 2011

Figure 4. Annual Loads of Selenium Discharged from the Grassland Drainage Area

Figure 5. Selenium Discharged from the Grasslands Drainage Area

Figure 6. Salts Discharged from the Grasslands Drainage Area

Table 1a. Grassland Bypass Project - Current Water Quality Monitoring Program - Stations, Parameters, and Sampling Frequencies (Through June 2011)

	Station / Site / Location	Flow	pH	Electrical Conductivity	Temperature	Boron	Molybdenum	Nutrients	Selenium	Total Suspended Solids	Sampling Agency
San Luis Drain											
A	Grassland Bypass Channel	Da		Wc		Wc			Wc	Wg	GAF
B	Near Gun Club Road		Wg	Wg	Wg	Wg	Mg	Mg(1)	Wg		GAF
										Wg	GAF
				Dc		Dc			Dc		RB
B2	Terminus	C									GAF
	Mud Slough (north)										
C	upstream of SLD discharge	estimate	Wg	Wg	Wg	Wg	Mg	Mg(1)	Wg		RB
D	downstream of SLD discharge		Wg	Wg	Wg	Wg	Mg	Mg(1)	Wg		RB
		C		C	C						USGS
I2	backwater		Wg	Wg	Wg	Wg			Wg		MP157
Grasslands Wetland Water Supply Channels											
F	Salt Slough at Hwy 165		Wg	Wg	Wg	Wg			Wg		RB
		C		C	C						USGS
J	Camp 13 Ditch			Wg		Wg			Wg		GWD
K	Agatha Canal			Wg		Wg			Wg		GWD
L2	San Luis Canal			Wg		Wg			Wg		GWD
M2	Santa Fe Canal			Wg		Wg			Wg		GWD
San Joaquin River											
G	Fremont Ford		Wg	Wg	Wg	Wg	Mg	Mg(1)	Wg		RB
		C		C	C						USGS
H1	upstream of Newman WW			Wg		Wg			Wg		GAF
H	Hills Ferry (CDFG fish screen)			Wg		Wg			Wg		GAF
		C		C	C						USGS
N	Crows Landing		Wg	Wg	Wg	Wg	Mg	Mg(1)	Wg		RB
		C		C	C						USGS
				Dc		Dc			Dc		RB

Required for WDR 5-01-234

Sampling Frequency
C = Continuous
Dc = 24-hour composite
Mg = Monthly grab
Wc = Weekly composite
Wg = Weekly grab

Sampling Agency
GAF - Grassland Area Farmers
GWD = Grasslands Water District
MP-157 = Bureau of Reclamation Env. Monitoring Branch
RB = California Regional Water Quality Control Board
USGS = US Geological Survey

(1) Sampling frequency increases to twice monthly during irrigation season (March through August), and monthly September through February
Nutrients consist of Nitrate as N, Ammonia, TKN, total Phosphorous, and orthophosphate.

Table 1b. Grassland Bypass Project - Interim Water Quality Monitoring Program - Stations, Parameters, and Sampling Frequencies (After July 2011)

Station	Site / Location	Flow	pH	Electrical Conductivity	Temperature	Boron	Molybdenum	Nutrients	Selenium	Total Suspended Solids	Sampling Agency
San Luis Drain											
A	Grassland Bypass Channel	Da		Wc		Wc			Wc	Wg	GAF
B	Near Gun Club Road		Wg	Wg	Wg	Wg	Mg	Mg(1)	Wg		SCC
										Wg	GAF
				Dc		Dc			Dc		MP157
B2	Terminus	C									GAF
Mud Slough (north)											
C	upstream of SLD discharge	estimate	Wg	Wg	Wg	Wg	Mg	Mg(1)	Wg		SCC
D	downstream of SLD discharge		Wg	Wg	Wg	Wg	Mg	Mg(1)	Wg		SCC
		C		C	C						USGS
I2	backwater		Wg	Wg	Wg	Wg			Wg		SCC
Grasslands Wetland Water Supply Channels											
F	Salt Slough at Hwy 165		Wg	Wg	Wg	Wg			Wg		SCC
		C		C	C						USGS
J	Camp 13 Ditch			Wg		Wg			Wg		GWD
K	Agatha Canal			Wg		Wg			Wg		GWD
L2	San Luis Canal			Wg		Wg			Wg		GWD
M2	Santa Fe Canal			Wg		Wg			Wg		GWD
San Joaquin River											
G	Fremont Ford		Wg	Wg	Wg	Wg	Mg	Mg(1)	Wg		SCC
		C		C	C						USGS
H1	upstream of Newman WW			Wg		Wg			Wg		GAF
H	Hills Ferry (CDFG fish screen)			Wg		Wg			Wg		GAF
		C		C	C						USGS
N	Crows Landing		Wg	Wg	Wg	Wg	Mg	Mg(1)	Wg		SCC
		C		C	C						USGS
				Dc		Dc			Dc		MP157

Required for WDR 5-01-234

Sampling Frequency: C = Continuous; Dc = 24-hour composite; Mg = Monthly grab; Wc = Weekly composite; Wg = Weekly grab

Sampling Agency: GAF - Grassland Area Farmers; GWD = Grasslands Water District; MP-157 = Bureau of Reclamation Env. Monitoring Branch; SCC = Bureau of Reclamation South-Central California Area Office; USGS = US Geological Survey

(1) Sampling frequency increases to twice monthly during irrigation season (March through August), and monthly September through February

Nutrients consist of Nitrate as N, Ammonia, TKN, total Phosphorous, and orthophosphate.

Table 2a. Monthly Rainfall on the Grasslands Watershed

	Firebaugh Telles CIMIS 007 (1) inches	Los Banos CIMIS 056 (1) inches	Panoche CIMIS 124 (1) inches	Panoche WD (2) inches	Los Banos NOAA (3) inches
Jan 2010	1.91	1.57	1.15	2.04	2.62
Feb 2010	1.89	0.24	2.02	1.99	2.06
Mar 2010	0.60	0.16	0.54	0.51	0.62
Apr 2010	1.79	2.04	1.44	1.39	2.59
May 2010	0.13	0.10	0.30	0.00	0.18
Jun 2010	0.05	0.02	0.00	0.00	0.04
Jul 2010	0.00	0.00	0.00	0.00	0.00
Aug 2010	0.00	0.00	0.00	0.00	0.00
Sep 2010	0.00	0.00	0.00	0.00	0.00
Oct 2010	0.33	0.11	0.34	0.32	0.54
Nov 2010	1.35	1.39	1.19	1.19	1.55
Dec 2010	2.10	2.51	1.98	2.02	3.92
Jan 2011	0.83	1.38	0.99	0.86	0.38
Feb 2011	1.44	1.47	1.54	1.52	1.53
Mar 2011	2.03	2.12	1.85	1.85	2.32
Apr 2011	0.25	0.19	0.11	0.11	0.09
May 2011	0.01	0.80	0.47	0.47	0.34
Jun 2011	0.80	0.65	0.63	0.63	0.70
Jul 2011	0.00	0.00	0.00	0.00	0.00
Aug 2011	0.00	0.00	0.00	0.00	0.00
Sep 2011	0.00	0.00	0.00	0.00	0.00
Oct 2011	0.43	1.31	0.54	0.16	0.64
Nov 2011	0.75	0.83	0.97	0.86	0.26
Dec 2011	0.08	0.09	0.12	0.07	0.12

Table 2b. Annual Rainfall on the Grasslands Watershed - Water Years 1997 – 2011

Water Year	Firebaugh Telles CIMIS 007 (1) inches	Los Banos CIMIS 056 (1) inches	Panoche CIMIS 124 (1) inches	Panoche WD (2) inches	Los Banos NWS (3) inches
WY 1997	8.27	11.68	11.23	8.31	12.06
WY 1998	15.83	21.30	16.53	16.07	23.97
WY 1999	6.06	12.54	5.11	4.33	7.03
WY 2000	4.61	7.87	4.46	6.42	8.52
WY 2001	7.55	7.78	6.75	5.25	8.88
WY 2002	5.70	7.24	4.50	4.87	5.88
WY 2003	8.23	8.26	6.33	6.57	8.44
WY 2004	5.85	7.38	3.94	5.62	8.52
WY 2005	12.98	14.32	10.36	13.13	15.54
WY 2006	11.23	7.80	9.35	9.74	10.60
WY 2007	3.57	4.47	3.92	3.76	4.48
WY 2008	4.71	5.57	3.83	3.85	6.22
WY 2009	2.63	6.02	4.08	4.11	5.96
WY 2010	7.88	6.87	5.65	7.96	11.42
WY 2011	9.14	10.62	9.10	8.97	11.37

Table 2c. Annual Rainfall on the Grasslands Watershed - Calendar Years 1997 – 2011

Calendar Year	Firebaugh Telles CIMIS 007 (1) inches	Los Banos CIMIS 056 (1) inches	Panoche CIMIS 124 (1) inches	Panoche WD (2) inches	Los Banos NWS (3) inches
1997	8.43	10.79	11.58	7.01	10.23
1998	13.06	18.86	12.79	14.04	21.08
1999	4.77	11.03	4.01	3.60	5.77
2000	5.83	8.71	6.62	7.78	10.69
2001	9.36	10.21	7.38	6.62	9.59
2002	6.13	7.57	4.33	4.62	6.85
2003	6.35	6.70	5.23	5.72	7.67
2004	9.25	10.10	5.69	9.25	11.44
2005	9.71	10.29	8.63	9.32	11.12
2006	10.67	7.44	9.78	9.74	9.47
2007	3.61	5.07	3.07	3.13	5.31
2008	3.99	5.08	3.77	3.62	5.89
2009	3.67	7.38	3.22	5.17	7.53
2010	10.15	8.14	8.96	9.46	14.12
2011	6.62	8.84	7.22	6.53	6.38

Data sources: For Tables 2a-c
(1) CIMIS - California Department of Water Resources, California Irrigation Management Information System
http://wwwcimis.water.ca.gov/cimis/data.jsp
(2) Panoche Water District
(3) NOAA, Western Regional Climate Center, revised 12 Jan 2012
http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca5118

Table 3a. Monthly Loads of Selenium Discharged from the San Luis Drain (Station B2)

	Monthly Selenium Load Value (1) pounds	Monthly Selenium Discharge (2) pounds	Exceedance of Monthly Load Value pounds	Exceedance of Monthly Load Value percent	Incentive credit (3)
Jan 2010	398	192			206
Feb 2010	472	160			312
Mar 2010	472	251			221
Apr 2010	490	87			403
May 2010	497	242			255
Jun 2010	212	137			75
Jul 2010	214	91			123
Aug 2010	225	94			131
Sep 2010	264	43			221
Oct 2010	260	17			243
Nov 2010	260	65			195
Dec 2010	398	176			222
Jan 2011	211	160			51
Feb 2011	488	278			210
Mar 2011	488	379			109
Apr 2011	506	270			236
May 2011	512	235			277
Jun 2011	354	220			134
Jul 2011	356	123			233
Aug 2011	366	96			270
Sep 2011	332	50			282
Oct 2011	328	44			284
Nov 2011	328	49			279
Dec 2011	211	93			118

Table 3b. Annual Loads of Selenium Discharged from the San Luis Drain (Station B/B2)

Water Year	Annual Selenium Load Value	Annual Selenium Discharge	Annual Difference	
	pounds	pounds	pounds	percent
WY 1997	7,096	6,960	-136	-2%
WY 1998	7,096	8,768	1,672	24%
WY 1999	6,813	5,124	-1,689	-25%
WY 2000	6,528	4,603	-1,925	-29%
WY 2001	6,246	4,377	-1,869	-30%
WY 2002	5,360	3,939	-1,421	-27%
WY 2003	5,027	4,029	-998	-20%
WY 2004	4,696	3,871	-825	-18%
WY 2005	4,585	4,284	-301	-7%
WY 2006	4,148	3,405	-743	-18%
WY 2007	3,625	2,549	-1,076	-30%
WY 2008	3,301	1,740	-1,561	-47%
WY 2009	3,169	1,241	-1,928	-61%
WY 2010	4,093	1,578	-2,515	-61%
WY 2011	4,531	2,068	-2,463	-54%

Table 3c. Annual Loads of Selenium Discharged from the San Luis Drain (Station B/B2) into Mud Slough Compared to Load Values - Calendar Years 1997 – 2011

Calendar Year	Annual Selenium Load Value	Annual Selenium Discharge	Annual Difference		Cumulative Incentive Credits (4)
	pounds	pounds	pounds	percent	pounds
1997	7,096	6,854	-242	-3%	
1998	7,096	8,877	1,781	25%	
1999	6,813	4,992	-1,821	-27%	
2000	6,528	4,507	-2,021	-31%	
2001	6,144	4,299	-1,845	-30%	1,845
2002	5,327	4,176	-1,151	-22%	2,996
2003	4,995	4,007	-988	-20%	3,984
2004	4,664	3,672	-992	-21%	4,976
2005	4,566	4,286	-280	-6%	
2006	4,480	3,718	-762	-17%	5,738
2007	3,545	2,275	-1,270	-36%	7,008
2008	3,236	1,686	-1,550	-48%	8,558
2009	3,296	1,241	-2,055	-62%	10,613
2010	4,162	1,555	-2,607	-63%	13,220
2011	4,480	1,997	-2,483	-55%	15,703

Notes for Tables 3a-c

(1) 2001 Use Agreement, Appendix C
(2) Attributable Selenium Discharge: San Francisco Estuary Institute
(3) 2009 Use Agreement, Appendix I
(4) 2009 Use Agreement, Appendix J
(5) Actual Selenium Discharge is less than 5 percent over the Load Value
(6) includes 14 pounds of selenium in flood water discharged to the Agatha Canal
(7) Grassland Area Farmers estimate

Table 4a. Monthly Loads of Salt Discharged from the Grassland Drainage Area Compared to Salinity Load

	Monthly Salinity Load Values (1)	Actual Monthly Discharge (2)	Exceedance of Monthly Salinity Load Value		Incentive credit (3)
	tons	tons	tons	percent	
Jan 2010	10,526	4,650			5,876
Feb 2010	18,455	5,440			13,015
Mar 2010	21,352	6,900			14,452
Apr 2010	17,653	4,560			13,093
May 2010	17,659	7,440			10,219
Jun 2010	18,191	5,510			12,681
Jul 2010	19,283	5,380			13,903
Aug 2010	16,225	5,540			10,685
Sep 2010	9,006	3,310			5,696
Oct 2010	5,665	1,630			4,035
Nov 2010	6,205	6,300	95	2%	
Dec 2010	7,626	7,010			
Jan 2011	12,396	6,800			5,501
Feb 2011	19,618	10,050			9,568
Mar 2011	23,241	13,440			9,801
Apr 2011	17,104	10,160			6,944
May 2011	16,762	8,450			8,312
Jun 2011	17,339	7,830			9,509
Jul 2011	17,521	5,540			11,981
Aug 2011	15,549	5,450			10,099
Sep 2011	8,214	3,790			4,424
Oct 2011	6,308	3,640			2,668
Nov 2011	6,555	3,330			3,225
Dec 2011	7,240	5,120			2,120

Table 4b. Annual Loads of Salt Discharged from the Grassland Drainage Area Compared to Salinity Load Values - Calendar Years 1997 - 2011

Calendar Year	Annual Salinity Load Value	Annual Salinity Discharge	Annual Difference	
	tons	tons	tons	percent
WY 1997		176,750		
WY 1998		211,340		
WY 1999		143,910		
WY 2000		135,250		
WY 2001		125,080		
WY 2002	190,300	111,220	-79,080	-42%
WY 2003	181,890	113,600	-68,290	-38%
WY 2004	172,376	110,700	-61,676	-36%
WY 2005	168,245	126,990	-41,255	-25%
WY 2006	167,846	111,070	-56,776	-34%
WY 2007	155,977	77,120	-78,857	-51%
WY 2008	148,464	55,280	-93,184	-63%
WY 2009	134,350	47,840	-86,510	-64%
WY 2010	163,752	59,290	-104,462	-64%
WY 2011	167,240	86,450	-80,790	-48%

Table 4c. Annual Loads of Salt Discharged from the Grassland Drainage Area Compared to Salinity Load Values - Calendar Years 1997 – 2011

Calendar Year	Annual Salinity Load Value tons	Annual Salinity Discharge tons	Annual Difference tons	Annual Difference percent	Cumulative Incentive credit
1997		174,300			
1998		214,730			
1999		138,660			
2000		133,330			
2001		121,440			
2002	190,300	115,040	-75,260	-40%	75,260
2003	180,785	114,260	-66,525	-37%	141,785
2004	171,271	111,900	-59,371	-35%	201,156
2005	167,846	123,650	-44,196	-26%	245,352
2006	167,846	113,220	-54,626	-33%	299,978
2007	289,929	119,990	-169,939	-59%	469,917
2008	133,841	48,170	-85,671	-64%	555,588
2009	164,941	58,230	-106,711	-65%	662,300
2010	167,883	88,460	-79,423	-47%	741,723
2011	167,847	83,600	-84,247	-50%	825,970

Notes:
(1) Appendix E of the 2009 Use Agreement
(2) Monthly Loads calculated from flow and salinity data reported by the San Luis and Delta-Mendota Water Authority for Station A.
(3) Appendix I of the 2009 Use Agreement

Table 5. Grassland Drainage Area - Water Years 1986 – 2011

Water Year (1)	Flow	Flow Weighted Loads			Flow Weighted Concentration				
		Selenium	Boron	TDS	Selenium	Boron	EC	TDS	
	acre-feet	pounds	1000 pounds	tons	µg/L	mg/L	µS/cm	mg/L	Reference
WY 1986	67,006	9,524	787	214,250	52.3	4.3		2,351	(2)
WY 1987	74,902	10,959	889	241,526	53.8	4.4		2,371	(2)
WY 1988	65,327	10,097	821	236,301	56.8	4.6		2,660	(2)
WY 1989	54,186	8,718	743	202,420	59.2	5.0		2,747	(2)
WY 1990	41,662	7,393	672	171,265	65.2	5.9		3,023	(2)
WY 1991	29,290	5,858	544	129,899	73.5	6.8		3,261	(2)
WY 1992	24,533	5,083	435	110,327	76.2	6.5		3,307	(2)
WY 1993	41,197	8,856	730	183,021	79.0	6.5		3,267	(2)
WY 1994	38,670	8,468	645	171,495	80.5	6.1		3,261	(2)
WY 1995	57,574	11,875	868	237,530	75.8	5.6		3,034	(2)
WY 1996	52,978	10,034	723	197,526	69.6	5.0		2,742	(3)
Pre-Project Averages	49,760	8,806	714	190,510	67.4	5.5		2,910	
WY 1997	37,800	7,418	772	176,750	67.5	7.3	4,480	3,315	(4)
WY 1998	43,570	8,436	868	211,340	70.6	7.7	4,838	3,580	(4)
WY 1999	30,510	5,178	620	143,910	65.3	7.7	4,820	3,567	(4)
WY 2000	29,330	4,685	583	135,250	61.3	7.4	4,614	3,414	(4)
WY 2001	27,050	4,509	538	125,080	62.8	7.4	4,605	3,408	(4)
WY 2002	25,820	3,815	509	111,220	58.3	7.4	4,397	3,254	(4)
WY 2003	25,250	3,865	543	113,600	61.6	8.1	4,552	3,368	(4)
WY 2004	25,370	3,813	513	110,700	60.9	7.6	4,445	3,290	(4)
WY 2005	27,540	3,701	613	126,990	49.0	8.2	4,584	3,392	(4)
WY 2006	23,080	3,612	508	111,070	58.2	8.1	4,782	3,538	(4)
WY 2007	16,480	2,581	309	77,120	57.3	7.0	4,660	3,449	(4)
WY 2008	13,230	1,743	281	55,280	46.6	7.7	4,151	3,072	(4)
WY 2009	12,340	1,350	244	47,840	38.3	7.1	3,826	2,832	(4)
WY 2010	13,640	1,686	326	59,290	43.7	8.8	4,335	3,208	(4)
WY 2011	16,540	2,140	458	86,450	44.4	10.2	5,211	3,856	(4)
Project Averages	24,500	3,902	512	112,790	56.4	7.8	4,553	3,370	

References:

(1) Water Year: October - September

(2) CVRWQCB, February 1998. Loads of Salt, Boron, and Selenium in the Grassland Watershed and Lower San Joaquin River, October 1985 to September 1995; Volume I: Load Calculations. Table 16.

(3) CVRWQCB, December 1998. Agricultural Drainage Contribution to Water Quality in the Grassland Watershed of Western Merced County, California: October 1995 - September 1997 (Water Years 1996 and 1997). Table 20

(4) Concentrations and loads calculated from data for GBP Site A

Table 6. Grassland Watershed (Mud and Salt Sloughs) - Water Years 1986 – 2011

Water Year (1)	Flow	Flow Weighted Loads			Flow Weighted Concentration				
		Selenium	Boron	TDS	Selenium	Boron	EC	TDS	
	acre-feet	pounds	1000 pounds	tons	µg/L	mg/L	µS/cm	mg/L	Reference
WY 1986	284,316	6,643	1,368	494,544	8.6	1.8		1,279	(2)
WY 1987	233,843	7,641	1,265	438,904	12.0	2.0		1,380	(2)
WY 1988	230,454	8,132	1,301	455,959	13.0	2.1		1,455	(2)
WY 1989	211,393	8,099	1,139	389,325	14.1	2.0		1,354	(2)
WY 1990	194,656	7,719	1,121	380,564	14.6	2.1		1,438	(2)
WY 1991	102,162	3,899	912	221,542	14.0	2.2		1,595	(2)
WY 1992	85,428	2,919	522	197,352	12.6	2.3		1,699	(2)
WY 1993	167,955	6,871	1,066	336,522	15.0	2.3		1,473	(2)
WY 1994	183,546	7,980	1,116	379,408	16.0	2.2		1,520	(2)
WY 1995	263,769	10,694	1,459	499,339	14.9	2.0		1,392	(2)
WY 1996	267,948	9,491	1,299	477,725	13.0	1.8		1,311	(3)
Pre-Project averages	202,320	7,281	1,143	388,290	13.4	2.1		1,450	
WY 1997	287,010	7,428	1,391	446,690	12.4	2.2	1,794	1,231	(4)
WY 1998	378,670	8,648	1,871	627,420	10.6	2.2	1,972	1,350	(4)
WY 1999	253,130	5,668	1,214	401,340	9.2	1.9	1,749	1,198	(4)
WY 2000	235,490	3,952	1,122	372,340	7.5	2.0	1,788	1,223	(4)
WY 2001	226,750	4,902	1,086	382,900	9.7	1.9	1,912	1,311	(4)
WY 2002	180,160	3,913	952	327,460	9.7	2.1	2,015	1,381	(4)
WY 2003	216,140	4,020	2,315	374,000	8.1	3.8	1,887	1,294	(4)
WY 2004	210,520	3,928	1,011	350,600	8.2	2.0	1,879	1,290	(4)
WY 2005	265,880	4,847	1,341	436,320	7.4	2.0	1,794	1,230	(4)
WY 2006	284,900	3,864	1,667	435,330	5.5	2.0	1,631	1,120	(4)
WY 2007	183,500	2,509	676	276,370	6.6	1.6	1,771	1,210	(4)
WY 2008	152,560	1,810	663	262,960	5.9	1.9	1,968	1,350	(4)
WY 2009	117,410	1,341	532	217,630	4.8	1.9	2,096	1,438	(4)
WY 2010	168,830	1,804	748	111,350	5.0	1.8	2,045	1,400	(4)
WY 2011	174,360	2,374	1,007	289,990	4.1	1.7	1,678	1,149	(4)
Project Averages	222,350	4,067	1,173	354,180	7.6	2.1	1,865	1,278	

References:

(1) Water Year - October - September

(2) CVRWQCB, February 1998. Loads of Salt, Boron, and Selenium in the Grassland Watershed and Lower San Joaquin River, October 1985 to September 1995; Volume I: Load Calculations. Table 17.

(3) CVRWQCB, December 1998. Agricultural Drainage Contribution to Water Quality in the Grassland Watershed of Western Merced County, California: October 1995 - September 1997 (Water Years 1996 and 1997) Table 21.

(4) Loads and concentrations calculated from data for GBP Sites D and F (Mud Slough and Salt Slough, including GBP discharge)

Table 7. San Joaquin River at Patterson and Crows Landing - Water Years 1986 - 2011

Water Year (1)	Flow Weighted Loads				Flow Weighted Concentration				
	Flow	Selenium	Boron	TDS	Selenium	Boron	EC	TDS	
	acre-feet	pounds	1000 pounds	tons	µg/L	mg/L	µS/cm	mg/L	Reference
WY 1986	2,676,764	10,568	2,563	991,086	1.5	0.4		272	(2)
WY 1987	662,135	8,857	1,681	715,301	4.9	0.9		794	(2)
WY 1988	549,412	9,330	1,854	731,877	6.2	1.2		980	(2)
WY 1989	438,398	7,473	1,305	543,916	6.3	1.1		912	(2)
WY 1990	404,163	6,125	1,142	537,896	5.6	1.0		979	(2)
WY 1991	291,223	3,548	760	419,457	4.5	1.0		1,059	(2)
WY 1992	304,151	3,064	740	391,336	3.7	0.9		946	(2)
WY 1993	891,230	8,209	1,588	686,212	3.4	0.7		566	(2)
WY 1994	562,301	7,270	1,260	584,834	4.8	0.8		765	(2)
WY 1995	3,504,034	14,291	2,296	1,236,981	1.6	0.2		260	(2)
WY 1996	1,445,730	10,686	1,765	805,600	2.7	0.5		410	(3)
Pre-Project Averages	1,066,320	8,129	1,541	694,950	4.1	0.8		720	
WY 1997	3,782,320	12,329	2,706	928,880	3.2	0.6	820	508	(4)
WY 1998	4,904,910	15,821	3,072	1,511,480	1.4	0.4	601	373	(4)
WY 1999	1,015,480	6,708	1,591	680,120	2.7	0.7	902	559	(4)
WY 2000	1,027,440	6,353	1,630	703,910	2.5	0.7	976	605	(4)
WY 2001	653,430	5,595	1,396	623,560	3.2	0.8	1,162	720	(4)
WY 2002	533,960	4,056	1,227	517,360	3.1	0.9	1,202	745	(4)
WY 2003	546,130	4,149	4,666	576,340	2.9	3.0	1,244	771	(4)
WY 2004	554,550	4,078	1,341	564,500	2.8	0.9	1,226	760	(4)
WY 2005	1,721,000	5,297	1,895	881,460	1.3	0.5	722	448	(4)
WY 2006	3,437,650	5,652	1,862	947,330	1.0	0.4	569	353	(4)
WY 2007	607,180	2,997	1,064	538,700	1.8	0.7	1,103	684	(4)
WY 2008	580,500	2,233	1,036	493,120	1.4	0.7	766	475	(4)
WY 2009	336,670	1,526	742	361,510	1.6	0.8	1,165	722	(4)
WY 2010	822,650	2,280	1,138	108,042	1.2	0.6	938	582	(4)
WY 2011	2,936,190	4,102	1,513	702,004	0.5	0.3	467	290	(4)
Project Averages	1,564,000	5,545	1,792	675,890	2.0	0.8	924	573	

References:

(1) Water Year - October - September

(2) CVRWQCB, February 1998. Loads of Salt, Boron, and Selenium in the Grassland Watershed and Lower San Joaquin River, October 1985 to September 1995; Volume I: Load Calculations. Table 18.

(3) CVRWQCB, December 1998. Water Quality of the Lower San Joaquin River: Lander Avenue to Vernalis, October 1995 - September 1997 (Water Years 1996 and 1997) Table 12.

(4) Concentrations and loads calculated from data for GBP Site N (SJR at Crows Landing)

Table 8a. Water Quality in the San Joaquin River at Hills Ferry (Station H)

	Flow acre-feet	Specific Conductance µmhos/cm		Selenium µg/L		Boron mg/L	
Jan 2010	NA	1,999		33.0		2.6	
Feb 2010	NA	2,007	1,407	0.3		1.4	
Mar 2010	67,330	1,333	1,255	1.2		1.2	
Apr 2010	65,850	1,007	984	1.2	<0.8	0.5	0.6
May 2010	52,630	1,051	1,019	1.6		1.1	
Jun 2010	42,240	1,028	1,014	1.7	1.8	0.7	0.5
Jul 2010	20,290	1,464	1,347	1.9	1.4	0.9	0.7
Aug 2010	15,190	1,388	1,272	1.7	2.3	0.9	0.8
Sep 2010	21,210	979	993	1.1	2.0	0.7	0.7
Oct 2010	25,460	1,102	1,122	0.6		0.7	
Nov 2010	28,220	1,417	1,428	0.7		0.9	
Dec 2010	62,350	957	1,280	2.3	2.3	1.1	1.0
Jan 2011	142,990	549	488	0.7		0.3	
Feb 2011	92,370	855	988	1.0	1.8	0.5	0.7
Mar 2011	124,290	842	836	1.5	0.5	0.6	0.2
Apr 2011	148,760	496	446	0.9	0.5	0.4	0.4
May 2011	150,290	349	343	0.6	0.5	0.3	0.1
Jun 2011	119,170	408	377	1.0	1.4	0.3	0.4
Jul 2011	104,410	552	333	0.7	<0.4	0.3	0.1
Aug 2011	29,570	968	837	1.4	1.5	0.6	0.7
Sep 2011	22,800	918	1,441	1.0	1.5	0.6	0.8
Oct 2011	35,180	876	895	0.8	0.8	0.6	0.5
Nov 2011	26,790	1,044	1,128	0.7		0.6	
Dec 2011	21,800	1,811	2,012	1.3		1.1	
Data Source:	(3)	(2)	(3)	(2)	(1)	(2)	(1)

(1) San Joaquin River Restoration Program data (monthly grab)
(2) San Luis and Delta-Mendota Water Authority data (weekly grab)
(3) US Geological Survey preliminary data (continuous measurement)

Table 8b. Summary Statistics, October 1995 - December 2011

	Specific Conductance µmhos/cm	Selenium µg/L	Boron mg/L
Maximum	3,700	41	5.3
Minimum	128	<0.4	0.1
Median	1,605	3	1.2
Average	1,548	5	1.2
Standard deviation	637	5	0.6
Number of Samples	396	425	479

Figure 1. Map of the Grassland Bypass Project

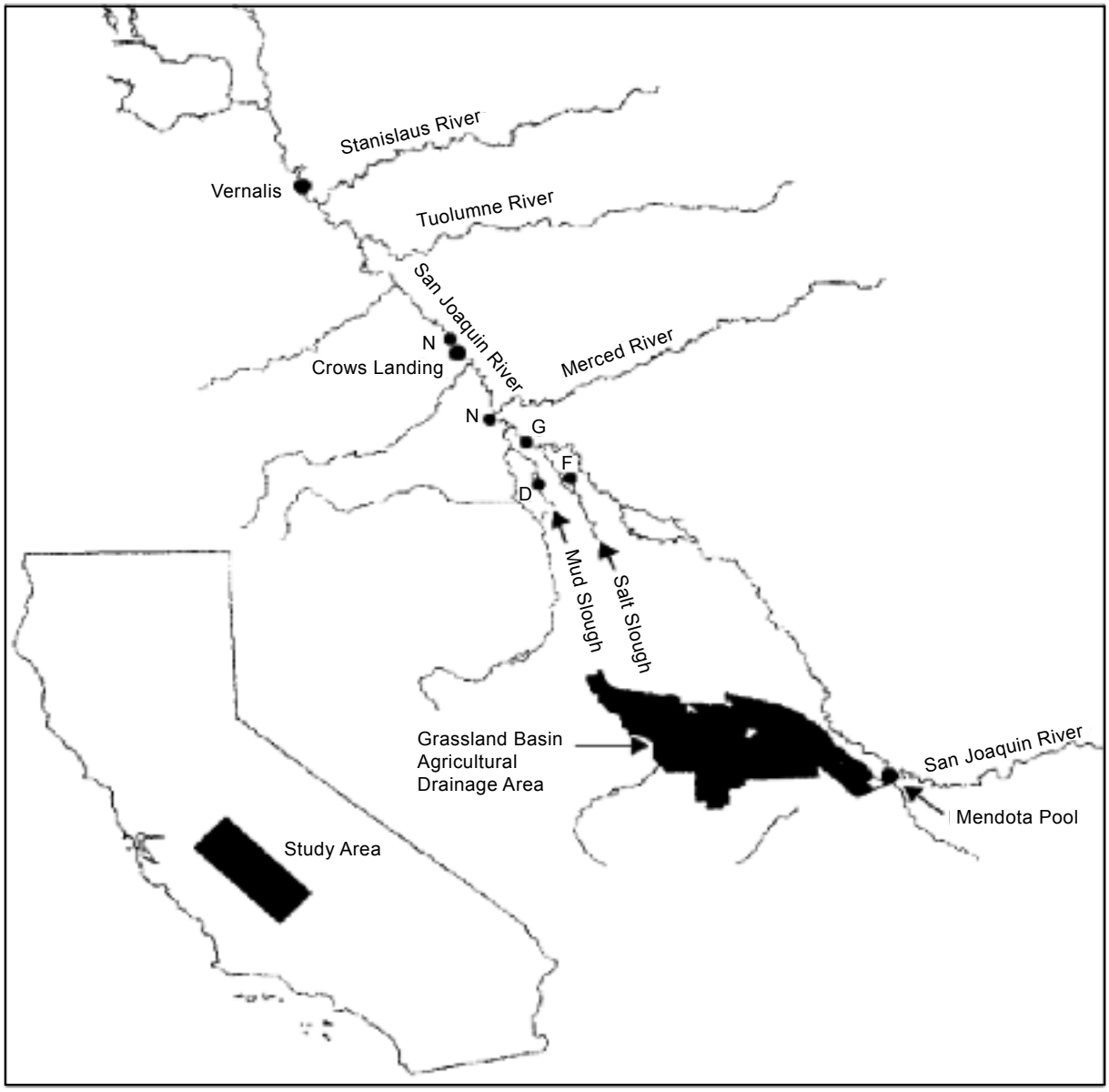


Figure 2. Grassland Bypass Project - Schematic Diagram Showing Locations of GBP Monitoring Sites Relative to Major Hydrologic Features of the Study Area

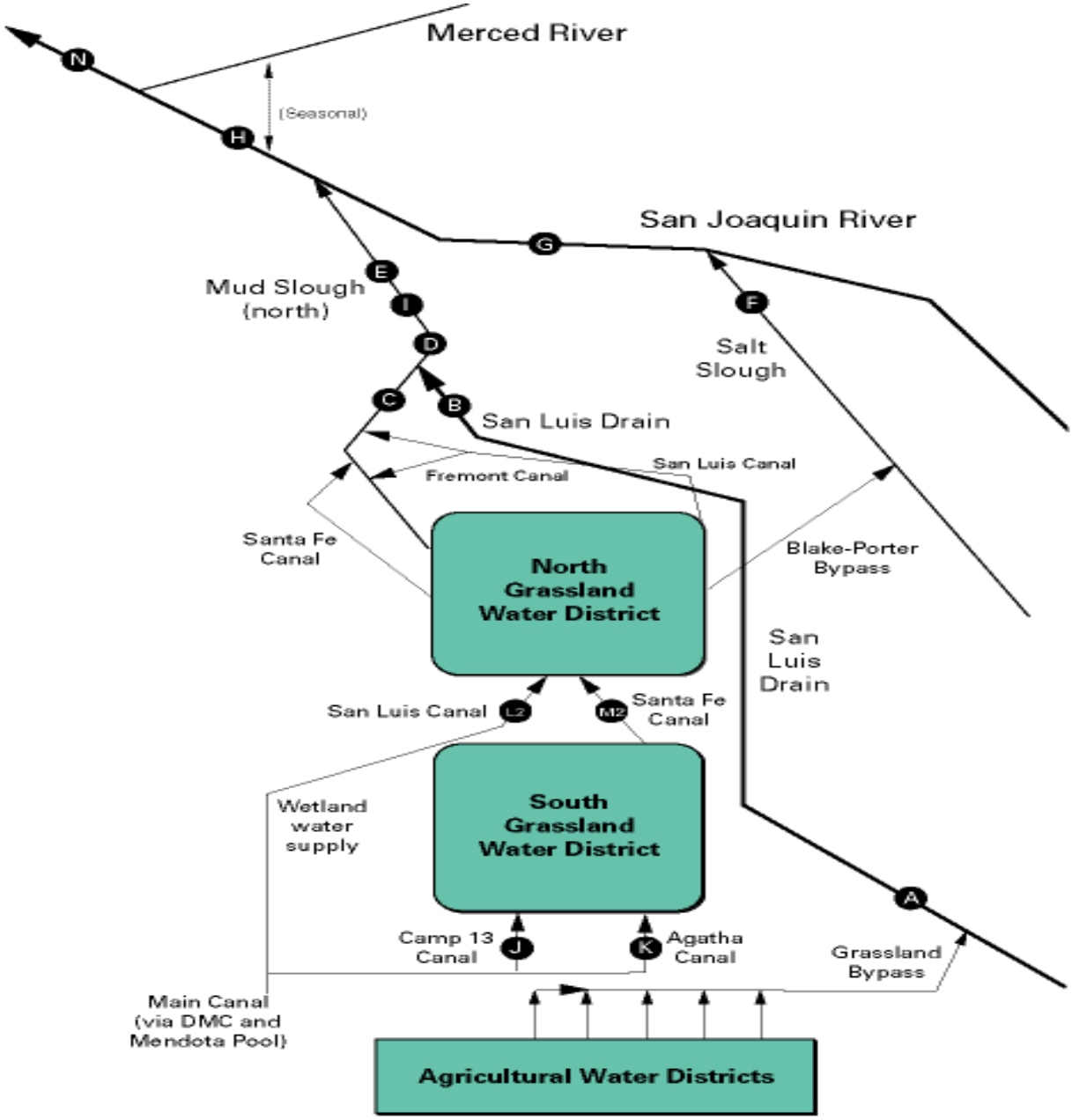


Figure 3. Comparison of Rainfall and Flow from the Grassland Drainage Area 2010 – 2011

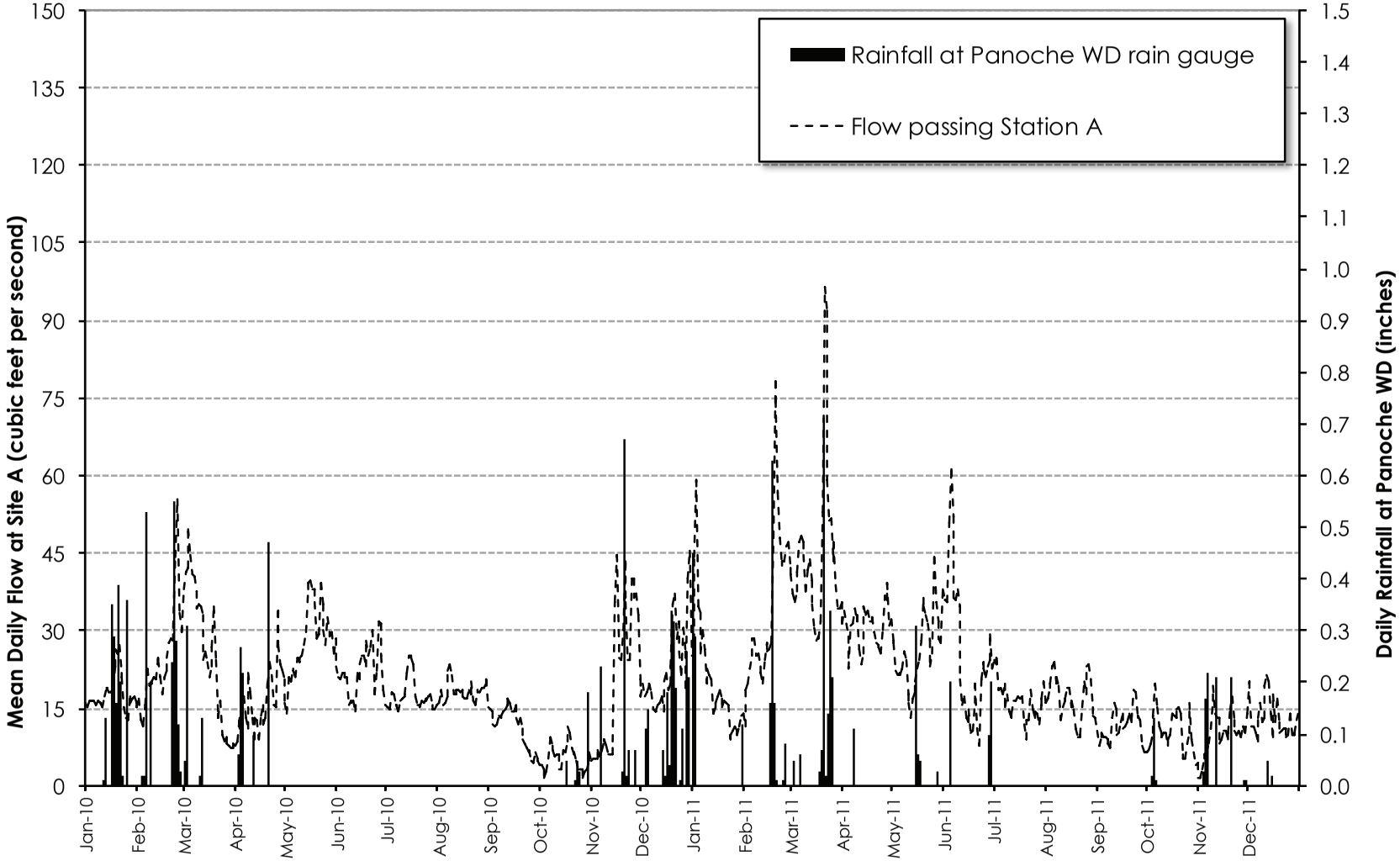


Figure 4. Grassland Bypass Project Annual Loads of Selenium Discharged from the Grassland Drainage Area

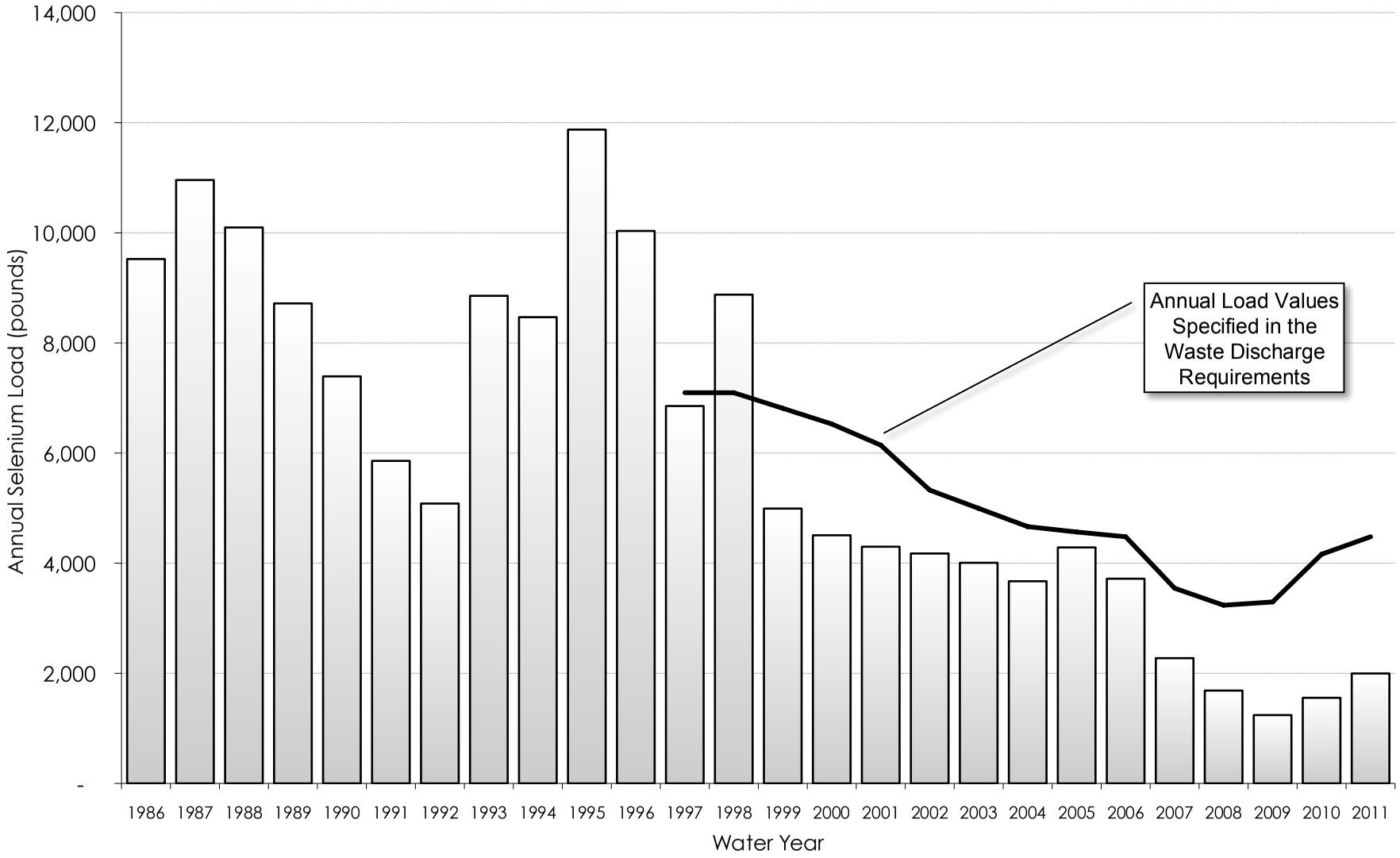


Figure 5. Selenium Discharged from the Grasslands Drainage Area (pounds)

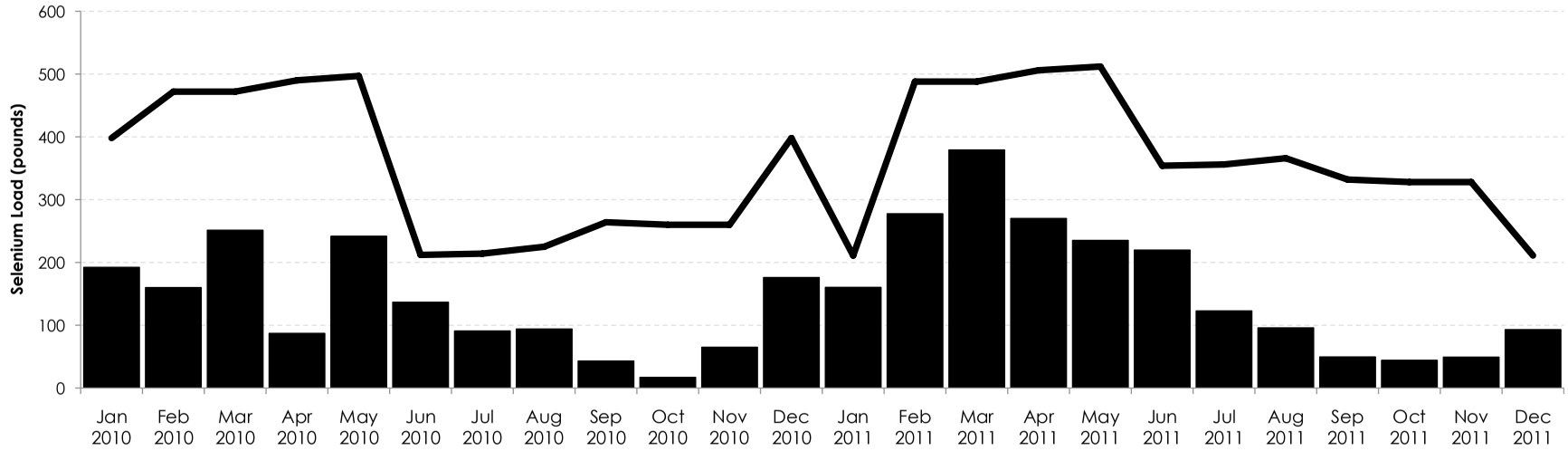
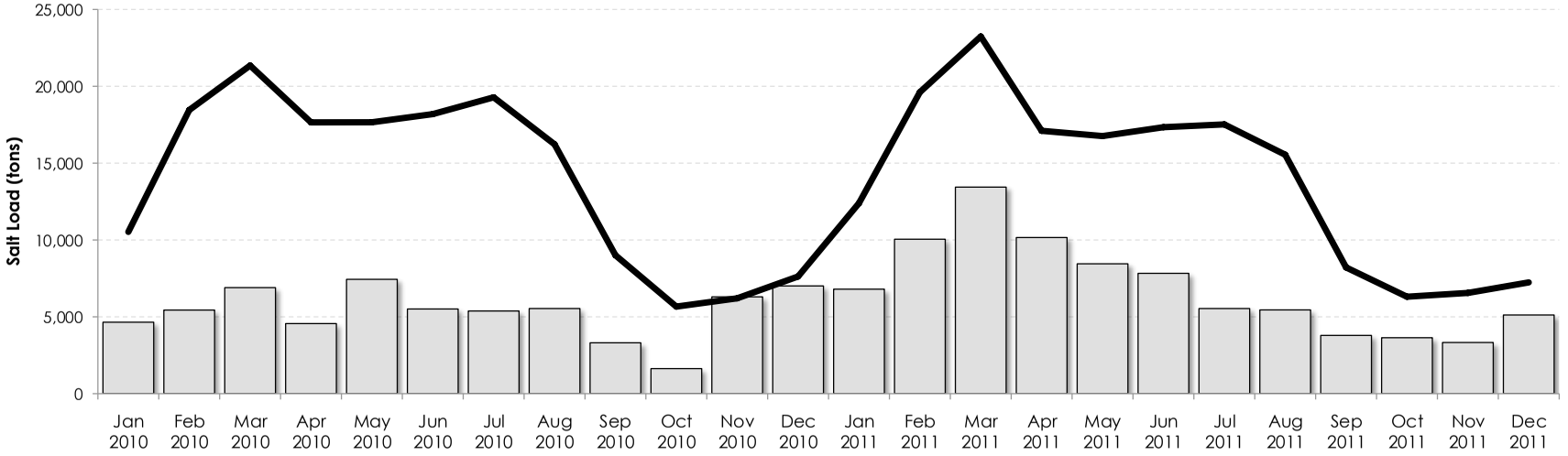
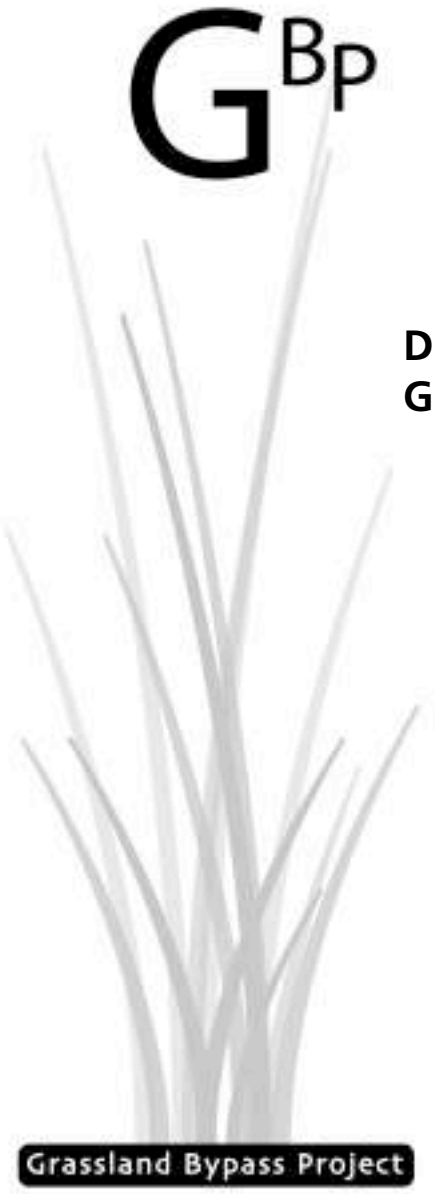


Figure 6. Salt Discharged from the Grasslands Drainage Area (tons)





CHAPTER 2

Drainage Control Activities by the Grassland Area Farmers

January 1, 2010 – December 31, 2011

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The Grassland Area Farmers formed a regional drainage entity in March 1996 under the umbrella of the San Luis and Delta-Mendota Water Authority to implement the Grassland Bypass Project. The Project consolidates subsurface drainage flows on a regional basis and utilizes a portion of the federal San Luis Drain to convey the flows around the habitat areas (see **Figure 1**). Participants include the Broadview Water District, Charleston Drainage District, Firebaugh Canal Water District, Pacheco Water District, Panoche Drainage District, Widren Water District and the Camp 13 Drainage District (located in part of Central California Irrigation District). This entity includes approximately 97,000 gross acres of irrigated farmland on the westside of the San Joaquin Valley, referred to as the Grassland Drainage Area. The area is highly productive, producing an estimated $230 Million annually in agricultural crop market value, with an additional estimated $250 Million generated for the local and regional economies, for a total estimated economic value of $480 Million.

The Grassland Area Farmers have implemented several activities aimed at reducing discharge of subsurface drainage waters to the San Joaquin River. These activities have included the Grassland Bypass Project and the San Joaquin River Improvement Project (SJRIP). They also include: formation of a regional drainage entity, newsletters and other communication with the farmers, a monitoring program, using State Revolving Fund loans for improved irrigation systems, utilizing and installing drainage recycling systems to mix subsurface drainage water with irrigation supplies under strict limits, tiered water pricing and a tradable loads programs.

GRASSLAND BYPASS PROJECT

The Grassland Bypass Project is an innovative program that was designed to improve water quality in the channels used to deliver water to wetland areas. Prior to the Project, subsurface drainage water was conveyed through those channels enroute to the San Joaquin River which limited their availability to deliver high-quality habitat supplies. The Project consolidates subsurface drainage flows on a regional basis and utilizes a portion of the federal San Luis Drain to convey the flows around the habitat areas.

Negotiations between the San Luis & Delta-Mendota Water Authority and the U S Bureau of Reclamation to utilize a portion of the San Luis Drain for the Project commenced in 1988. Stakeholders included in the process were: U.S. Environmental Protection Agency, U.S. Fish & Wildlife Service, California Department of Fish and Game, the Central Valley Regional Water Quality Control Board, Contra Costa County and Contra Costa Water District. In late 1995, environmental documentation for the first five years was completed and the Use Agreement was signed. Discharge through the project began in September 1996. In September 2001, the Use Agreement was extended for another 8 years and 3 months (through December 2009). An Environmental Impact Report/Environmental Impact Statement was completed and on September 7, 2001 the Central Valley Regional Water Quality Control Board issued new Waste Discharge Requirements. Other items completed to support the continued use were a Biological Assessment/Biological Opinion, a selenium Total Maximum Monthly Load (TMML) report submitted by the Regional Board to EPA and a continued monitoring program. The new 2001 Use Agreement contains continued reductions in selenium discharge until ultimately TMML limits are achieved in 2005 for above normal and wet years and continued progress is made to meet water quality

objectives in 2010 for below normal, dry and critical years. The new Use Agreement also includes salinity reductions.

In 2007 negotiations renewed to extend the Use Agreement for a period of time up to December 2019 to allow the final measures to be implemented to reduce the discharge of sub-surface drainage water from the Grassland Drainage Area. An EIS/EIR has been completed for the time extension. CEQA for the project was adopted on October 8, 2009. A biological opinion was issued on December 18, 2009 and the USBR adopted the Record of Decision on December 21, 2009. The Central Valley Regional Water Quality Control Board adopted a Basin Plan Amendment incorporating a delay in meeting Mud Slough selenium standards on May 27, 2010 and this Basin Plan was approved by the State Water Resources Control Board on October 5, 2010. This Basin Plan was subsequently approved by the State Office of Administrative Law. Steps ongoing include coordination with the Oversight Committee for the Use Agreement and the Regional Water Quality Control Board for issuance of new Waste Discharge Requirements.

Figures 2a through **2d** show the monthly discharges from the Grassland Bypass Project from WY 1997 through the end of calendar year 2011. In August 2005 the Grassland Basin Drainers formally requested revisions to the selenium load values for selenium. This puts the load values in the Use Agreement in step with the load values in the Waste Discharge Requirements, which include setting the TMML for four different year types (wet, above normal, dry/below normal and critical). Annual discharges compared to load limits are shown on **Figure 3**. Future load limits are also shown.

Table 1 sets forth discharges from the Grassland Drainage Area for the period Water Year 1996 through Water Year 2011. The Grassland Bypass Project began in Water Year 1997. Water Year 2010 was an above-normal year type in the San Joaquin River and Water Year 2011 was a wet year type. These year types affect the discharge from the Grassland Bypass Project, both in terms of the TMML Load Allocation (more is allowed in wetter years) and in actual discharge (the discharged loads tend to be higher in wet year types). The discharge has been reduced significantly since before the project began in Water Year 1995 as follows:

- A selenium load reduction of 87% in Water Year 2010 and 82% in 2011 (compared to the 1996 pre-project discharge).
- A salt load reduction of 72% in 2010 and 63% in 2011
- A boron load reduction of 64% in 2010 and 52% in 2011
- An overall discharge reduction of 75% in 2010 and 68% in 2011.

Selenium load discharged from the Grassland Drainage Area compared with monthly targets are shown in **Figure 2a** through **2d**. Selenium discharges were not exceeded in any month in 2010 or 2011. **Figure 3** shows discharged load through 2011 along with historic discharges and the "glidepath" in the Use Agreement after the August 2005 request for revision of the TMML for selenium. Annual targets were met in 2010 and 2011.

Water Year 2010 was designated an above normal year type and WY 2011 a wet year type in accordance with the Waste Discharge Requirements. During Water Year 2010 and 2011, the 5 ppb 4-day average selenium water quality objective at Crows Landing was met at all times.

In WY 1996, prior to the Grassland Bypass Project, the mean selenium concentration in Salt Slough at Lander Avenue was 16 parts per billion (ppb). The 2 ppb monthly mean water quality objective for Salt Slough was met in all months in both WY 2010 and 2011. In WY 1996 the monthly mean selenium concentration at Camp 13 Ditch was 55.9 parts per billion (ppb). Selenium levels in the Camp 13 Ditch were below the 2 ppb monthly mean threshold except for February 2011 (2.2 ppb). Selenium levels in the Agatha Canal did not exceed the 2 ppb monthly threshold at any time.

SAN JOAQUIN RIVER WATER QUALITY IMPROVEMENT PROJECT

Funds provided from Proposition 13 allowed for the purchase and improvement of 4,000 acres of land within the Grassland Drainage Area as part of the San Joaquin River Water Quality Improvement Project (SJRIP) for the purpose of drain water disposal. The location of the SJRIP Project is shown in **Figure 1** and the cropping details for WY 2011 are shown in **Figure 4**. The first phase of the SJRIP was implemented in the winter of WY 2001 with the planting of salt tolerant crops and construction of distribution facilities. In 2007, with funding from California's Proposition 50, an additional 2,000 acres of reuse area was purchased. Since the project's inception, the planted acreage has increased from the original 1,821 acres to more than 5,200 acres, which have been irrigated with drainage water or blended water. In 2010, 12,400 acre feet of drain water was applied to the project, reusing 3,200 pounds of selenium, 72,000 tons of salt, and 353,000 pounds of boron. 21,600 acre feet of drain water was reused in 2011. In addition to the currently planted acreage, funding from the U.S. Bureau of Reclamation.

The SJRIP project is the key for the Grassland Drainage Area as a whole to meet future selenium load limits. Future phases call for development of the additional acreage, installation of subsurface drainage systems and implementation of treatment and salt disposal components.

A tiered contaminant monitoring program has been a part of the SJRIP projects. 2011 is the eleventh year of bird egg monitoring at the project site. Eggs were collected from recurvirostrids (black-necked stilt and American avocet), killdeer, and red-winged blackbirds. Results for recurvirostrids are shown in **Figure 5**.

The selenium concentration (geometric mean 68 ppm dry wt.) of two eggs collected from separate black-necked stilt nests within the easterly project area was higher than most years, but within the range of egg-selenium concentrations in recurvirostrid eggs collected during biological monitoring since 2002. The sample size of recurvirostrid eggs collected from the project area has been 2 each year since 2009, which is a positive step and is reflective of efforts to limit drainwater exposure to waterbirds. The small sample size does, however, result in much greater variance of means and makes comparisons to past years difficult. For example, the egg-selenium concentration of recurvirostrid eggs collected in 2010 was 12.9 ppm and in 2009 was 8.7 ppm.

Panoche Drainage District acquired 1,901 acres of additional lands in 2007. Monitoring on these lands began in 2008 even though application of drainwater to the newly acquired lands has not yet

begun. The results from 2008 to 2011 will provide data that describes the baseline (pre-project) conditions of these 1,901 acres.

Hazing birds during the nesting season, diligent water management, and modification of drains to discourage avian use continued during this reporting period. Only 2 recurvirostrid nesting attempts occurred in the entire 4,000 acre eastern project area. There were no recurvirostrid nesting attempts in the 1,901 acre western project area. Hazing and closing drains will continue as part of the operation of the improvement project in future years.

The following measures were implemented in 2007 and continued in 2011 to reduce exposure potential and mitigate exposure to birds.

1. Reduced exposure potential by reducing attractiveness of drainage ditches for nesting.

2. Reduced exposure potential by hazing birds from nesting near, and foraging in, irrigation (and drainage) ditches.

3. Flooded field contingency plan.

4. Provide mitigation breeding habitat.

5. Reducing exposure to open drains.

2008 was also the first year of monitoring designed to detect potential selenium exposure to San Joaquin kit foxes by monitoring selenium levels in vegetation and small mammals. Results are available in the annual monitoring reports located on the GBP website at: www.sfei.org/gbp. In 2010 monitoring of blood and hair in coyote was initiated. Levels measured in 2010 and 2011 show concentrations below concern levels.

A mitigation site has continued to be provided that has resulted in additional nest-attempts.

OTHER ACTIVITIES

Figures 6a and **6b** show an estimate of the impact of control activities that occurred during Water Year 2010 and 2011 (respectively). Conservation, which includes improved irrigation application, tiered water pricing and tailwater controls accounted for a reduction of approximately 6,900 pounds of selenium from historic loads in 2010 and increased to an estimated 4,800 pounds in 2011. Reuse and treatment, which includes recycling, use of subsurface drainage water on salt tolerant crops and displacement of subsurface drainage water such as for wetting of roadways for dust control, resulted in a 4,200 pound reduction Water Year 2010 and 5,800 pounds in 2011. Discharge to the San Joaquin River through the Grassland Bypass Project was 1,600 pounds in WY 2010 and 2,100 pounds in WY 2011. The Grassland Area Farmers and member districts are continuing advances into drainage management and disposal with the cooperation of federal and state agencies. Continued funding is being sought for these activities.

Tables

Table 1. Grassland Drainage Area – Volume and Loads
Table 2. San Joaquin River Improvement Project – Volume and Loads

Figures

Figure 1. Grassland Bypass Project Location Map
Figure 2a. Discharge from the Grassland Bypass Project – October 1996 through September 2001
Figure 2b. Discharge from the Grassland Bypass Project – October 2001 through December 2004
Figure 2c. Discharge from the Grassland Bypass Project – January 2005 through December 2008
Figure 2d. Discharge from the Grassland Bypass Project – January 2009 through December 2012
Figure 3. Grassland Drainage Area Selenium Discharge and Targets
Figure 4. SJRIP Cropping Details
Figure 5. SJRIP Egg Mean Selenium Levels and Nesting Pairs
Figure 6a. Historic Drainage Water (lbs selenium)
Figure 6b. Historic Drainage Water (lbs selenium)

Table 1. Grassland Drainage Area – Volume and Loads

Water Year	Discharge (acre feet)	Selenium Load (lbs)	Boron Load (lbs)	Salt Load (tons)
1995	57,570	11,875	868,000	237,530
1996	53,000	10,036	830,700	197,500
1997	39,860	7,096	682,300	172,600
1998	49,244	9,118	967,200	213,500
1999	32,310	5,124	630,200	149,100
2000	31,260	4,603	606,700	135,000
2001	28,254	4,377	423,300	120,000
2002	28,391	3,939	550,500	116,100
2003	27,290	4,029	575,000	118,152
2004	27,700	3,871	536,000	120,200
2005	29,960	4,288	585,000	138,900
2006	25,995	3,563	538,000	119,646
2007	18,531	2,554	278,000	79,094
2008	15,695	1,737	280,000	66,459
2009	13,166	1,264	236,000	56,223
2010	14,529	1,577	315,000	67,661
2011	18,513	2,085	419,000	87,537
% Reduction 95-10	75%	87%	64%	72%
% Reduction 96-11	68%	82%	52%	63%

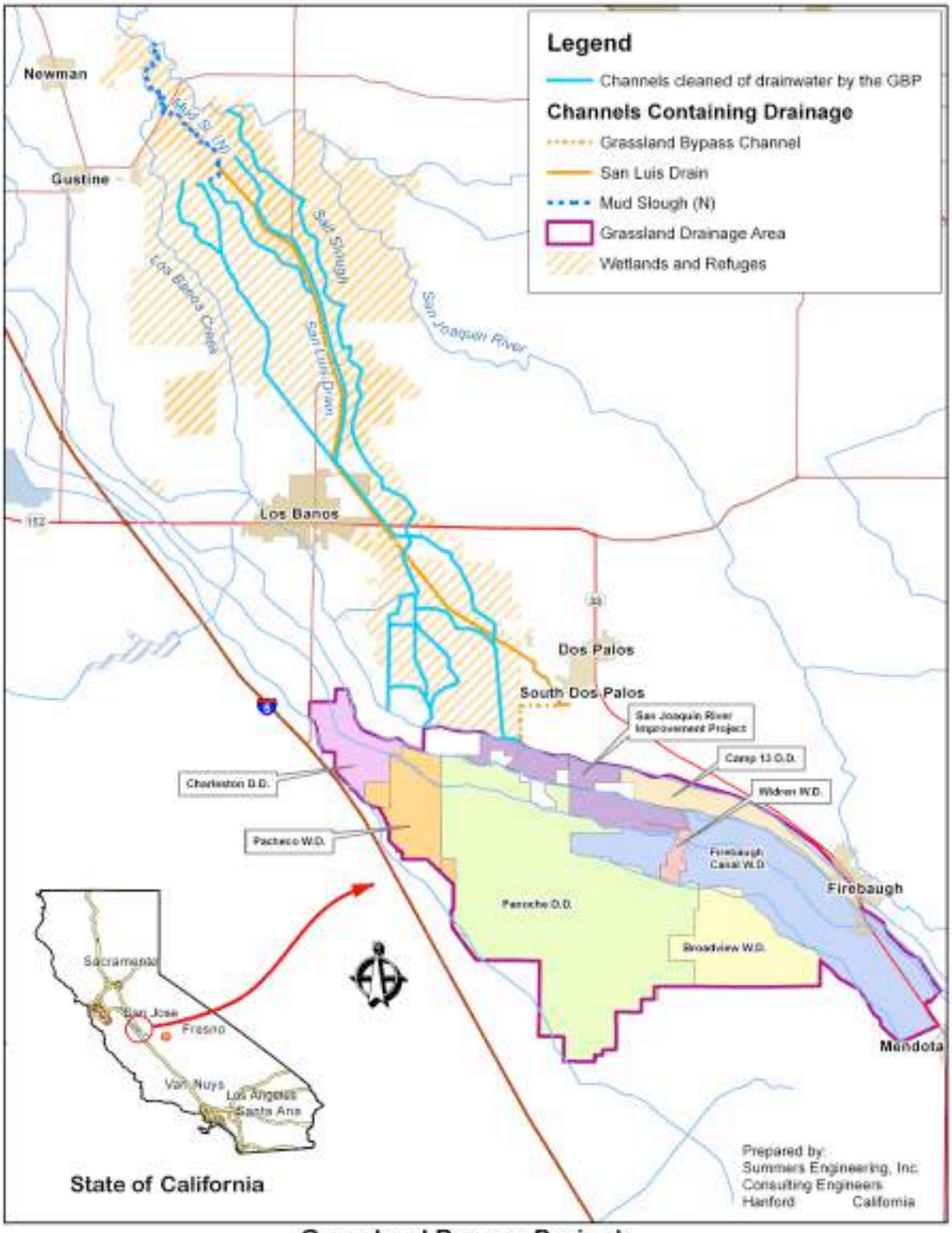
Note: WY 97, 98 and 2005 include discharges through Grasslands Water District.

Table 2. San Joaquin River Improvement Project – Volume and Loads

Water Year	Reused Drain Water (acre feet)	Displaced Selenium (pounds)	Displaced Boron (pounds)	Displaced Salt (tons)
1998¥	1,211	329	NA	4,608
1999¥	2,612	321	NA	10,230
2000¥	2,020	423	NA	7,699
2001	2,850	1,025	61,847	14,491
2002	3,711	1,119	77,134	17,715
2003	5,376	1,626	141,299	27,728
2004	7,890	2,417	193,956	41,444
2005	8,143	2,150	210,627	40,492
2006	9,139	2,825	184,289	51,882
2007	11,233	3,441	210,582	61,412
2008	14,955	3,844	238,435	80,900
2009	11,595	2,807	198,362	60,502
2010	13,119	3,298	370,752	75,362
2011	21,623	4,394	454,675	102,417

NA = Not Available
¥ PDD drainage reuse project prior to SJRIP

Figure 1. Grassland Bypass Project Location Map



Grassland Bypass Project
Location Map

Figure 2a. Discharge from the Grassland Bypass Project – October 1996 through September 2001

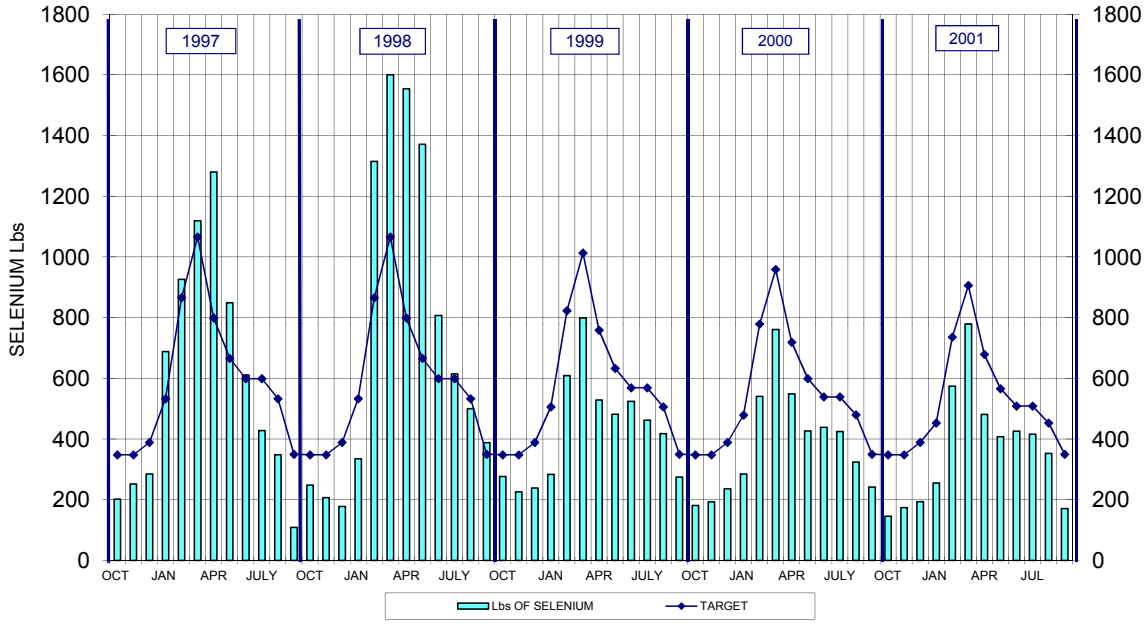


Figure 2b. Discharge from the Grassland Bypass Project – October 2001 through December 2004

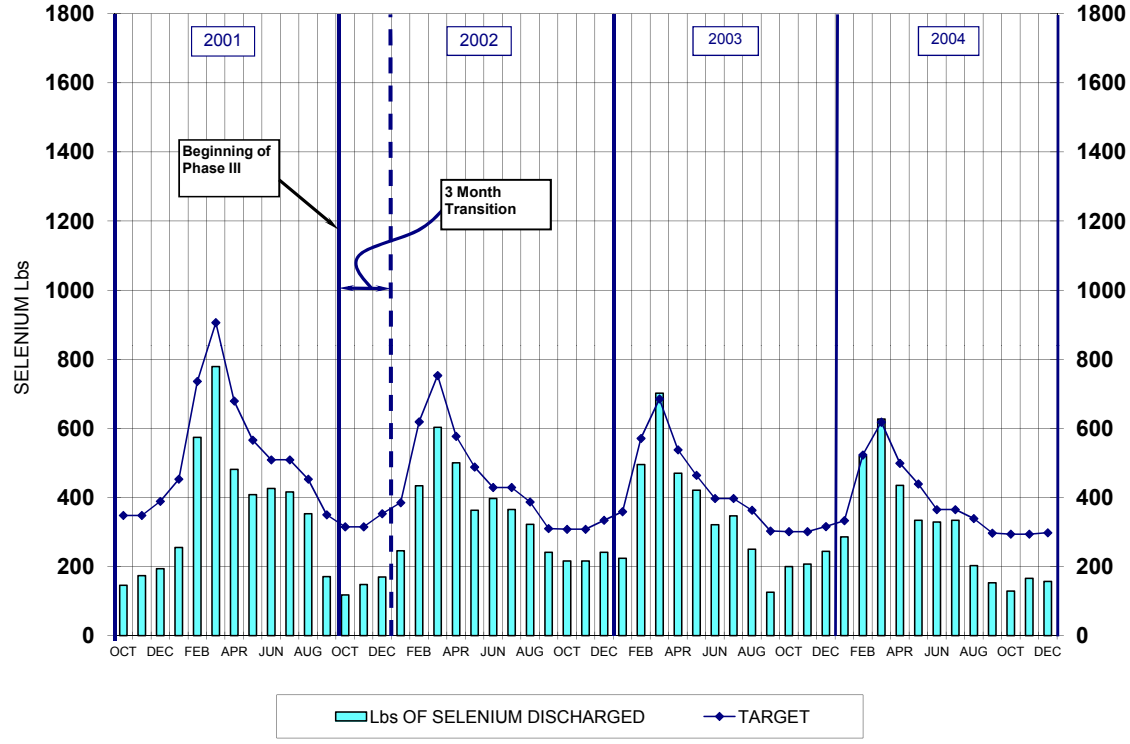


Figure 2c. Discharge from the Grassland Bypass Project – January 2005 through December 2008

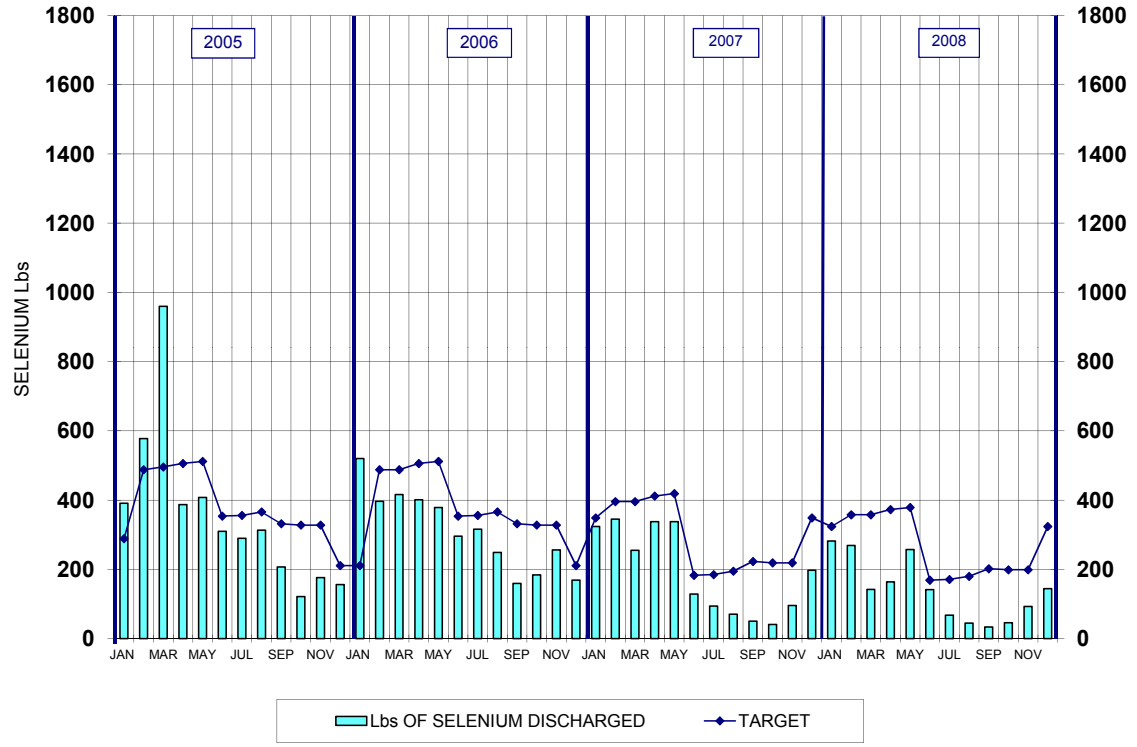


Figure 2d. Discharge from the Grassland Bypass Project – January 2009 through December 2012

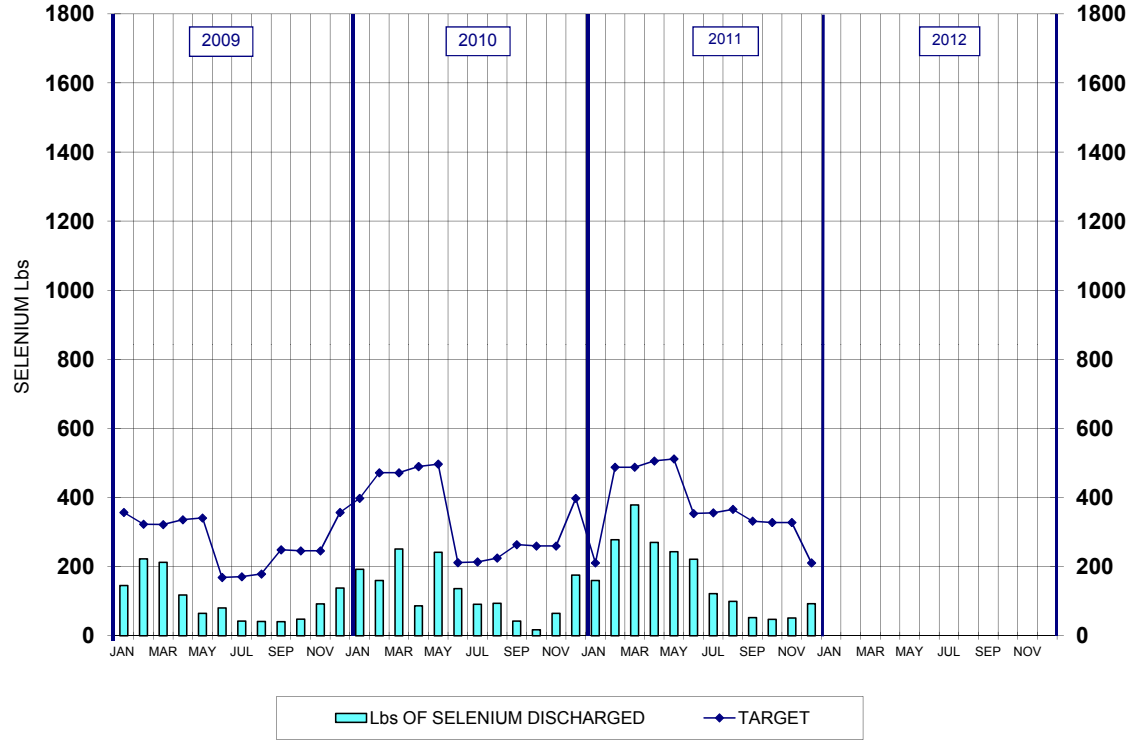


Figure 3. Grassland Drainage Area Selenium Discharge and Targets

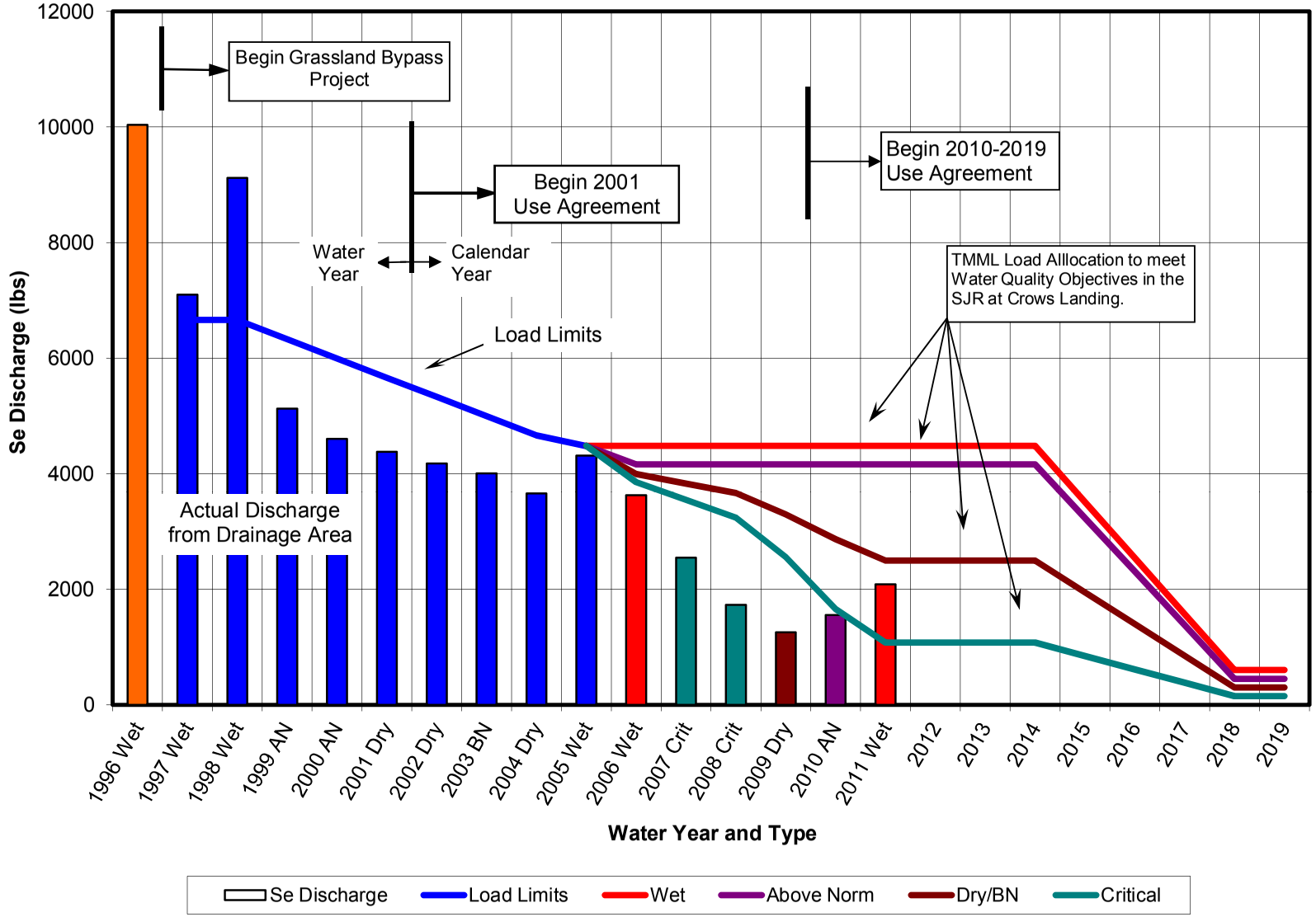


Figure 4. SJRIP Cropping Details

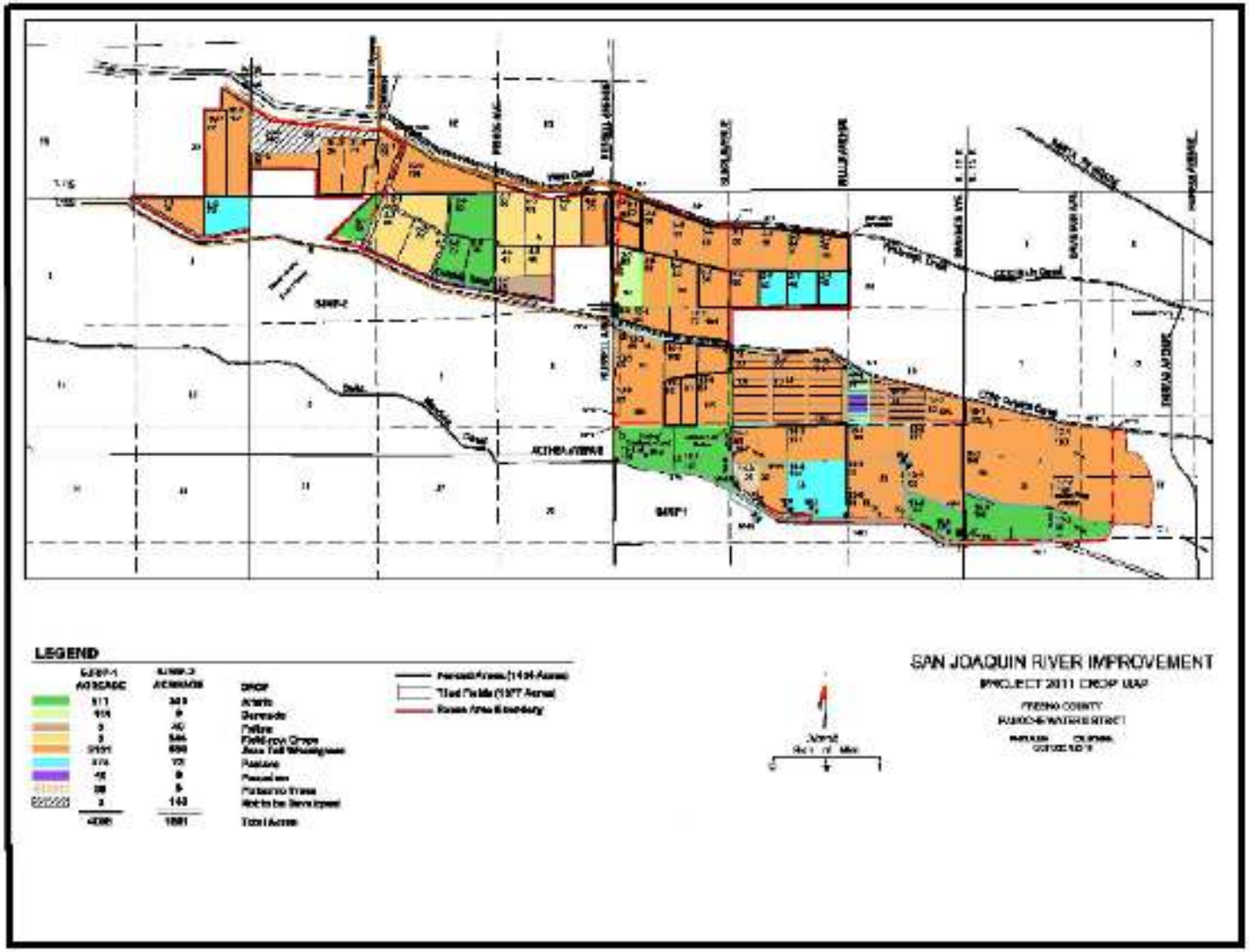
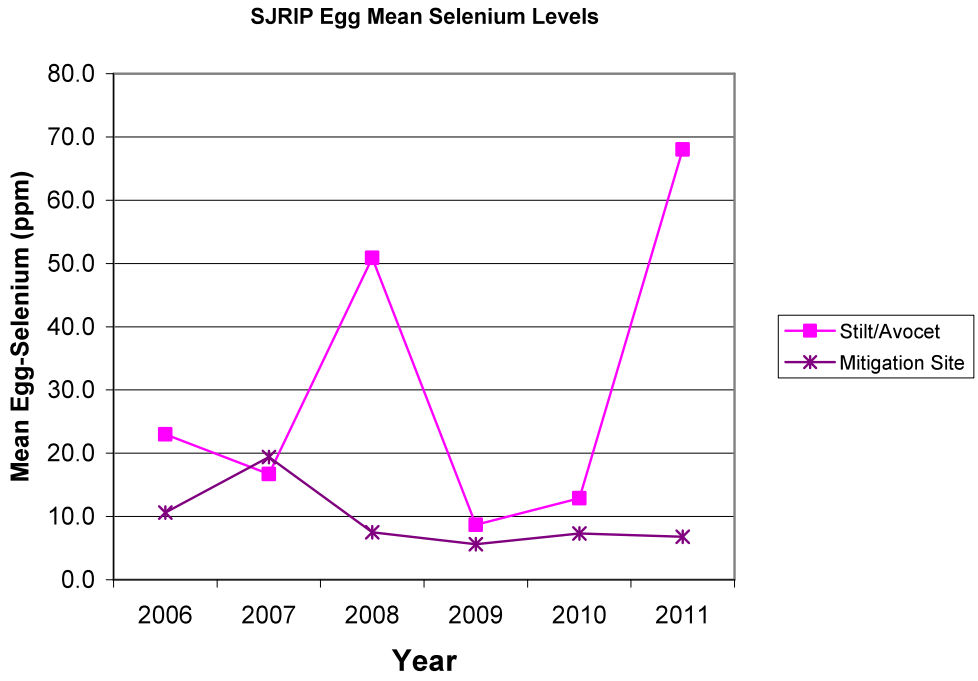


Figure 5. SJRIP Egg Mean Selenium Levels and Nesting Pairs



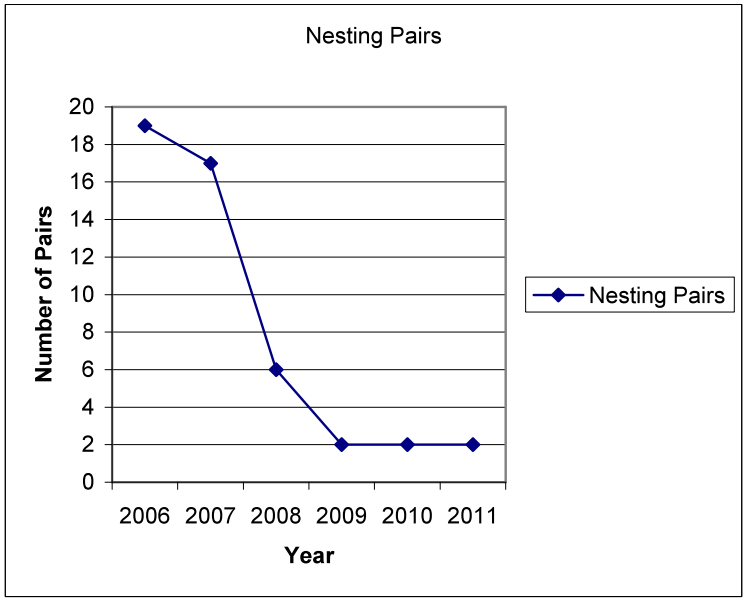


Figure 6a. 2010 Historic Drainage Water (lbs selenium)

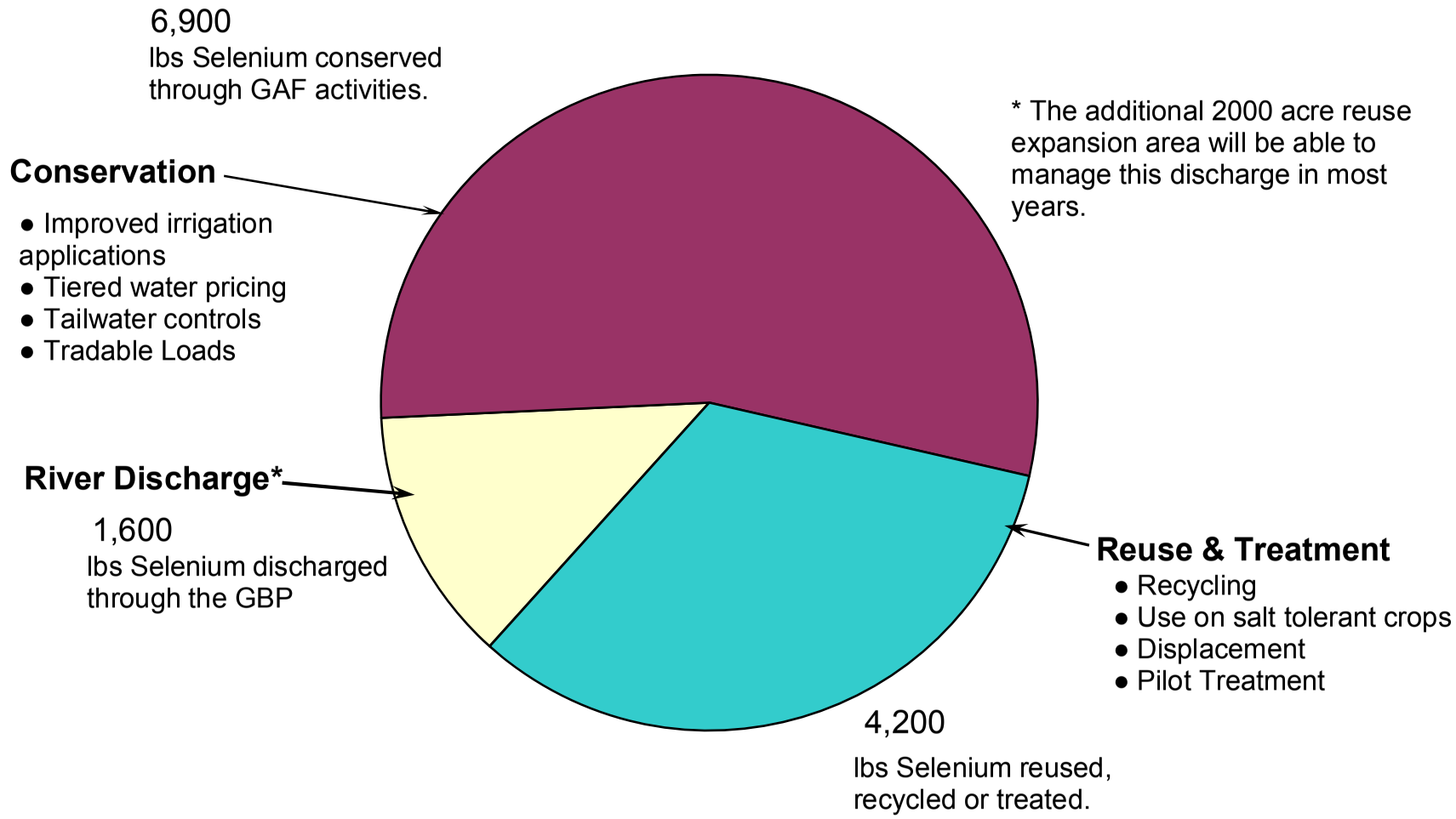
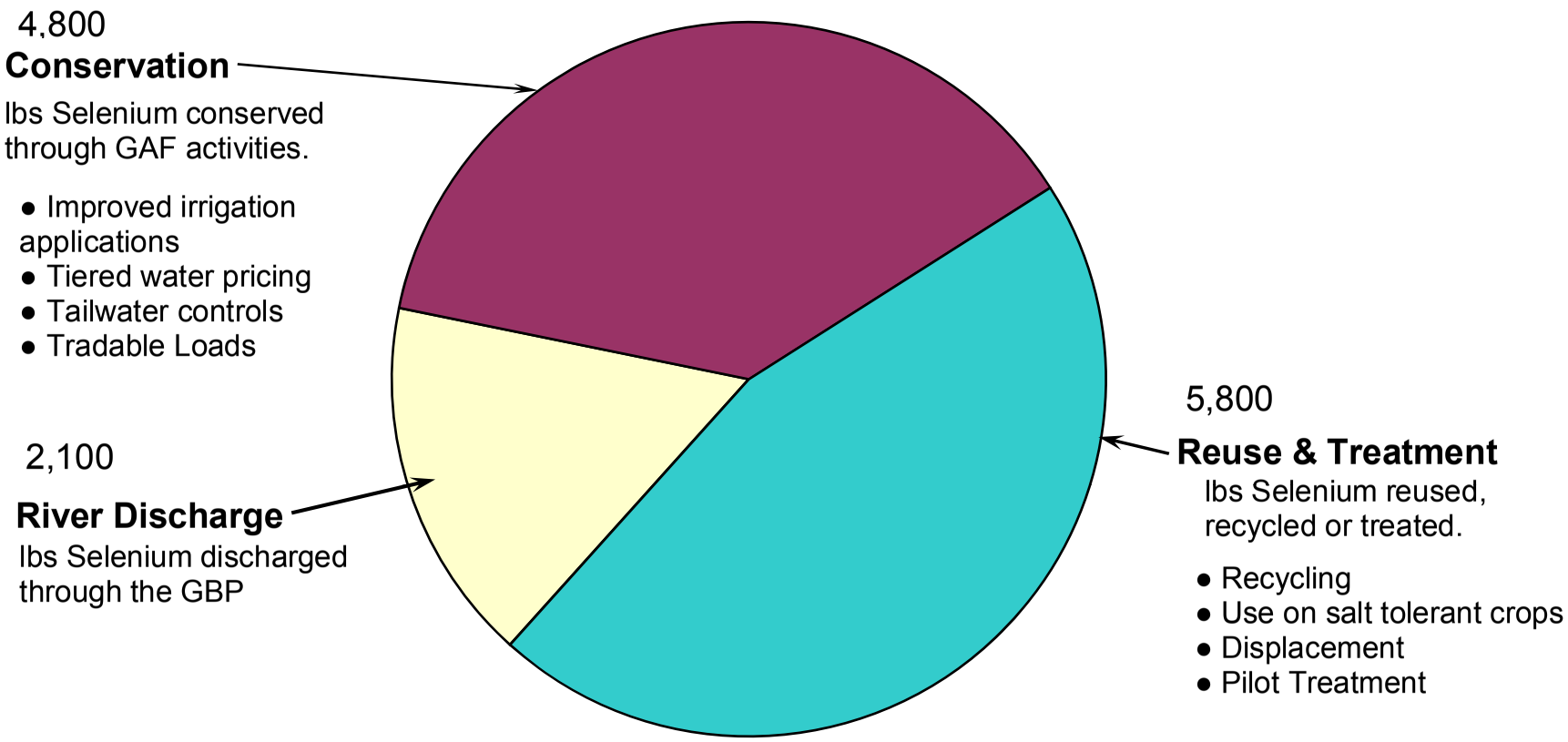


Figure 6b. 2011 Historic Drainage Water (lbs selenium)



CHAPTER 3

Flow and Salinity Monitoring

January 1, 2010 – December 31, 2011

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SUMMARY

Flow and electrical conductivity (EC) are measured to monitor the effects of the Grassland Bypass Project (GBP) on the San Luis Drain, Mud Slough, Salt Slough, and the San Joaquin River. The U.S. Geological Survey (USGS) measured flow and EC at five monitoring stations (B, D, F, G, and N). The San Luis & Delta-Mendota Water Authority (Authority) measured flow and EC in the San Luis Drain at Stations A and B2. The California Regional Water Quality Control Board, Central Valley Region (Regional Board), measured the EC of water quality samples collected at five other sites in the Grasslands wetland water supply channels (C, J, K, L2, and M2) through June 2011. Reclamation collected data from these sites after July 2011. The San Francisco Estuary Institute compiled this information in monthly and quarterly reports.

Table 1 is a summary of how flow and salinity are measured at Stations A, B2, C, D, F, G, and N. **Tables 2 - 8** summarize the monthly average flows, flow-weighted EC measurements, and salt loads in water passing the seven stations from January 2010 through December2011. **Table 9** lists the average monthly EC of water in the Grasslands wetlands supply channels and the San Joaquin River.

Figures 3a and 3b in Chapter 1 show the pattern of rainfall and discharge from the 97,000 acres that make up the Grassland Drainage Area (GDA) for 2010 and 2011. Note the minor increases in flow following winter rainstorms and minimal flows during summer months.

STATION A - SAN LUIS DRAIN NEAR SOUTH DOS PALOS, CALIFORNIA

Grassland Bypass Project Station A	
Location	San Luis Drain Check 17, near South Dos Palos, California
Agency ID	Regional Board MER562 Formerly USGS 11262890
Responsibility	San Luis & Delta-Mendota Water Authority (Panoche Drainage District)
Parameters	Stage, electrical conductivity, temperature
Equipment	Sharp-crested weir, stilling well with a Stevens recorder and shaft encoder, staff gauge, weir stick; electrical conductivity/temperature sensor; data logger.

Description

Station A is located near South Dos Palos, California. Its purpose is to measure the volume and quality of agricultural drain water from the Grassland Drainage Area (GDA) as it enters the San Luis Drain from the Grassland Bypass Channel.

Data Summary

Table 2a summarizes the monthly flow and salinity of water that passed Station A from January 2010 to December 2011. **Tables 2b and 2c** list the annual averages and totals. The total flow in 2010 was 13,850 acre-feet and 15,650 acre-feet in 2011 (**Table 2c**). The average flow rate was 19.2 and 21.7 cfs with a daily maximum of 97 cfs on March 21, 2011. The monthly average EC of water in 2010 was 4,556 microSiemens per centimeter (µS/cm) and 5,407 µS/cm in 2011.

STATION B2 - SAN LUIS DRAIN NEAR GUSTINE, CALIFORNIA

Grassland Bypass Project Station B2	
Location	Terminus of the San Luis Drain
Agency ID	Regional Board MER535 Formerly USGS 11262895
Responsibility	San Luis & Delta-Mendota Water Authority (Panoche Drainage District)
Parameters	Stage, velocity, electrical conductivity, temperature
Equipment	Sharp-crested weir, stilling well with a Stevens recorder and shaft encoder, staff gauge, weir stick; electrical conductivity/temperature sensor; data logger

Description

Station B2 is located about 30 miles northwest of Station A at the terminus of the Drain. It is the primary site for measuring the flow and selenium load discharged from the GDA into Mud Slough. The performance of the GBP to manage flows and selenium loads is assessed at this site.

Measurements of flow and EC are taken by the San Luis and Delta-Mendota Water Authority. The Regional Board collects water quality samples from the bridge about two miles upstream in the Drain (Site B) because there is no source of electricity at the terminus for its autosampler.

Data Summary

Table 3a summarizes the monthly flow and salinity of water that passed Station B from January 2010- December 2011. **Tables 3b** and **3c** list the annual averages and totals. The total flow of water passing Station B was in 2010 was 14,710 acre-feet, and 18,020 acre-feet in 2011, with an average rate of 20.3 to 25.0 cfs (**Table 3c**). Peak daily flow was 100 cfs on March 22, 2011. The monthly average EC of water passing Site B was 4,583 µS/cm in 2010, and 4,205 µS/cm in 2011. The total loads of salt discharged to Mud Slough in 2010 and 2011 is estimated to be 68,150 and 69,100 tons.

STATION C - MUD SLOUGH (NORTH), UPSTREAM OF SAN LUIS DRAIN DISCHARGE

Grassland Bypass Project Station C	
Location	Mud Slough, approximately 1/2 mile upstream of San Luis Drain terminus
Agency ID	Regional Board MER536
Responsibility	Regional Board (through June 2011); Reclamation (after July 2011)
Parameters	Electrical conductivity, temperature, pH, boron
Equipment	None

Description

Station C is located in Mud Slough upstream from the end of the San Luis Drain. Water at this monitoring station derives primarily from managed wetlands in the North and South Grassland Water District and the Kesterson National Wildlife Refuge. Data collected at this site are considered a baseline for measuring the impact of the GBP on the slough. The Regional Board collected weekly water quality samples here.

Data Summary

Table 4a summarizes the monthly flow and salinity of water that passed Station C during 2010 and 2011. Flow was not measured at this site, but was estimated as the difference between flows passing Stations D and B.

We estimate that 124,200 acre-feet of water flowed past this site during 2010, and 76,490 acre-feet in 2011. The average flow was 98 cfs with a daily maximum of 363 cfs on February 26, 2011. The average monthly EC of water that passed Station C in 2010 was 1,498 and 1,330 µS/cm in 2011.

STATION D - MUD SLOUGH NEAR GUSTINE, CALIFORNIA, DOWNSTREAM FROM THE SAN LUIS DRAIN DISCHARGE

Grassland Bypass Project Station D	
Location	Mud Slough near Gustine, California
Agency ID	USGS 11262900 Regional Board MER542
Responsibility	US Geological Survey (flow, EC, temp) Regional Board (EC, water quality)
Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station D is located in Mud Slough downstream from the terminus of the SLD.

Data Summary

Table 5 summarizes the monthly flow and salinity of water that passed Station D from January 2010 to December 2011. The estimate of flow for 2010 and 2011 was 165,780 acre-feet of water. The flow from the San Luis Drain was 20 percent of this volume. The average flow rate was 115 cfs, with a maximum of 412 cfs on February 26, 2011. The monthly average EC of water was 2,462 µS/cm. We estimate that 349,540 tons of salt passed this site in 2010 and 2011 combined, of which 43 percent were from the San Luis Drain.

STATION F - SALT SLOUGH AT HIGHWAY 165 (LANDER AVENUE)

Grassland Bypass Project Station F	
Location	Salt Slough at Highway 165 near Stevinson, California
Agency ID	USGS 11261100 Regional Board MER531
Responsibility	US Geological Survey
Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station F is where flow and water quality are monitored in Salt Slough, an important channel for supplying water to local wildlife refuges. The GBP has removed most of the agricultural drainage water from Grassland wetland supply channels. The water in Salt Slough is largely derived from wetlands in the Los Banos Wildlife Area, and the San Luis National Wildlife Refuge Complex.

Data Summary

Table 6 summarizes the monthly flow and salinity of water that passed Station F between January 2010 and December 2011.

We estimate that 258,990 acre-feet of water passed the site in 2010 and 2011 combined at an average rate of 179 cfs. The highest daily flow was 511 cfs on March 28, 2011. The monthly average EC of water was about 1,237 μS/cm, and we estimate the total load of salt in the water to have been 293,930 tons. There were no discharges of agricultural drainage water from the GDA into the Grasslands wetlands water supply channels during 2010 and 2011.

STATION G - SAN JOAQUIN RIVER AT FREMONT FORD, CALIFORNIA

Grassland Bypass Project Station G	
Location	San Joaquin River at Fremont Ford, California
Agency ID	USGS 11261500 Regional Board MER538
Responsibility	US Geological Survey (flow, EC, temp), Regional Board (EC, water quality)
Parameters	Stage, electrical conductivity, temperature
Equipment	Design Analysis CO2 bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, GOES transmitter.

Description

Station G is located along the San Joaquin River next to the Highway 140 bridge, about five miles northeast of Gustine, California. It is about two miles upstream from the confluence of the river and Mud Slough. This site is used to measure the baseline flows and quality of water in the River before it receives water from the GBP.

Data Summary

Table 7 summarizes the monthly flow and salinity of water that passed Station G between January 2010 and December 2011. The amount of water that passed this site in 2010 and 2011 was 2,083,250 acre-feet at an average rate of 1,437 cfs. The highest flow of 14,900 cfs occurred on March 30, 2011. The average EC of water was about 711 µS/cm. We estimate that about 610,290 tons of salt passed this site in 2010 and 2011.

STATION N - SAN JOAQUIN RIVER AT CROWS LANDING, CALIFORNIA

Grassland Bypass Project Station N	
Location	San Joaquin River at Crows Landing, California (USGS 11274550) (Regional Board STC504)
Responsibility	US Geological Survey (flow, EC, temp), Regional Board (EC, water quality)
Parameters	Stage, electrical conductivity, temperature
Equipment	Design Analysis CO2 bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station N is located at Crows Landing on the San Joaquin River, about eleven miles downstream of the tributary of the Merced River.

Data Summary

Table 8 summarizes the monthly flow and salinity of water that passed Station N between January 2010 and December 2011. The amount of water that passed this site in 2010 and 2011 was about 4,002,220 acre feet at an average rate of 2,773 cfs. The highest flow of 18,400 cfs occurred on March 30, 2011. The average EC of water was 670 µS/cm. We estimate that 1,409,390 tons of salt were in the water that passed this point in 2010 and 2011 combined. Discharge from the GDA contributed one percent of the flow and 11 percent of the salt load passing this site.

OTHER MONITORING STATIONS

Panoche Drainage District staff collected samples of water each week from Camp 13 Ditch, Agatha Canal, CCID San Luis Canal, and Santa Fe Canals (Stations J, K, L2, and M2, respectively). These samples were analyzed by the Regional Water Quality Control Board through June 2011, and by Reclamation from July 2011 on. The purpose of these samples is to ensure that no agricultural drainage water from the GDA enters wetland supply channels in Grasslands Water District. The EC of each sample was measured in the field.

Table 9 summarizes monthly average EC of water in wetland supply channels, Salt Slough, and San Joaquin River in 2010 and 2011. The data show a general increase in salinity as water passes through the southern portion of Grasslands Water District, as measured at Sites J and K, through the northern portion of Grasslands Water District at Sites L2 and M2, then into Salt Slough and the lower San Joaquin River.

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Figure 1. Map of the Grassland Bypass Project
Figure 2. Grassland Bypass Project - Schematic Diagram Showing Locations of GBP Monitoring Sites Relative to Major Hydrologic Features of the Study Area

Table 1. Summary of Flow & Salinity Monitoring

Station	Agency	Parameter	Sample frequency	EC to TDS Conversion Factor (1)
A	SLDMWA	Flow	Continuous	0.74
	SLDMWA	EC	Continuous	
	CVRWQCB/ Reclamation (3)	EC	Weekly composite of daily samples	
B	CVRWQCB/ Reclamation (3)	EC	Daily composite samples and weekly grab samples	0.74
B2	SLDMWA	Flow	Continuous	0.74
	SLDMWA	EC	Continuous	
	USGS		Monthly	
C	Reclamation	Flow	Calculated (2)	0.68
	CVRWQCB/ Reclamation (3)	EC	Weekly grab	
D	USGS	Flow	Continuous	0.69
	USGS	EC	Continuous	
	CVRWQCB/ Reclamation (3)	EC	Weekly grab	
F	USGS	Flow	Continuous	0.68
	USGS	EC	Continuous	
	CVRWQCB/ Reclamation (3)	EC	Weekly grab	
G	USGS	Flow	Continuous	0.68
	USGS	EC	Continuous	
	CVRWQCB/ Reclamation (3)	EC	Weekly grab	
N	USGS	Flow	Continuous	0.62
	USGS	EC	Continuous	
	CVRWQCB/ Reclamation (3)	EC	Daily composite samples	
	CVRWQCB/ Reclamation (3)	EC	Weekly grab	

(1) CVRWQCB, February 1998. Loads of Salt, Boron, and Selenium in the Grassland Watershed and Lower San Joaquin River, October 1985 - September 1995 Volume I: Load Calculations. Sacramento, California

(2) Difference in flow measured at Stations D and Station B2

(3) CVRQCB measured EC at these sites through June 2011; Reclamation has done so since July 2011.

Table 2a. Monthly Flow and Salinity of Water Entering the San Luis Drain (Station A)

	Flow		Salinity		
	Average	Total	Flow-weighted Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
January 2010	18.0	1,100	4,199	3,110	4,650
February 2010	24.0	1,330	4,068	3,010	5,440
March 2010	25.4	1,560	4,396	3,250	6,900
April 2010	16.5	980	3,778	2,800	3,730
May 2010	28.6	1,760	4,208	3,110	7,440
June 2010	22.0	1,310	4,177	3,090	5,510
July 2010	17.5	1,070	5,005	3,700	5,380
August 2010	18.3	1,120	4,916	3,640	5,540
September 2010	11.3	670	4,901	3,630	3,310
October 2010	5.4	330	4,919	3,640	1,630
November 2010	20.5	1,220	5,131	3,800	6,300
December 2010	22.8	1,400	4,974	3,680	7,010
January 2011	20.2	1,240	5,440	4,030	6,800
February 2011	34.7	1,930	5,174	3,830	10,050
March 2011	44.0	2,700	4,943	3,660	13,440
April 2011	30.8	1,840	5,490	4,060	10,160
May 2011	26.2	1,610	5,212	3,860	8,450
June 2011	25.8	1,540	5,052	3,740	7,830
July 2011	16.4	1,010	5,447	4,030	5,540
August 2011	17.0	1,040	5,202	3,850	5,450
September 2011	11.4	680	5,543	4,100	3,790
October 2011	10.3	630	5,744	4,250	3,640
November 2011	10.3	610	5,436	4,020	3,330
December 2011	13.3	820	6,197	4,590	5,120
Summary, October 1996 - December 2011					
Maximum	123.0	7,100	6,197	4,590	38,430
Minimum	5.4	330	3,311	2,450	1,630
Median	26.8	1,610	4,582	3,390	7,010
Average	33.6	2,020	4,569	3,381	9,307
Count	183	183	183	183	183

Data sources: Calculated from mean daily flow and EC data collected by San Luis & Delta-Mendota Water Authority
Total acre-feet, TDS, and Salt load - calculated

Note: EC - TDS conversion: 0.74

Table 2b. Average Flow and Salinity at Station A, Water Years 1997 – 2011

	Average cfs	Total acre-feet	Electrical conductivity µS/cm	Total dissolved solids mg/L	Salt load tons
WY 1997	52.3	37,800	4,480	3,320	176,700
WY 1998	60.6	43,570	4,838	3,580	211,330
WY 1999	42.2	30,510	4,820	3,570	143,880
WY 2000	40.5	29,330	4,614	3,410	135,260
WY 2001	37.4	27,050	4,605	3,410	125,100
WY 2002	35.7	25,820	4,397	3,250	111,200
WY 2003	35.0	25,250	4,552	3,370	113,630
WY 2004	35.1	25,370	4,445	3,290	110,630
WY 2005	38.1	27,540	4,584	3,390	127,030
WY 2006	32.0	23,080	4,782	3,540	111,070
WY 2007	22.9	16,480	4,660	3,450	77,140
WY 2008	18.2	13,230	4,151	3,070	73,900
WY 2009	17.2	12,340	3,827	2,830	71,510
WY 2010	18.9	13,610	4,266	3,157	71,600
WY 2011	22.9	16,540	5,211	46,280	86,450

Table 2c. Average Flow and Salinity at Station A, Calendar Years 1997 – 2011

	Average cfs	Total acre-feet	Electrical conductivity µS/cm	Total dissolved solids mg/L	Salt load tons
1997	50.7	36,590	4,702	3,480	174,250
1998	61.5	44,220	4,841	3,580	214,730
1999	41.4	29,910	4,659	3,450	138,620
2000	39.9	28,920	4,609	3,410	133,360
2001	36.3	26,190	4,645	3,440	121,460
2002	36.7	26,520	4,439	3,290	115,030
2003	35.1	25,360	4,559	3,370	114,240
2004	35.5	25,730	4,403	3,260	111,860
2005	37.2	26,870	4,581	3,390	123,670
2006	32.1	23,180	4,924	3,640	113,260
2007	21.9	15,760	4,460	3,300	71,600
2008	19.1	13,880	3,975	2,940	69,730
2009	17.2	12,340	3,843	2,840	67,290
2010	19.2	13,850	4,556	3,372	62,840
2011	21.7	15,650	5,407	3,448	64,990

Table 3a. Monthly Flow and Salinity of Water in the San Luis Drain (Station B/B2)

	Flow		Salinity		
	Average	Total	Flow-weighted Electrical conductivity	Total Dissolved Solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
January 2010	23.3	1,430	4,704	3,480	6,770
February 2010	28.5	1,580	4,671	3,460	7,430
March 2010	30.1	1,850	4,982	3,690	9,280
April 2010	16.0	950	4,954	3,670	4,740
May 2010	26.6	1,630	4,585	3,390	7,510
June 2010	20.3	1,210	4,371	3,230	5,320
July 2010	14.2	870	5,102	3,780	4,470
August 2010	15.1	930	5,216	3,860	4,880
September 2010	11.8	700	4,399	3,260	3,100
October 2010	11.0	680	3,694	2,730	2,520
November 2010	18.0	1,070	4,063	3,010	4,380
December 2010	29.4	1,810	4,254	3,150	7,750
January 2011	26.0	1,600	4,793	3,550	7,720
February 2011	39.5	2,190	5,140	3,800	11,320
March 2011	48.9	3,010	4,941	3,660	14,980
April 2011	33.7	2,000	5,582	4,130	11,230
May 2011	27.3	1,680	5,138	3,800	8,680
June 2011	27.0	1,610	4,780	3,540	7,750
July 2011	15.9	980	4,333	3,210	4,280
August 2011	17.1	1,050	3,858	2,850	4,070
September 2011	13.9	830	3,402	2,520	2,840
October 2011	15.9	980	2,996	2,220	2,960
November 2011	16.5	980	2,566	1,900	2,530
December 2011	18.0	1,110	2,934	2,170	3,280
Summary, October 1996 - December 2011					
Maximum	125.9	7,110	5,759	4,260	34,230
Minimum	9.9	590	2,566	1,900	2,520
Median	30.0	1,790	4,276	3,160	7,830
Average	36.2	2,177	4,311	3,190	9,548
Count	183	183	183	183	183

Data sources: Calculated from mean daily flow and EC data collected by San Luis & Delta-Mendota Water Authority
Total acre-feet, TDS, and salt load - calculated
Note: EC - TDS conversion: 0.74

Table 3b. Average Flow and Salinity at Station B/B2, Water Years 1997 – 2011

	Average cfs	Total acre-feet	Electrical conductivity µS/cm	Total dissolved solids mg/L	Salt load tons
WY 1997	52.0	37,560	4,257	3,150	167,830
WY 1998	63.9	45,950	4,438	3,280	205,110
WY 1999	44.7	32,310	4,650	3,440	149,140
WY 2000	43.1	31,260	4,301	3,180	135,010
WY 2001	39.1	28,250	4,191	3,100	120,030
WY 2002	39.3	28,400	4,069	3,010	116,190
WY 2003	37.8	27,270	4,319	3,200	118,760
WY 2004	38.2	27,700	4,173	3,090	116,350
WY 2005	41.8	30,160	4,315	3,190	132,560
WY 2006	36.0	25,970	4,605	3,410	121,050
WY 2007	25.7	18,540	4,235	3,130	79,700
WY 2008	21.6	15,670	4,120	3,050	65,930
WY 2009	18.3	13,160	4,254	3,150	66,470
WY 2010	20.1	14,520	4,617	3,418	75,550
WY 2011	25.7	18,510	4,498	39,950	87,520

Table 3c. Average Flow and Salinity at Station B/B2, Calendar Years 1997 – 2011

	Average cfs	Total acre-feet	Electrical conductivity µS/cm	Total dissolved solids mg/L	Salt Load tons
1997	51.9	37,490	4,354	3,220	169,330
1998	64.3	46,240	4,563	3,380	208,860
1999	44.6	32,250	4,532	3,350	146,580
2000	41.7	30,210	4,189	3,100	128,600
2001	38.8	28,010	4,200	3,110	119,210
2002	39.3	28,460	4,155	3,070	117,760
2003	38.2	27,550	4,282	3,170	119,330
2004	39.0	28,290	4,129	3,060	118,000
2005	41.1	29,610	4,420	3,270	132,060
2006	35.8	25,890	4,589	3,400	120,500
2007	25.0	17,990	4,096	3,030	75,550
2008	21.9	15,860	4,096	3,030	66,200
2009	17.9	12,920	4,367	3,230	64,090
2010	20.3	14,710	4,583	3,393	68,150
2011	25.0	18,020	4,205	3,398	69,100

Table 4a. Monthly Flow and Salinity of Water in Mud Slough Upstream of the San Luis Drain (Station C)

	Estimated Flow (*)		Salinity		
	Average	Total	Flow-weighted Electrical conductivity	Total Dissolved Solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
January 2010	132	8,110	1,955	1,329	14,660
February 2010	77	4,740	2,314	1,573	10,140
March 2010	153	9,380	2,029	1,380	17,600
April 2010	48	2,840	2,520	1,714	6,620
May 2010	15	930	2,833	1,926	2,440
June 2010	34	2,030	1,481	1,007	2,780
July 2010	14	880	1,255	854	1,020
August 2010	23	1,400	855	581	1,110
September 2010	32	1,880	1,127	766	1,960
October 2010	94	5,770	1,140	775	6,080
November 2010	118	7,040	1,415	962	9,210
December 2010	176	10,820	1,533	1,043	15,340
January 2011	195	11,980	1,840	1,251	20,380
February 2011	174	9,340	1,776	1,207	15,340
March 2011	223	13,710	1,546	1,051	19,600
April 2011	121	7,180	2,097	1,426	13,920
May 2011	70	4,300	1,141	776	4,540
June 2011	58	3,430	1,265	860	4,010
July 2011	26	1,620	1,086	738	1,630
August 2011	26	1,610	1,080	734	1,610
September 2011	26	1,550	791	538	1,130
October 2011	110	6,790	789	537	4,960
November 2011	147	8,740	1,069	727	8,640
December 2011	102	6,240	1,479	1,005	8,530
Summary, October 1996 - December 2011					
Maximum	832	46,190	2,865	1,948	35,580
Minimum	2	120	603	410	200
Median	78	4,810	1,474	1,003	6,020
Average	95	5,738	1,518	1,032	7,807
Count	183	183	183	183	183

Data sources: Flow - Calculated difference between Stations B and D.
EC - California Regional Water Quality Control Board, Site MER536
Total acre-feet, TDS, and salt load - calculated

Note: EC - TDS conversion: 0.68

Table 4b. Average Flow and Salinity at Station C, Water Years 1997 – 2011

	Average	Total	Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
WY 1997	129	93,370	1,300	884	99,310
WY 1998	193	136,640	1,185	806	146,390
WY 1999	96	69,040	1,427	970	90,120
WY 2000	87	63,210	1,432	974	84,150
WY 2001	90	64,640	1,706	1,160	92,780
WY 2002	65	46,910	1,679	1,142	77,280
WY 2003	84	61,050	1,512	1,028	92,730
WY 2004	82	59,540	1,569	1,067	91,640
WY 2005	112	80,420	1,310	891	106,240
WY 2006	124	90,100	1,270	864	118,720
WY 2007	73	53,670	1,610	1,095	72,090
WY 2008	63	45,990	1,856	1,262	74,690
WY 2009	51	36,440	1,859	1,264	73,890
WY 2010	67	48,980	1,769	1,203	66,930
WY 2011	109	78,350	1,392	11,363	112,790

Data sources: Calculated from data published by San Francisco Estuary Institute

Table 4c. Average Flow and Salinity at Station C, Calendar Years 1997 – 2011

	Average	Total	Electrical conductivity	Total dissolved solids	Salt Load
	cfs	acre-feet	µS/cm	mg/L	tons
1997	122	87,960	1,380	939	103,010
1998	193	137,080	1,127	766	139,970
1999	92	66,490	1,457	991	89,570
2000	91	65,900	1,422	967	86,550
2001	84	60,890	1,788	1,216	96,100
2002	72	51,840	1,650	1,122	83,590
2003	81	58,300	1,482	1,008	84,430
2004	82	59,730	1,548	1,053	89,870
2005	119	85,390	1,307	889	111,940
2006	124	89,840	1,254	853	115,470
2007	60	44,040	1,669	1,135	66,930
2008	54	39,340	1,926	1,310	69,810
2009	56	40,330	1,863	1,267	63,200
2010	90	124,200	1,498	1,019	178,590
2011	106	76,490	1,330	994	168,450

Table 5a. Monthly Flow and Salinity of Water in Mud Slough Downstream of the San Luis Drain (Station D)

	Flow		Salinity		
	Average	Total	Flow-weighted Electrical conductivity	Total Dissolved Solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
January 2010	155	9,540	2,315	1,600	20,760
February 2010	114	6,330	2,812	1,940	16,700
March 2010	183	11,230	2,497	1,720	26,270
April 2010	64	3,790	3,169	2,190	11,290
May 2010	42	2,560	3,718	2,570	8,950
June 2010	54	3,240	2,983	2,060	9,080
July 2010	29	1,760	3,417	2,360	5,650
August 2010	38	2,330	3,023	2,090	6,620
September 2010	43	2,580	2,323	1,600	5,610
October 2010	105	6,450	1,472	1,020	8,950
November 2010	136	8,110	1,798	1,240	13,680
December 2010	205	12,630	1,916	1,320	22,670
January 2011	221	13,580	2,044	1,410	26,040
February 2011	220	12,240	2,253	1,550	25,800
March 2011	272	16,720	2,157	1,490	33,880
April 2011	154	9,190	2,815	1,940	24,250
May 2011	97	5,980	2,664	1,840	14,960
June 2011	85	5,040	2,371	1,640	11,240
July 2011	42	2,590	3,655	2,520	8,880
August 2011	43	2,670	2,741	1,890	6,860
September 2011	40	2,380	2,167	1,500	4,860
October 2011	126	7,770	1,277	880	9,300
November 2011	163	9,720	1,426	980	12,950
December 2011	120	7,350	2,075	1,430	14,290
Summary, October 1996 - December 2011					
Maximum	958	53,190	4,089	2,820	80,440
Minimum	7	410	1,195	820	1,450
Median	110	6,540	2,590	1,790	14,890
Average	131	7,856	2,591	1,788	17,016
Count	183	183	183	183	183

Data sources: Calculated from mean daily flow and EC data collected by USGS # 11262900
Total acre-feet, TDS, and salt load - calculated

Note: EC - TDS conversion: 0.69

Table 5b. Average Flow and Salinity at Station D, Water Years 1997 – 2011

	Average	Total	Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
WY 1997	181	130,930	2,390	1,649	254,020
WY 1998	257	182,580	2,600	1,794	369,220
WY 1999	141	101,360	2,582	1,781	229,760
WY 2000	131	94,440	2,496	1,722	201,560
WY 2001	129	92,870	2,737	1,889	214,330
WY 2002	104	75,280	2,809	1,938	184,890
WY 2003	122	88,200	2,688	1,855	208,450
WY 2004	120	87,190	2,704	1,866	197,370
WY 2005	154	110,600	2,535	1,749	246,560
WY 2006	160	116,100	2,273	1,568	242,890
WY 2007	100	72,130	2,542	1,754	144,190
WY 2008	85	61,680	2,804	1,935	140,690
WY 2009	58	41,700	2,875	1,984	141,380
WY 2010	83	60,150	2,744	1,895	136,320
WY 2011	135	97,580	2,338	19,360	202,070

Table 5c. Average Flow and Salinity at Station D, Calendar Years 1997 – 2011

	Average	Total	Electrical conductivity	Total dissolved solids	Salt Load
	cfs	acre-feet	µS/cm	mg/L	tons
1997	174	125,450	2,471	1,705	256,730
1998	258	183,320	2,559	1,766	365,490
1999	137	98,740	2,588	1,786	225,660
2000	133	96,070	2,467	1,703	201,320
2001	123	88,890	2,768	1,910	211,980
2002	111	80,260	2,827	1,951	195,210
2003	119	85,750	2,621	1,808	197,230
2004	121	87,960	2,738	1,889	202,250
2005	160	115,030	2,513	1,734	251,260
2006	160	115,750	2,241	1,547	237,630
2007	86	61,940	2,611	1,802	136,320
2008	80	58,150	2,868	1,979	139,310
2009	56	40,330	2,908	2,007	138,030
2010	97	70,550	2,620	1,809	156,230
2,011	132	95,230	2,304	1,793	161,510

Table 6a. Monthly Flow and Salinity of Water in Salt Slough (Station F)

	Flow		Salinity		
	Average	Total	Flow-weighted Electrical conductivity	Total Dissolved Solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
January 2010	113	6,950	1,891	1,290	12,190
February 2010	157	8,730	1,830	1,240	14,720
March 2010	307	18,890	1,630	1,110	28,520
April 2010	195	11,210	1,400	950	14,480
May 2010	138	8,470	1,231	840	9,680
June 2010	149	8,870	1,091	740	8,930
July 2010	140	8,600	1,021	690	8,070
August 2010	147	9,060	888	600	7,390
September 2010	97	5,790	1,098	750	5,910
October 2010	118	7,230	1,222	830	8,160
November 2010	160	9,520	1,287	880	11,390
December 2010	188	11,530	1,416	960	15,050
January 2011	161	9,920	1,618	1,100	14,840
February 2011	235	13,040	1,350	920	16,320
March 2011	433	26,640	1,251	850	30,800
April 2011	245	14,590	1,272	870	17,260
May 2011	200	12,300	983	670	11,210
June 2011	205	12,210	965	660	10,960
July 2011	146	8,990	794	540	6,600
August 2011	193	11,890	761	520	8,410
September 2011	138	8,210	889	600	6,700
October 2011	166	10,220	879	600	8,340
November 2011	208	12,400	989	670	11,300
December 2011	61	3,730	1,939	1,320	6,700
Summary, October 1996 - December 2011					
Maximum	631	35,030	2,242	1,520	61,460
Minimum	41	2,530	708	480	3,430
Median	159	9,520	1,287	880	11,160
Average	182	10,968	1,322	899	13,528
Count	183	183	183	183	183

Data sources: Calculated from mean daily flow and EC data collected by USGS # 11361100
Total acre-feet, TDS, and salt load - calculated

Note: EC - TDS conversion: 0.68

Table 6b. Average Flow and Salinity at Station F, Water Years 1997 – 2011

	Average	Total	Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
WY 1997	216	156,080	1,294	880	192,670
WY 1998	273	196,090	1,387	943	258,200
WY 1999	210	151,770	1,192	810	171,580
WY 2000	195	141,050	1,314	894	170,780
WY 2001	185	133,880	1,340	911	168,570
WY 2002	145	104,880	1,445	982	142,570
WY 2003	177	127,940	1,334	907	165,550
WY 2004	170	123,330	1,296	882	153,230
WY 2005	215	155,280	1,267	862	189,760
WY 2006	234	168,800	1,189	808	192,440
WY 2007	154	111,370	1,272	865	132,180
WY 2008	125	90,930	1,427	970	122,520
WY 2009	94	67,810	1,574	1,070	119,020
WY 2010	146	105,430	1,365	928	128,000
WY 2011	202	146,070	1,151	9,400	157,700

Table 6c. Average Flow and Salinity at Station F, Calendar Years 1997 – 2011

	Average	Total	Electrical conductivity	Total dissolved solids	Salt Load
	cfs	acre-feet	µS/cm	mg/L	tons
1997	205	147,940	1,355	922	187,890
1998	281	201,370	1,292	879	254,640
1999	204	147,380	1,255	853	172,000
2000	194	140,370	1,284	873	168,570
2001	181	131,100	1,399	951	170,140
2002	161	116,600	1,403	954	154,570
2003	163	117,730	1,342	912	152,290
2004	170	123,500	1,285	874	152,490
2005	224	161,730	1,261	858	197,990
2006	232	167,460	1,163	791	186,770
2007	143	102,810	1,336	909	128,000
2008	114	82,890	1,489	1,012	113,810
2009	103	74,110	1,501	1,021	103,720
2010	159	114,850	1,334	907	144,490
2011	199	144,140	1,141	891	147,140

Table 7a. Monthly Flow and Salinity of Water in San Joaquin River at Fremont Ford (Station G)

	Flow		Salinity		
	Average cfs	Total acre-feet	Flow-weighted Electrical conductivity µS/cm	Total Dissolved Solids mg/L	Salt load tons
January 2010	347	21,350	897	610	17,710
February 2010	271	15,050	1,204	820	16,780
March 2010	873	53,700	925	630	46,010
April 2010	904	53,770	699	480	35,100
May 2010	714	43,910	595	400	23,890
June 2010	486	28,920	656	450	17,700
July 2010	242	14,910	967	660	13,380
August 2010	208	12,760	874	590	10,240
September 2010	248	14,760	648	440	8,830
October 2010	207	12,710	893	610	10,540
November 2010	252	14,970	1,180	800	16,290
December 2010	843	51,810	573	390	27,480
January 2011	4,738	291,320	181	120	47,540
February 2011	1,024	56,880	809	550	42,550
March 2011	3,994	245,580	297	200	66,800
April 2011	9,633	573,190	130	90	70,160
May 2011	3,412	209,770	159	110	31,380
June 2011	2,599	154,670	119	80	16,830
July 2011	2,062	126,810	164	110	18,970
August 2011	386	23,760	656	450	14,540
September 2011	255	15,160	815	550	11,340
October 2011	263	16,180	759	520	11,440
November 2011	375	22,310	900	610	18,510
December 2011	146	9,000	1,959	1,330	16,280
Summary, October 1996 - December 2011					
Maximum	12,240	728,440	2,601	1,770	79,250
Minimum	48	2,830	72	50	4,580
Median	222	13,160	1,373	930	15,980
Average	759	45,765	1,303	886	20,584
Count	121	121	183	183	121

Data sources: Calculated from mean daily flow and EC data collected by USGS # 11261500
Total acre-feet, TDS, and salt load - calculated by USBR

Note: EC - TDS conversion: 0.68

Table 7b. Average Flow and Salinity at Station G, Water Years 1997 – 2011

	Average cfs	Total acre-feet	Electrical conductivity µS/cm	Total dissolved solids mg/L	Salt load tons
WY 1997			1,388	944	
WY 1998			1,282	871	
WY 1999			1,434	975	
WY 2000			1,525	1,037	
WY 2001			1,761	1,198	
WY 2002	220	133,270	1,433	974	171,780
WY 2003	220	156,100	1,486	1,010	217,950
WY 2004	220	161,760	1,493	1,015	219,220
WY 2005	890	642,060	901	612	367,580
WY 2006	2,670	1,931,210	787	535	344,360
WY 2007	220	156,740	1,355	922	196,040
WY 2008	211	152,550	1,520	1,030	183,960
WY 2009	130	93,520	1,710	1,160	178,690
WY 2010	395	286,220	1,003	683	191,340
WY 2011	2,450	1,776,630	498	4,060	374,420

Table 7c. Average Flow and Salinity at Station G, Calendar Years 1997 – 2011

	Average cfs	Total acre-feet	Electrical conductivity µS/cm	Total dissolved solids mg/L	Salt Load tons
1997			1,467	997	
1998			1,221	830	
1999			1,463	995	
2000			1,517	1,031	
2001			1,812	1,232	
2002	220	163,110	1,439	978	207,890
2003	190	140,470	1,534	1,043	204,000
2004	240	172,020	1,435	976	225,940
2005	900	647,690	874	593	371,630
2006	2,671	1,931,950	765	518	339,730
2007	193	139,080	1,495	1,020	191,340
2008	197	142,100	1,604	1,090	171,030
2009	148	106,520	1,578	1,070	158,010
2010	466	338,620	843	573	243,950
2011	2,407	1,744,630	579	533	273,780

Table 8a. Monthly Flow and Salinity of Water in the San Joaquin River at Crows Landing (Station N)

	Flow		Salinity		
	Average	Total	Flow-weighted Electrical conductivity	Total Dissolved Solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
January 2010	1,030	63,300	1,029	638	54,940
February 2010	930	51,460	1,285	796	55,740
March 2010	1,700	104,530	1,007	624	88,750
April 2010	1,710	101,480	690	428	59,010
May 2010	1,490	91,560	645	400	49,790
June 2010	1,130	67,370	743	461	42,240
July 2010	550	33,910	1,066	661	30,470
August 2010	520	32,060	973	603	26,310
September 2010	940	55,700	565	350	26,530
October 2010	820	50,370	741	459	31,470
November 2010	830	49,380	971	602	40,420
December 2010	2,070	123,110	772	479	80,170
January 2011	6,020	370,000	334	207	104,290
February 2011	4,590	254,880	381	236	81,950
March 2011	7,320	449,980	345	214	130,900
April 2011	14,160	842,590	205	127	145,640
May 2011	6,670	409,990	169	105	58,370
June 2011	4,300	256,030	265	164	57,260
July 2011	4,090	251,350	260	161	55,040
August 2011	1,190	73,470	594	368	36,810
September 2011	1,070	61,340	547	339	28,320
October 2011	1,630	100,150	442	274	37,370
November 2011	1,120	66,770	738	457	41,540
December 2011	670	41,440	1,318	817	46,060
Summary, October 1996 - December 2011					
Maximum	25,600	1,574,300	1,731	1,073	360,320
Minimum	220	13,760	160	100	15,180
Median	950	58,320	1,007	624	46,130
Average	2,177	130,486	948	588	60,047
Count	183	183	183	183	183

Data sources: Calculated from mean daily flow and EC data collected by USGS # 11274550
Total acre-feet, TDS, and salt load - calculated

Note: EC - TDS conversion: 0.62

Table 8b. Average Flow and Salinity at Station N, Water Years 1997 – 2011

	Average cfs	Total acre-feet	Electrical conductivity µS/cm	Total dissolved solids mg/L	Salt load tons
WY 1997	5,410	3,844,610	820	508	1,080,680
WY 1998	6,870	4,904,910	601	373	1,511,480
WY 1999	1,410	1,015,480	902	559	680,120
WY 2000	1,420	1,027,440	976	605	703,910
WY 2001	900	653,430	1,162	720	623,560
WY 2002	740	533,960	1,202	745	517,360
WY 2003	750	546,130	1,244	771	576,340
WY 2004	760	554,550	1,226	760	564,500
WY 2005	2,380	1,721,000	722	448	881,460
WY 2006	4,750	3,437,650	569	352	947,330
WY 2007	838	607,180	1,103	684	538,700
WY 2008	810	586,030	1,053	653	494,720
WY 2009	467	336,670	1,266	785	487,410
WY 2010	981	709,070	938	582	496,440
WY 2011	4,428	3,192,490	465	3,463	850,640

Table 8c. Average Flow and Salinity at Station N, Calendar Years 1997 – 2011

	Average cfs	Total acre-feet	Electrical conductivity µS/cm	Total dissolved solids mg/L	Salt Load tons
1997	5,060	3,590,680	975	604	1,073,460
1998	7,090	5,064,330	453	281	1,516,010
1999	1,210	864,600	1,017	631	664,560
2000	1,470	1,059,180	905	561	689,550
2001	880	638,210	1,174	728	623,850
2002	720	523,240	1,235	766	528,420
2003	720	521,480	1,258	780	559,210
2004	790	573,270	1,213	752	574,950
2005	2,430	1,755,440	697	432	892,060
2006	4,800	3,473,920	567	352	962,650
2007	748	540,800	1,095	679	496,440
2008	723	523,470	1,107	686	467,340
2009	494	356,380	1,270	787	439,850
2010	1,143	824,230	874	542	585,840
2011	4,403	3,177,990	467	506	635,190

Table 9a. Electrical Conductivity of Water in Grassland Wetland Supply Channels

GBP Station:	J	K	L2	M2	C	F	G
CVRWQCB Site ID:	MER505	MER506	MER563	MER545	MER536	MER531	MER538
	Camp 13	Agatha Canal	San Luis Canal d/s of Splits	Santa Fe Canal d/s of Splits	Mud Slough above San Luis Drain	Salt Slough	San Joaquin River at Fremont Ford
	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm
January 2010	923	820	780	1,455	1,955	1,891	897
February 2010	770	863	1,113	1,565	2,314	1,830	1,204
March 2010	702	1,476	1,538	1,838	2,029	1,630	925
April 2010	523	1,403	1,235	1,395	2,520	1,400	699
May 2010	405	735	1,363	908	2,833	1,231	595
June 2010	382	362	1,084	732	1,481	1,091	656
July 2010	383	508	793	925	1,255	1,021	967
August 2010	444	460	496	832	855	888	874
September 2010	575	823	578	733	1,127	1,098	648
October 2010	555	555	578	815	1,140	1,222	893
November 2010	448	458	1,018	942	1,415	1,287	1,180
December 2010	1,562	690	653	1,183	1,533	1,416	573
January 2011	226	282	556	1,192	1,840	1,618	181
February 2011	455	385	1,158	1,280	1,776	1,350	809
March 2011	288	710	1,585	1,445	1,546	1,251	297
April 2011	193	1,575	2,053	1,385	2,097	1,272	130
May 2011	224	154	1,168	618	1,141	983	159
June 2011	230	174	477	738	1,265	965	119
July 2011	164	167	1,321	691	1,086	794	164
August 2011	371	316	505	538	1,080	761	656
September 2011	341	334	377	420	791	889	815
October 2011	281	284	523	503	789	879	759
November 2011	365	406	666	808	1,069	989	900
December 2011	515	485	1,404	1,253	1,479	1,939	1,959
Summary, October 1996 - December 2011							
Maximum	3,055	2,948	2,116	2,358	2,864	2,242	2,601
Minimum	107	61	103	420	603	708	72
Median	634	585	868	1,123	1,474	1,287	1,373
Average	698	683	974	1,198	1,518	1,322	1,303
Count	183	183	161	161	183	183	183

Data source: Annual average electrical conductivity calculated from weekly grab samples collected by the Regional Board

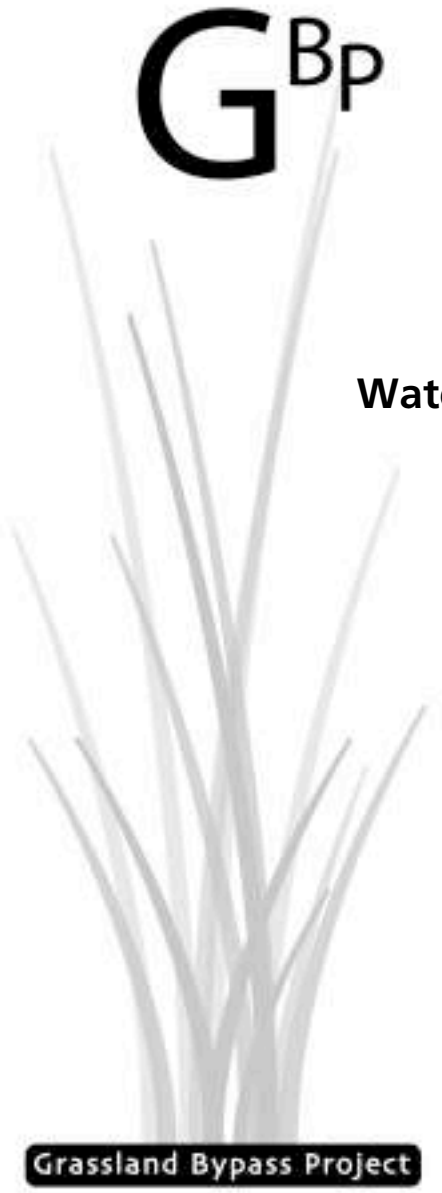
Notes: Site H averages for 1997 - 1999 were calculated from weekly grab samples collected by the Regional Board.
Site H 2001 - 2011 averages calculated from weekly grab samples collected by the Grassland Area Farmers.

Table 9b. Average Electrical Conductivity of Water in Grassland Wetland Supply Channels, Water Years 1997 – 2011

GBP Station	J	K	L2	M2	C	F	G
CVRWQCB Site ID:	MER505	MER506	MER563	MER545	MER536	MER531	MER538
Location	Camp 13	Agatha Canal	San Luis Canal, d/s of Splits	Santa Fe Canal, d/s of Splits	Mud Slough above San Luis Drain	Salt Slough	San Joaquin River at Fremont Ford
Units	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm
WY 1997	835	572			1,300	1,294	1,388
WY 1998	1,424	969			1,185	1,387	1,282
WY 1999	522	597	738	1,302	1,427	1,192	1,434
WY 2000	667	583	925	1,359	1,432	1,314	1,525
WY 2001	640	714	1,190	1,281	1,706	1,340	1,761
WY 2002	721	902	1,039	1,373	1,679	1,445	1,433
WY 2003	727	622	895	1,313	1,512	1,334	1,486
WY 2004	650	641	849	1,325	1,569	1,296	1,493
WY 2005	598	727	816	1,186	1,310	1,267	901
WY 2006	469	366	973	862	1,271	1,189	787
WY 2007	670	631	970	1,149	1,610	1,272	1,355
WY 2008	681	727	1,143	1,241	1,856	1,422	1,520
WY 2009	938	1,006	1,319	1,262	1,859	1,574	1,710
WY 2010	579	771	960	1,120	1,769	1,365	1,003
WY 2011	421	483	954	937	1,392	1,151	498

Table 9c. Average Electrical Conductivity of Water in Grassland Wetland Supply Channels, Calendar Years 1997 – 2011

GBP Station	J	K	L2	M2	C	F	G
CVRWQCB Site ID:	MER505	MER506	MER563	MER545	MER536	MER531	MER538
Location	Camp 13	Agatha Canal	San Luis Canal, d/s of Splits	Santa Fe Canal, d/s of Splits	Mud Slough above San Luis Drain	Salt Slough	San Joaquin River at Fremont Ford
Units	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm
1997	1,040	615			1,380	1,355	1,467
1998	1,168	879			1,127	1,292	1,221
1999	630	686	829	1,356	1,457	1,255	1,463
2000	632	558	1,168	1,276	1,422	1,284	1,517
2001	657	751	1,064	1,331	1,788	1,399	1,812
2002	740	886	978	1,369	1,650	1,403	1,439
2003	695	610	849	1,304	1,482	1,342	1,534
2004	657	647	818	1,317	1,549	1,285	1,435
2005	572	707	878	1,140	1,307	1,261	874
2006	472	346	884	864	1,254	1,163	765
2007	685	665	1,074	1,199	1,669	1,331	1,495
2008	690	744	1,135	1,248	1,926	1,489	1,604
2009	932	992	1,301	1,248	1,863	1,501	1,578
2010	639	763	936	1,110	1,705	1,334	843
2011	304	439	983	906	1,330	1,141	579



CHAPTER 4
Water Quality Monitoring

January 1, 2010 – December 31, 2011

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Introduction

The monitoring program for the Grassland Bypass Project (GBP), including water quality monitoring, is described in detail in the Compliance Monitoring Program for the Use and Operation of the Grassland Bypass Project, Phase II (USBR et. al., 2002). This chapter provides a summary of the water quality monitoring program, modifications to the plan for the ninth year of operation of Phase II of the GBP (January 1, 2010 to December 31, 2011), and water quality trends observed during this period. Detailed water quality data of individual monitoring stations will not be provided in this summary, as the San Francisco Estuary Institute (SFEI) has presented this information in annual narrative and graphical summary reports (www.sfei.org/gbp/reports).

Monitoring Program

Prior to June 31, 2011 the Central Valley Regional Water Quality Control Board (CVRWQCB) had an ongoing water quality monitoring program related to regulatory activities for agricultural subsurface drainage from the Grassland watershed. The water quality monitoring program for the GBP is an adaptation of the CVRWQCB monitoring program. The CVRWQCB conducted most of the water quality sampling. The Panoche Water District (under contract with the San Luis & Delta-Mendota Water Authority; SL&D-MWA) assisted the CVRWQCB by collecting samples at Stations A, J, K, L2, and M2. Samples were then transferred to and processed by the CVRWQCB and analyzed by its contract laboratories. The CVRWQCB conducted quality assurance (QA) reviews of the data before submitting them to the SFEI for reporting.

On June 31st, 2011 the U.S. Bureau of Reclamation (Reclamation) assumed the sampling responsibilities of the CVRWQB. Starting on that date, samples are now transferred and processed by the Reclamation. Analyses of the samples are conducted by its contract laboratories. The Reclamation's quality assurance (QA) team reviews all of the data before it is published. The Panoche Water District continues to assist USBR with sample collection at Stations A, J, K, L2, and M2.

Monitoring Objectives

The water quality monitoring program was designed to provide data for evaluating compliance with commitments in the Project Waste Discharge Requirements, the Use Agreement, and associated documents. The commitments include:

- Monthly and annual selenium load limits on discharges
- No degradation of the San Joaquin River water quality relative to the pre-Project condition
- Cessation of discharge of agricultural subsurface drainage to the wetland channels
- Management of flows in the San Luis Drain (SLD) so as to not mobilize channel sediments

The Monitoring Program was also designed to verify the validity of assumptions expressed in documents associated with the GBP. The assumptions include:

- The GBP is expected to result in selenium concentrations less than 2 µg/L in approximately 93 miles of wetland water supply channels.

- The increased frequency of exceeding selenium water quality objectives in Mud Slough (north) will be offset by a reduction of exceedances in Salt Slough.

In addition, the Monitoring Program was intended to provide data to be used to assess spatial and temporal trends in water quality parameters of concern and to characterize habitats in which biological samples were collected.

Sampling Locations

Monitoring was conducted in four areas; the SLD, Mud Slough (north), the San Joaquin River, and the Grassland wetland water supply channels, including Salt Slough. **Table 1** summarizes the Monitoring Program, and sampling locations are depicted in **Figure 2** in Chapter 1.

Frequency of Sampling

The frequency of sampling is outlined in **Table 1**. Weekly composite samples were collected at Station A (inflow to the SLD). Daily composite samples were collected at Station B (discharge from the SLD), and at Station N (San Joaquin River at Crows Landing). At Station A, daily samples were composited into a weekly sample to be used along with continuous flow data to calculate weekly selenium load inflow to the SLD. At Station B, daily composite samples along with continuous flow data were used to calculate daily selenium load discharge to Mud Slough (north). At Station N, daily composite samples were collected in order to calculate loads and evaluate compliance with Basin Plan water quality objectives. Compliance at Station N for the selenium water quality objective is 5 µg/L 4-day for all water year types. Since the objective is based on a 4-day average concentration, consecutive daily samples are required at this station. The remaining stations were sampled on a weekly basis. **Table 2** shows the summary of the selenium water quality objectives and compliance time table for Mud Slough as well as the San Joaquin River from the Mud Slough Confluence to the Merced River.

Sampling Methodology

Three types of sampling techniques were utilized, depending on the frequency of sampling and data needs: auto-sampler, mid-channel depth-integrated, and grab sample from channel bank. Auto-samplers were used to collect daily and weekly composite samples because of the remoteness of the station and frequency of sampling at stations A, B, and N. At Stations A, B, and D, structures such as a bridge or platform over the channel permitted the collection of mid-channel, depth-integrated samples. At other stations, a grab sample was collected from the stream bank. With respect to stream hydrology, lateral and vertical homogeneity was assumed for dissolved constituents at all sampling stations.

Modifications to the Water Quality Monitoring Program

During the Phase I of the GBP a number of issues were resolved with respect to the water quality monitoring program. These modifications and clarifications to the monitoring program are discussed in the previous Annual Reports (USBR, 1998 and SFEI, 1999, 2000, 2001, 2003, 2004 and 2005).

Water Quality Trends

Detailed water quality data for each monitoring station are presented in the Grassland Bypass Project Annual Narrative and Graphical Summary Reports, January 2010 to December 2011 (SFEI, 2011). Thus, this presentation will be limited to major water quality trends and findings for the thirteenth and fourteenth years of the GBP. Of primary interest are selenium concentrations in the San Joaquin River and water quality trends in Mud Slough (north). Also of interest are sporadic exceedances in the wetland channels of selenium water quality objectives established in the Water Quality Control Plan for the Sacramento/San Joaquin River Basins.

San Joaquin River

The selenium water quality objective is 5µg/L over a 4-day average. The compliance date was October 1, 2005 for above normal and wet water year types and was October 1, 2010 for critical, dry, and below normal water year types. Compliance with selenium water quality objectives specified in the Basin Plan is measured at Station N.

Figures 1 and 2 depict selenium concentrations in the San Joaquin River at monitoring Stations G (weekly grab), and N (4-day average and weekly grab) for 2010 and 2011. Station G is located at Fremont Ford, upstream of the Mud Slough (north) inflow to the San Joaquin River. Because this station is located upstream of drainage discharges from the GBP service area (except during flood events when drainage is occasionally routed to Salt Slough), selenium concentrations are generally low. Station N is located downstream of the GBP discharges conveyed by Mud Slough (north) and the Merced River inflow to the San Joaquin River. Merced River inflows dilute the upstream selenium contributions (CVRWQCB, 2002a).

For the months of January 2010 through December 2011, the applicable water quality objective is 5 µg/L 4-day average. Selenium concentrations remained below this performance goal for the 2010 and 2011 calendar years at both Site N and Site G. **Figures 3 and 4** shows the monthly means at Site N as well as the 5 µg/L objective. Due to autosampler malfunction and/or flooding in the area no samples were collected at Site N April 7, 2010 through April 20, 2010, May 19, 2010 through June 1, 2010, October 27, 2010 through November 2, 2010. No samples were collected between February 23, 2011 through March 15, 2011 and April 6, 2011 through May 17 2011.

The Basin Plan and the GBP Waste Discharge Requirements (WDRs) prohibit discharge of selenium from agricultural subsurface drainage systems in the Grassland Watershed to the San Joaquin River in amounts exceeding 8,000-pounds per water year. Compliance is measured at Station B.

Calculations using daily selenium data, preliminary USGS flow data, and the load calculation methods found in CVRWQCB (1998b) indicate that the annual selenium loads measured at Station B during Water Year 2010 was 1,578 pounds; well below the 8,000-pound annual load limit for the Grassland Watershed. During Water Year 2011, the annual selenium load was 2055 pounds, which was also well below the 8,000-pound limit.

Wetland Channels

Monthly mean selenium concentrations in the wetland channels during 2010 and 2011 are depicted in **Figure 5 and 6**. The monthly mean 2 µg/L selenium objective was met during all months of 2010 in Salt Slough (Site F), Camp 13 (site J) and Santa Fe Canal (Site M2). At Site K, selenium concentrations were in excess of the monthly mean 2 µg/L objective in January 2010. For 2011 the monthly mean 2 µg/L selenium was met in all months at Salt Slough (Site F), Agatha Canal (Site K), and Santa Fe Canal (Site M2). Monthly mean selenium concentrations slightly exceeded objectives at Camp 13 (Site J) in Febuary 2011 and at San Luis Canal (Site L2) in February, March and April 2011.

Regional Board staff conducted preliminary investigations on the potential sources of selenium, which are detailed in two separate reports (CVRWQCB, 2000 and CVRWQCB, 2002a). In summary, primary sources of selenium to the channels were determined to be diversions from the 94,000-acre Drainage Project Area (DPA) (both storm water flows and seepage from control gates), supply water, subsurface agricultural drainage from areas outside of the DPA, tailwater and local groundwater. To address the first source, diversions from the DPA, the Grassland Area Farmers (GAF) developed a storm water management plan, and internal control gates were sealed. These actions appear to have controlled peaks of selenium previously observed during storm events. Despite the storm water management plan and control gate modifications made by the GAF, selenium concentrations have continued to sporadically exceed the 2 µg/L monthly mean selenium objective in the wetland channels.

Mud Slough (North)

Selenium concentrations observed at Station D (Mud Slough (north) downstream of the SLD), during 2010 and 2011 are depicted in **Figure 7**. Water quality at Station D is dominated by the GBP drainage discharge. Selenium concentrations tend to be lowest from the fall through early winter (non-irrigation period) and highest during the irrigation period, which commences in mid winter (pre-plant irrigation) and lasts through the summer.

During 2010, the monthly average selenium concentrations at Station D ranged from 0.97 µg/L in October to 45.3 µg/L in May. During 2011, the monthly average selenium concentrations ranged from 1.0 µg/L in November to 22.5 µg/L in May. For comparison purposes, the 5 µg/L (4-day average) selenium water quality objective, which will apply after December 31, 2019 for Mud Slough (north) and the 15 µg/L performance goal, which applies December 31, 2015, are noted on **Figure 7**.Selenium concentrations regularly exceeded 5 µg/L at Station D. During 2010 and 2011, the observed concentration of selenium at Station C (Mud Slough (north) upstream of the drainage discharge) remained below 5 µg/L, as depicted in **Figure 8**. The maximum observed selenium concentration of 1.66 µg/L was noted for 2010 in July in Mud Slough upstream of SLD. For 2011 the maximum observed selenium concentration of 1.4 µg/L was also noted in July.

Boron Water Quality Objectives

Boron water quality objectives and monthly mean boron concentrations for Mud Slough, Salt Slough, and the San Joaquin River for 2010 and 2011 are presented in **Tables 5 and 6**.

During 2010, exceedances of the 2.0 µg/L objective occurred at Station D from March 16 through September 15. Exceedances also occurred at Station C in March, April, and May. The 5 µg/L (4-day average) objectives were met continuously at Station N throughout 2010.

During 2011, exceedances of the 2.0 µg/L objective occurred at Station D from March 1 through September 30. Exceedances also occurred at Station C in April. The 1.5 µg/L (4-day average) objectives were met continuously at Station N throughout 2011.

Sources of boron occur throughout the San Joaquin Basin and are not confined to the GBP service area (CVRWQCB, 2002a). The CVRWQCB is currently conducting a separate effort to control salt and boron loading to the lower San Joaquin Basin.

Molybdenum Water Quality Objectives

Molybdenum water quality objectives and monthly mean molybdenum concentrations for Mud Slough, Salt Slough, and the San Joaquin River for 2010 and 2011 are presented in **Tables 7 and 8**. For 2010 the data indicate that molybdenum concentrations were below the 19 µg/L water quality objectives in Mud Slough, Salt Slough, and the San Joaquin River throughout 2010 at Stations C, D, F, G, and N. Due to lab error no molybdenum samples were analyzed during the month of August.

For 2011 the data indicates that molybdenum concentrations were below the 19 µg/L water quality objective in Mud Slough above the San Luis Drain, Salt Slough and the San Joaquin River throughout 2011 at Stations C, F, G, and N. Exceedances occurred in Mud Slough below the San Luis Drain at Site D for the months of May and August 2011.

Nutrient Data

CVRWQCB and USBR staff collected nutrient samples at Stations B, C, D, G, and N. Available nutrient data for the San Luis Drain, Mud Slough (north), and the San Joaquin River are presented in **Tables 9 through 13**. For comparison purposes, the Primary Maximum Contaminant Level (MCL) for nitrate in drinking water is 10 mg/L nitrate expressed as nitrogen (CVR WQCB, 2003).

During 2010, nitrate levels in samples collected at Station B were above the MCL during January, March, May, and one of the sampling events in June, with a maximum recorded value of 17 mg/L. Nitrate levels in samples collected at site D during May were above the MCL with a maximum recorded value of 13.0 mg/L. Nitrate levels in samples collected at Stations C, G, and N were below the MCL in all samples collected during 2010.

During 2011, nitrate levels in samples collected at Station B were above the MCL during March, one sampling event in April, and two sampling events in May and June, with a maximum recorded value of 18.0 mg/L. Nitrate levels in samples collected at Stations C,D,G , and N were below the MCL in all samples collected during 2011.

Freshwater aquatic life criteria for ammonia are found in CVRWQCB (2003). The threshold value for ammonia toxicity is a function of both the temperature and pH of the ambient water from which the nutrient sample is collected. Temperature and pH field measurements were used to determine the ammonia toxicity threshold for each sample. Ammonia levels did not exceed the Ammonia Toxicity Thresholds throughout 2010 and 2011 at Stations B, C, D, G, and N.

Additional constituents (total Kjeldhal nitrogen, total phosphorus, and orthophosphate) continue to be collected to aid in the development of a TMDL for oxygen demanding substances in the San Joaquin River and future nutrient criteria.

Conclusions

Monitoring has shown that selenium concentrations in the San Joaquin River are a function of location in the River with respect to discharge points and tributary inflows, and of the assimilative capacity of the River. The lowest selenium concentrations in the San Joaquin River are upstream of Mud Slough (north) inflows. Mud Slough (north) inflow contains relatively high concentrations of selenium. The Merced River dilutes the San Joaquin River with respect to selenium. Selenium concentrations in the San Joaquin River at Station N, however, remain elevated relative to the background condition in the San Joaquin River at Station G.

The 2 µg/L monthly mean selenium water quality objective was exceeded in two of the wetland supply channels during 2010 and 2011. Selenium concentrations were substantially lower than pre-project conditions for all sites.

A number of sources may contribute to the exceedances of selenium water quality objectives in the wetland channels, including agricultural subsurface drainage from areas outside the GBP being discharged to the channels upstream of the wetlands.

For most of the year, the water quality of Mud Slough (north) downstream of the SLD inflow is governed by the GBP drainage discharge and fluctuates widely. Selenium concentrations tend to be lowest from the fall through early winter (non-irrigation period) and highest during the irrigation season, which commences in mid winter (pre-plant irrigation) and lasts through the summer. Selenium concentrations regularly exceeded 5 µg/L in Mud Slough (north) downstream of the SLD inflow for 2010 and 2011. Upstream of the drainage discharge, the concentration of selenium was below 2 µg/L in all samples collected during 2010 and 2011.

Boron water quality data from Mud Slough (north), Salt Slough, and the San Joaquin River were compared to applicable water quality objectives and there were no exceedances in the San Joaquin River or in Salt Slough for 2010 and 2011. Boron water quality objectives were exceeded during the irrigation season in Mud Slough (north) for 2010 and 2011. Sources of boron occur throughout the San Joaquin Basin and are not confined to the GBP. The CVRWQCB is concurrently conducting a separate effort to control salt and boron loading to the lower San Joaquin Basin.

Molybdenum water quality objectives were met in Salt Slough, and the San Joaquin River throughout 2010. For 2011 exceedances occurred in Mud Slough North (Site D) for the months of May and August.

Nitrate concentrations were frequently observed above the MCL in samples collected at Station B, and were the lowest during the summer months for 2010 and 2011. Nitrate concentrations were below the MCL at Stations C, D, G, and N in all samples collected during 2010 and 2011. Ammonia levels were observed below the toxicity threshold at all stations during 2010 and 2011.

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Table 1. Summary of Water Quality Monitoring Plan

Location	Site	Description	Purpose	Analytical Parameter	Frequency	Sampling Methodology
San Luis Drain	A	inflow to SLD	water quality of inflow	Se, B, SC	weekly composite	auto-sampler
				SC, TSS	weekly	mid-channel, grab
	B	discharge from SLD	water quality of discharge (for Se load calculation)	Se, B, SC	daily composite	auto-sampler
				pH, SC, Temp, Se, B, TSS[1], Mo[2], Nutrients[3]	weekly	mid-channel, grab
Mud Slough (north)	C	upstream of SLD discharge	Mud Slough (north) base water quality prior to receiving drainage discharges	pH, SC, Temp, Se, B, Mo[2], Nutrients[3]	weekly	grab
	D	downstream of discharge	Mud Slough (north) water quality as impacted by drainage discharge	pH, SC, Temp, Se, B, Mo[2], Nutrients[3]	weekly	mid-channel, grab
	I/I2	back water	water quality impact of Mud Slough (north) flooding in Kesterson Refuge	Se, B, SC	annually	grab
Wetland Channels	F	Salt Slough	water quality of habitat and to track improvements in former drainage conveyance channel	pH, SC, Temp, Se, B, Mo[2], Nutrients[3]	weekly	grab
	J	Camp 13	verify no discharge of drainage provision, water quality of wetland water supply channel	Se, B, SC	weekly	grab
	K	Agatha Canal	verify no discharge of drainage provision, water quality of wetland water supply channel	Se, B, SC	weekly	grab
	L2	San Luis Canal	water quality of wetland water supply channel	Se, B, SC	weekly	grab
	M2	Santa Fe Canal	water quality of wetland water supply channel	Se, B, SC	weekly	grab
San Joaquin River	G	at Fremont Ford (upstream of drainage inflow)	track improvements in former drainage conveyance channel and characterize water quality of habitat	pH, SC, Temp, Se, B, Mo[2], Nutrients[3]	weekly	grab
	N	at Crows Landing (downstream of Merced River confluence)	characterize water quality of habitat	Se, B, SC	daily composite	auto-sampler
				pH, SC, Temp, Se, B, Mo[2], Nutrients[3]	weekly	grab

Notes:

1 TSS required daily during storm events

2 Molybdenum required monthly

3 Nutrients required monthly September through February and every other week March through August

Table 2. Summary of Selenium Water Quality Objectives and Compliance Time Schedule

[Selenium Water Quality Objectives (**in bold**) and Performance Goals (*in italics*)]

Water Body/Water Year Type[1]	31 December 2015	31 December 2019
Mud Slough (north) and the San Joaquin River from the Mud Slough confluence to the Merced River	*15 ug/L monthly mean*	**5 ug/L 4-day average**

[1] The water year classification will be established using the best available estimate of the 60-20-20 San Joaquin Valley water year hydrologic classification (as defined in Footnote17 for Table 3 in the State Water Resources Control Board's Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, May 1995) at the 75% exceedance level using data from the Department of Water Resources Bulletin 120 series. The previous water year's classification will apply until an estimate is made of the current water year.

Table 3. Selenium Concentrations in the Grassland Watershed and San Joaquin River: 2010

Station ID	Description	Mean Monthly Concentration (µg/L) Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	WQO
C	Mud Slough (N) upstream of SLD Discharge	0.4	0.4	0.9	0.5	0.5	0.6	1.1	1.0	0.5	0.4	0.5	0.5	2.0
D	Mud Slough (N) downstream of SLD Discharge	7.2	8.7	8.8	8.5	39.9	17.6	18.4	14.6	7.2	1.3	3.8	5.6	
F	Salt Slough at Lander Avenue	0.5	0.6	0.7	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.5	0.6	2.0
G	SJR at Fremont Ford	0.7	0.5	0.5	0.4	0.8	0.4	0.4	0.4	0.2	0.4	0.5	0.5	2.0
N	SJR at Crows Landing Weekly Grab Samples	2.2	1.4	1.4	0.7	1.4	1.3	1.5	1.3	0.5	0.5	0.8	1.1	5.0
N	SJR at Crows Landing Daily Autosamples	1.5	1.5	1.5	0.7	1.3	1.2	1.3	1.4	0.6	0.5	0.6	0.8	5.0

Notes:

Bold = water quality objective exceedance

WQO = water quality objective in µg/L

NA = no data available

Table 4. Selenium Concentrations in the Grassland Watershed and San Joaquin River: 2011

Station ID	Description	Mean Monthly Concentration (µg/L) Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Monthly WQO
C	Mud Slough (N) upstream of SLD Discharge	0.5	0.7	0.8	0.6	0.9	1.0	0.7	1.1	0.8	0.3	0.3	0.2	0.2	2.0
D	Mud Slough (N) downstream of SLD Discharge	5.3	9.6	9.9	11.6	13.8	14.3	12.7	11.2	12.9	6.6	2.0	1.9	4.1	
F	Salt Slough at Lander Avenue	0.5	0.7	0.8	0.6	0.7	0.7	0.4	0.6	0.4	0.2	0.3	0.4	NA	2.0
G	SJR at Fremont Ford	NA	0.4	0.6	0.2	0.4	0.4	0.2	0.6	0.3	0.2	0.3	0.3	0.3	2.0
N	SJR at Crows Landing Weekly Grab Samples	0.4	0.5	0.8	0.4	0.5	0.6	0.5	0.6	0.8	0.5	0.3	0.5	0.9	5.0
N	SJR at Crows Landing Daily Autosamples	0.5	0.5	0.3	0.5	0.4	0.5	0.4	0.4	0.7	0.4	0.3	0.5	1.0	5.0

Notes:

Bold = water quality objective exceedance

WQO = water quality objective in µg/L

NA = no data available, site not accessible

Regional Board data

Reclamation data

Table 5. Boron Concentrations in the Grassland Watershed and San Joaquin River: 2010

Station ID	Description	Mean Monthly Concentration (mg/L)														Monthly WQO
		Jan-10	Feb-10	Mar-10		Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10		Oct-10	Nov-10	Dec-10	
C	Mud Slough (N) upstream of SLD Discharge	a	a	a	**2.1**	**2.4**	**3.0**	1.8	2.0	0.9	0.5	a	a	a	a	2.0
D	Mud Slough (N) downstream of SLD Discharge	a	a	a	**3.2**	**4.1**	**6.5**	**4.5**	**6.4**	**4.7**	**3.6**	a	a	a	a	2.0
F	Salt Slough at Lander Avenue	a	a	a	1.1	0.7	0.6	0.5	0.5	0.4	0.5	a	a	a	a	2.0
G	SJR at Fremont Ford	a	a	a	0.6	0.3	0.3	0.3	0.3	0.4	0.2	a	a	a	a	2.0
N	SJR at Crows Landing Weekly Grab Samples	0.9	1.0	1.0	0.7	0.5	0.4	0.5	0.8	0.7	0.3	0.4	0.4	0.7	0.7	1.5
N	SJR at Crows Landing Daily Autosamples	0.9	0.9	0.6	0.9	0.5	0.4	0.5	0.7	0.7	0.3	0.3	0.4	0.7	0.7	1.5

Notes:

Bold = water quality objective exceedance

WQO = water quality objective in mg/L

na = no data available

a = objective only applies 15 March through 15 September

Table 6. Boron Concentrations in the Grassland Watershed and San Joaquin River: 2011

Station ID	Description	Mean Monthly Concentration (mg/L) Jan-11	Feb-11	Mar-11		Apr-11	May-11	Jun-11		Jul-11	Aug-11	Sep-11		Oct-11	Nov-11	Dec-11	Monthly WQO
C	Mud Slough (N) upstream of SLD Discharge	a	a	a	1.5	**2.4**	1.6	1.2	1.3	1.2	0.9	0.6	a	a	a	a	2.0
D	Mud Slough (N) downstream of SLD Discharge	a	a	a	**3.0**	**4.6**	**4.0**	**2.7**	**3.3**	**3.5**	**4.6**	**3.4**	a	a	a	a	2.0
F	Salt Slough at Lander Avenue	a	a	a	0.8	0.6	0.4	0.4	0.4	0.4	0.3	0.5	a	a	a	a	2.0
G	SJR at Fremont Ford	a	a	a	0.3	0.0	0.1	3.0	0.1	0.1	0.2	0.3	a	a	a	a	2.0
N	SJR at Crows Landing Weekly Grab Samples	0.2	0.2	0.3	0.3	0.1	0.1	0.2	0.2	0.2	0.4	0.3	0.3	0.2	0.4	0.8	1.5
N	SJR at Crows Landing Daily Autosamples	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.2	0.4	0.3	0.3	0.2	0.5	0.8	1.5

Notes:

Bold = water quality objective exceedance
a = objective only applies 15 March through 15 September
WQO = water quality objective in mg/L
Regional Board data
na = no data available
Reclamation data

Table 7. Molybdenum Concentrations in the Grassland Watershed and San Joaquin River: 2010

Station ID	Description	Mean Monthly Concentration (ug/L)												Monthly WQO
		Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	
C	Mud Slough (N) upstream of SLD Discharge	6.3	8.4	4.5	7.5	18.1	2.0	12.4	NA	2.3	6.0	6.6	7.4	19.0
D	Mud Slough (N) downstream of SLD Discharge	12.2	11.6	9.3	11.4	17.7	1.5	17.9	NA	10.8	7.3	8.4	11.9	19.0
F	Salt Slough at Lander Avenue	9.1	8.9	8.7	5.0	7.3	5.7	6.0	NA	5.2	4.3	6.2	6.3	19.0
G	SJR at Fremont Ford	9.5	6.4	2.3	4.1	2.3	2.1	6.3	NA	2.7	4.6	4.5	6.3	19.0
N	SJR at Crows Landing Grab Samples	5.6	4.5	1.8	3.9	2.6	2.4	5.2	NA	2.6	3.3	3.3	5.6	10.0

Notes:

Bold	= water quality objective exceedance
WQO	= water quality objective in ug/L
na	= no data available

Table 8. Molybdenum Concentrations in the Grassland Watershed and San Joaquin River: 2011

Station ID	Description	Mean Monthly Concentration (ug/L) Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Monthly WQO
C	Mud Slough (N) upstream of SLD Discharge	5.8	10.1	4.0	8.0	14.2	7.8	8.7	6.9	14.0	7.3	4.9	5.0	6.5	19.0
D	Mud Slough (N) downstream of SLD Discharge	8.9	12.2	6.0	9.7	**20.4**	10.6	10.0	11.0	**21.0**	11.0	6.5	7.4	7.9	19.0
F	Salt Slough at Lander Avenue	8.1	7.1	6.9	9.4	8.0	5.3	7.5	8.0	6.3	5.7	5.0	5.1	NA	19.0
G	SJR at Fremont Ford	1.9	4.4	3.5	<1.4	NA	<1.4	2.0	1.7	5.2	5.1	4.4	5.3	8.7	19.0
N	SJR at Crows Landing Grab Samples	1.5	2.5	<1.4	NA	1.7	2.7	1.5	1.3	4.9	2.8	1.8	3.0	4.5	10.0

Notes:

Bold	= water quality objective exceedance		Regional Board data
WQO	= water quality objective in ug/L		Reclamation data
na	= no data available		

Table 9. Nutrient Series Data, Site B, SLD at terminus (MER535) January 2010 - December 2011

Parameter Units	Agency	Nitrate mg/L as N	Total Kjeldhal Nitrogen mg/L	Total Phosphorus mg/L	Ortho Phosphate mg/L as P	Dissolved Ammonia mg/L as N	Ammonia Toxicity Threshold mg/L as N
05 Jan 2010	(1)	14.0	<0.5	0.05	0.01	< 0.20	5.08
02 Feb 2010	(1)	7.0	1.0	0.10	0.02	< 0.20	1.91
02 Mar 2010	(1)	15.0	<0.5	0.12	0.03	< 0.20	1.75
16 Mar 2010	(1)	15.0	<0.5	0.09	<0.01	< 0.20	1.33
06 Apr 2010	(1)	3.4	2.5	0.09	0.02	0.78	3.14
20 Apr 2010	(1)	2.6	1.6	0.11	0.01	< 0.20	1.91
04 May 2010	(1)	17.0	1.1	0.07	0.01	NA	2.86
18 May 2010	(1)	14.0	1.3	NA	0.02	< 0.20	0.85
01 Jun 2010	(1)	12.0	1.7	0.10	<0.01	0.22	0.52
15 Jun 2010	(1)	6.8	1.9	0.12	0.05	NA	0.26
06 Jul 2010	(1)	4.4	2.7	0.16	0.04	NA	0.24
20 Jul 2010	(1)	3.9	3.0	0.16	<0.01	NA	1.53
03 Aug 2010	(1)	5.2	<0.5	0.19	0.03	< 0.20	0.24
17 Aug 2010	(1)	4.8	3.1	0.15	<0.01	< 0.20	2.23
07 Sep 2010	(1)	1.1	2.5	0.11	<0.01	NA	0.58
05 Oct 2010	(1)	0.1	1.6	0.09	<0.01	< 0.20	2.06
02 Nov 2010	(1)	<0.05	0.8	0.12	0.02	< 0.20	3.01
07 Dec 2010	(1)	9.0	0.9	0.05	<0.01	0.22	4.13
04 Jan 2011	(1)	7.3	<.5	0.09	0.04	< 0.20	3.18
01 Feb 2011	(1)	4.9	1	0.07	0.01	< 0.20	2.54
01 Mar 2011	(1)	15.0	1	0.09	0.04	< 0.20	2.33
15 Mar 2011	(1)	12.0	NA	0.11	0.18	NA	2.41
05 Apr 2011	(1)	8.5	2	0.14	<0.01	< 0.20	1.99
19 Apr 2011	(1)	15.0	1	0.09	0.06	< 0.20	1.27
03 May 2011	(1)	12.0	NA	0.14	<0.01	< 0.20	1.02
17 May 2011	(1)	9.8	2	0.12	NA	< 0.20	0.59
31 May 2011	(2)	16.0	2	0.13	0.01	< 0.20	0.58
07 Jun 2011	(1)	18.0	NA	0.13	0.02	< 0.20	0.94
14 Jun 2011	(2)	14.0	2.1	0.12	0.01	< 0.20	0.43
21 Jun 2011	(1)	2.3	2	0.13	0.05	0.34	0.46
28 Jun 2011	(2)	16.0	2.0	0.14	0.02	0.22	0.41
13 Jul 2011	(2)	8.8 H	2.1	0.16	0.01	< 0.20 L	0.32
26 Jul 2011	(2)	9.0	1.5	0.11	<0.01	< 0.20 L	0.29
11 Aug 2011	(2)	8.1	2.5	0.13	0.041	< 0.20	0.40
23 Aug 2011	(2)	6.0	2.7	0.15	0.07	< 0.20	0.23
22 Sep 2011	(2)	4.8	2.8	0.18	<0.01	< 0.20	0.35
06 Oct 2011	(2)	0.6	2.0 T	0.13	0.02	< 0.20	2.38
03 Nov 2011	(2)	1.2	1.9 T	0.13	0.01	0.67	1.79
08 Dec 2011	(2)	6.4	0.9	0.06	0.04	< 0.20	3.58

Data Source:	(1)	California Regional Water Quality Control Board, Central Valley Region
	(2)	Bureau of Reclamation, Mid-Pacific Region
Notes:		Water quality objective exceedance of 10 mg/L
	NA	No sample collected, result not available
	H	Results may have high bias
	V	Results may vary excessively
	T	Results obtained past holding time

Table 10. Nutrient Series Data, Site C, Mud Slough (North) Upstream of SLD (MER536) January 2010 - December 2011

Parameter	Agency	Nitrate	Total Kjeldhal Nitrogen	Total Phosphorus	Ortho Phosphate	Dissolved Ammonia	Ammonia Toxicity Threshold
Units		mg/L as N	mg/L	mg/L	mg/L as P	mg/L as N	mg/L as N
05 Jan 2010	(1)	0.07	1.0	0.32	0.34	<0.20	4.09
02 Feb 2010	(1)	0.13	1.2	0.29	0.24	<0.20	2.99
02 Mar 2010	(1)	0.96	<0.5	0.48	0.30	<0.20	2.22
16 Mar 2010	(1)	0.32	<0.5	0.40	NA	<0.20	2.07
06 Apr 2010	(1)	0.22	2.4	0.46	0.29	<0.20	2.26
20 Apr 2010	(1)	<0.05	1.9	0.69	0.50	<0.20	2.46
04 May 2010	(1)	<0.05	1.1	0.36	0.26	NA	3.39
18 May 2010	(1)	<0.05	0.6	NA	0.26	<0.20	2.41
01 Jun 2010	(1)	<0.05	1.3	0.37	0.20	<0.20	2.52
15 Jun 2010	(1)	<0.05	1.4	0.31	0.21	NA	2.33
06 Jul 2010	(1)	0.14	1.2	0.18	0.08	NA	1.37
20 Jul 2010	(1)	0.20	1.3	0.18	0.07	NA	1.67
03 Aug 2010	(1)	0.20	<0.5	0.18	0.07	<0.20	1.54
17 Aug 2010	(1)	<0.05	0.9	0.17	0.03	<0.20	0.73
07 Sep 2010	(1)	0.25	0.9	0.17	0.12	NA	1.16
05 Oct 2010	(1)	0.18	1.1	0.41	0.31	<0.20	3.17
02 Nov 2010	(1)	0.16	1.2	0.40	0.32	0.22	3.65
07 Dec 2010	(1)	0.13	1.3	0.20	0.15	<0.20	3.26
04 Jan 2011	(1)	0.36	NA	0.32	0.24	NA	2.72
01 Feb 2011	(1)	0.13	1.2	0.23	0.18	0.22	2.84
01 Mar 2011	(1)	0.65	1.0	0.26	0.14	<0.20	1.63
15 Mar 2011	(1)	0.36	NA	0.47	0.41	NA	2.57
05 Apr 2011	(1)	0.13	1.1	0.45	0.30	0.20	2.44
19 Apr 2011	(1)	0.23	1.5	0.49	0.41	<0.20	1.74
03 May 2011	(1)	<0.05	NA	0.43	0.30	<0.20	1.68
17 May 2011	(1)	0.20	3.2	0.86	NA	<0.20	2.44
31 May 2011	(2)	0.24	1.1	0.21	0.1	0.67	2.49
07 Jun 2011	(1)	0.40	NA	0.24	0.13	<0.20	2.51
14 Jun 2011	(2)	0.46	1.4	0.23	0.11	<0.20	1.89
21 Jun 2011	(1)	0.31	2.0	0.19	0.16	0.22	0.88
28 Jun 2011	(2)	0.26	1.4	0.23	0.14	<0.20	1.37
13 Jul 2011	(2)	0.12 H	1.2	0.21	0.09	< 0.20 L	0.50
26 Jul 2011	(2)	0.16	0.9	0.16	0.06	< 0.20 L	3.34
11 Aug 2011	(2)	0.55	0.9	0.15	0.11	<0.20	0.44
23 Aug 2011	(2)	0.39	0.8	0.17	0.12	<0.20	0.43
08 Sep 2011	(2)	0.06	1.4	0.33	0.18	<0.20	0.10
06 Oct 2011	(2)	0.29	1.1 T	0.39	0.28	<0.20	2.26
03 Nov 2011	(2)	0.16	1.0 T	0.31	0.21	0.67	1.29
08 Dec 2011	(2)	0.10	0.9	0.16	0.11	<0.20	1.79

Data Source:	(1)	California Regional Water Quality Control Board, Central Valley Region
	(2)	Bureau of Reclamation, Mid-Pacific Region
Notes:	NA	No sample collected, result not available
	H	Results may have high bias
	V	Results may vary excessively
	T	Results obtained past holding time

Table 11. Nutrient Series Data, Site D, Mud Slough (North) Downstream of SLD (MER542) January 2010 - December 2011

Parameter	Agency	Nitrate	Total Kjeldhal Nitrogen	Total Phosphorus	Ortho Phosphate	Dissolved Ammonia	Ammonia Toxicity Threshold
Units		mg/L as N	mg/L	mg/L	mg/L as P	mg/L as N	mg/L as N
05 Jan 2010	(1)	3.4	0.9	0.16	0.15	<0.20	4.40
02 Feb 2010	(1)	1.4	1.2	0.27	0.16	<0.20	2.80
02 Mar 2010	(1)	3.2	1.6	0.36	0.18	<0.20	2.37
16 Mar 2010	(1)	3.5	NA	0.35	NA	<0.20	1.97
06 Apr 2010	(1)	0.9	2.4	0.41	0.06	<0.20	2.33
20 Apr 2010	(1)	1.2	1.6	0.36	0.05	<0.20	2.97
04 May 2010	(1)	10.0	1.2	0.18	0.03	NA	3.18
18 May 2010	(1)	13.0	1.3	NA	0.02	<0.20	1.04
01 Jun 2010	(1)	4.4	1.6	0.27	0.02	<0.20	1.16
15 Jun 2010	(1)	2.5	1.7	0.24	0.08	NA	1.13
06 Jul 2010	(1)	1.8	1.8	0.21	0.01	NA	0.51
20 Jul 2010	(1)	2.2	2.0	0.17	0.01	NA	2.48
03 Aug 2010	(1)	2.0	NA	0.23	0.05	<0.20	0.41
17 Aug 2010	(1)	1.4	2.0	0.20	0.04	<0.20	1.37
07 Sep 2010	(1)	0.9	1.3	0.14	0.04	NA	1.10
05 Oct 2010	(1)	0.2	1.2	0.39	0.26	<0.20	1.82
02 Nov 2010	(1)	0.1	1.2	0.39	0.17	<0.20	3.58
07 Dec 2010	(1)	1.5	NA	NA	0.13	NA	3.54
04 Jan 2011	(1)	1.5	NA	0.28	0.21	NA	2.84
01 Feb 2011	(1)	1.0	1.1	0.21	0.14	<0.20	3.14
01 Mar 2011	(1)	2.5	1.1	0.24	0.15	<0.20	2.13
15 Mar 2011	(1)	2.2	NA	0.42	0.38	NA	2.49
05 Apr 2011	(1)	1.5	1.3	0.42	0.14	<0.20	2.43
19 Apr 2011	(1)	3.6	1.5	0.38	0.15	<0.20	1.62
03 May 2011	(1)	4.7	NA	0.31	<0.01	<0.20	1.15
17 May 2011	(1)	2.6	1.8	0.35	NA	<0.20	1.39
31 May 2011	(2)	3.0	1.6	0.20	0.02	<0.20	1.71
07 Jun 2011	(1)	7.5	NA	0.19	0.03	0.22	1.49
14 Jun 2011	(2)	3.9	1.6	0.20	0.013	<0.20	1.44
21 Jun 2011	(1)	0.8	1.3	0.20	0.10	0.34	1.15
28 Jun 2011	(2)	1.8	1.4	0.22	0.055	<0.20	1.33
13 Jul 2011	(2)	0.3 H	1.0	0.22	0.07	<0.20 L	0.39
26 Jul 2011	(2)	3.2	1.2	0.14	0.02	0.30 L	0.39
11 Aug 2011	(2)	2.2	1.5	0.18	0.029	<0.20	0.63
23 Aug 2011	(2)	1.4	1.2	0.18	0.07	<0.20	0.61
08 Sep 2011	(2)	2.4	1.9	0.22	0.02	0.22	0.37
06 Oct 2011	(2)	0.4	1.3 T	0.38	0.23	<0.20	3.59
03 Nov 2011	(2)	0.2	1.0 T	0.28	0.16	0.34	3.10
08 Dec 2011	(2)	1.0	1.1	0.13	0.11	<0.20	2.80

Data Source:	(1)	California Regional Water Quality Control Board, Central Valley Region
	(2)	Bureau of Reclamation, Mid-Pacific Region
Notes:		Water quality objective exceedance
	NA	No sample collected, result not available
	H	Results may have high bias
	V	Results may vary excessively
	T	Results obtained past holding time

Table 12. Nutrient Series Data, Site G, San Joaquin River at Fremont Ford (MER538) January 2010 - December 2011

Parameter	Agency	Nitrate	Total Kjeldhal Nitrogen	Total Phosphorus	Ortho Phosphate	Dissolved Ammonia	Ammonia Toxicity Threshold
Units		mg/L as N	mg/L	mg/L	mg/L as P	mg/L as N	mg/L as N
05 Jan 2010	(1)	0.19	0.6	0.17	0.12	<0.20	4.02
02 Feb 2010	(1)	0.28	0.8	0.23	0.17	<0.20	4.40
02 Mar 2010	(1)	1.10	1.3	0.28	0.20	<0.20	4.66
16 Mar 2010	(1)	1.30	NA	0.18	NA	<0.20	5.56
06 Apr 2010	(1)	0.65	0.9	0.21	0.15	<0.20	5.21
20 Apr 2010	(1)	0.30	0.6	0.19	0.14	<0.20	2.15
04 May 2010	(1)	0.18	0.6	0.16	0.11	NA	3.47
18 May 2010	(1)	0.23	0.7	NA	0.23	<0.20	2.04
01 Jun 2010	(1)	0.22	0.8	0.17	0.09	<0.20	1.92
15 Jun 2010	(1)	0.89	1.1	0.26	0.23	NA	2.34
06 Jul 2010	(1)	1.30	1.0	0.29	0.20	NA	1.99
20 Jul 2010	(1)	1.40	1.1	0.34	0.26	NA	2.88
03 Aug 2010	(1)	0.96	NA	0.32	0.22	<0.20	1.60
17 Aug 2010	(1)	0.69	0.9	0.30	0.19	<0.20	1.91
07 Sep 2010	(1)	0.33	0.7	0.22	0.18	NA	2.34
05 Oct 2010	(1)	0.18	0.7	0.23	0.19	<0.20	2.97
02 Nov 2010	(1)	0.41	<0.5	0.23	0.16	<0.20	4.93
07 Dec 2010	(1)	0.37	0.8	0.17	0.11	<0.20	4.70
04 Jan 2011	(1)	0.47	NA	0.25	0.19	NA	1.97
01 Feb 2011	(1)	0.39	0.8	0.19	0.13	<0.20	4.29
01 Mar 2011	(1)	1.80	1.1	0.24	0.17	<0.20	2.26
15 Mar 2011	(1)	1.90	NA	0.32	0.35	NA	4.16
05 Apr 2011	(1)	<.05	1.1	0.34	0.08	<0.20	5.00
17 May 2011	(1)	0.14	<0.5	0.14	NA	<0.20	3.22
31 May 2011	(2)	0.19	< 0.5	0.16	0.09	0.22	3.53
07 Jun 2011	(1)	0.29	NA	0.17	0.11	<0.20	3.22
14 Jun 2011	(2)	0.27	0.8	0.15	0.07	<0.20	1.66
21 Jun 2011	(1)	0.07	<0.5	0.11	0.10	0.22	2.78
26 Jul 2011	(2)	0.84	1.3	0.32	0.21	< 0.20 L	1.24
11 Aug 2011	(2)	0.81	1.1	0.28	0.19	< 0.20	1.25
23 Aug 2011	(2)	0.53	0.7	0.29	0.26	< 0.20	1.55
08 Sep 2011	(2)	0.40	0.8	0.29	0.21	< 0.20	1.95
06 Oct 2011	(2)	0.26	0.8 T	0.22	0.15	< 0.20	3.21
03 Nov 2011	(2)	0.16	0.7 T	0.22	0.15	0.78	2.80
08 Dec 2011	(2)	0.31	0.7	0.25	0.22	< 0.20	2.80

Data Source:	(1)	California Regional Water Quality Control Board, Central Valley Region
	(2)	Bureau of Reclamation, Mid-Pacific Region
Notes:		Water quality objective exceedance
	NA	No sample collected, result not available
	H	Results may have high bias
	V	Results may vary excessively
	T	Results obtained past holding time

Table 13. Nutrient Series Data, Site N, San Joaquin River at Crows Landing (STC504)

Parameter	Agency	Nitrate	Total Kjeldhal Nitrogen	Total Phosphorus	Ortho Phosphate	Dissolved Ammonia	Ammonia Toxicity Threshold
Units		mg/L as N	mg/L	mg/L	mg/L as P	mg/L as N	mg/L as N
05 Jan 2010	(1)	1.90	0.7	0.16	0.11	<0.20	5.39
02 Feb 2010	(1)	1.30	1.1	0.24	0.19	<0.20	3.14
02 Mar 2010	(1)	1.20	1.1	0.27	0.15	<0.20	4.21
16 Mar 2010	(1)	1.60	NA	0.23	NA	<0.20	3.94
06 Apr 2010	(1)	2.00	1.0	0.26	0.18	<0.20	4.63
20 Apr 2010	(1)	1.10	<0.5	0.20	0.13	<0.20	2.26
04 May 2010	(1)	0.63	<0.5	0.15	0.10	NA	3.79
18 May 2010	(1)	1.30	0.6	NA	0.11	<0.20	2.53
01 Jun 2010	(1)	1.10	0.8	0.18	0.09	<0.20	3.34
15 Jun 2010	(1)	1.30	0.8	0.21	0.18	NA	1.98
06 Jul 2010	(1)	2.40	1.0	0.23	0.13	NA	1.70
20 Jul 2010	(1)	1.80	1.3	0.26	0.12	NA	2.05
03 Aug 2010	(1)	2.60	NA	0.28	0.16	<0.20	1.53
17 Aug 2010	(1)	2.50	0.8	0.23	0.15	<0.20	1.57
07 Sep 2010	(1)	2.00	0.6	0.18	0.14	NA	2.01
05 Oct 2010	(1)	2.60	0.6	0.21	0.17	<0.20	2.72
02 Nov 2010	(1)	1.50	<0.5	0.18	0.12	<0.20	4.38
07 Dec 2010	(1)	2.00	NA	NA	0.11	<0.20	3.14
04 Jan 2011	(1)	0.48	NA	0.22	0.16	NA	3.07
01 Feb 2011	(1)	0.27	<0.5	0.09	0.05	<0.20	4.25
01 Mar 2011	(1)	0.82	0.7	0.12	0.08	<0.20	2.36
15 Mar 2011	(1)	0.70	NA	0.12	0.16	NA	3.58
19 Apr 2011	(1)	0.13	<0.5	0.14	0.13	<0.20	3.62
03 May 2011	(1)	0.15	NA	0.13	0.87	<0.20	4.12
17 May 2011	(1)	0.30	<0.5	0.14	NA	<0.20	3.38
31 May 2011	(2)	0.38	0.7	0.12	< 0.01	0.22	2.82
07 Jun 2011	(1)	1.10	NA	0.17	0.10	<0.20	3.44
14 Jun 2011	(2)	0.81	0.7	0.17	0.08	<0.20	2.42
21 Jun 2011	(1)	0.49	0.2	0.14	0.13	0.22	2.91
28 Jun 2011	(2)	0.20	0.6	0.12	0.07	0.22	1.42
13 Jul 2011	(2)	0.20 H	0.6 T	0.12	0.07	< 0.20 L	1.95
26 Jul 2011	(2)	2.00	0.7	0.23	0.13	< 0.20 L	2.17
11 Aug 2011	(2)	2.80	1.0	0.24	0.14	<0.20	1.68
23 Aug 2011	(2)	2.00	0.7	0.24	0.18	<0.20	2.03
08 Sep 2011	(2)	2.40	0.8	0.22	0.15	<0.20	1.60
06 Oct 2011	(2)	1.20	< 0.5 T	0.15	0.10	<0.20	2.56
03 Nov 2011	(2)	1.80	0.7 T	0.15	0.11	<0.20	3.58
08 Dec 2011	(2)	1.40	< 0.5	0.13	0.11	<0.20	2.80

Data Source:	(1)	California Regional Water Quality Control Board, Central Valley Region
	(2)	Bureau of Reclamation, Mid-Pacific Region
Notes:		Water quality objective exceedance
	NA	No sample collected, result not available
	H	Results may have high bias
	V	Results may vary excessively
	T	Results obtained past holding time

Figure 1. Selenium Concentration in the San Joaquin River 2010

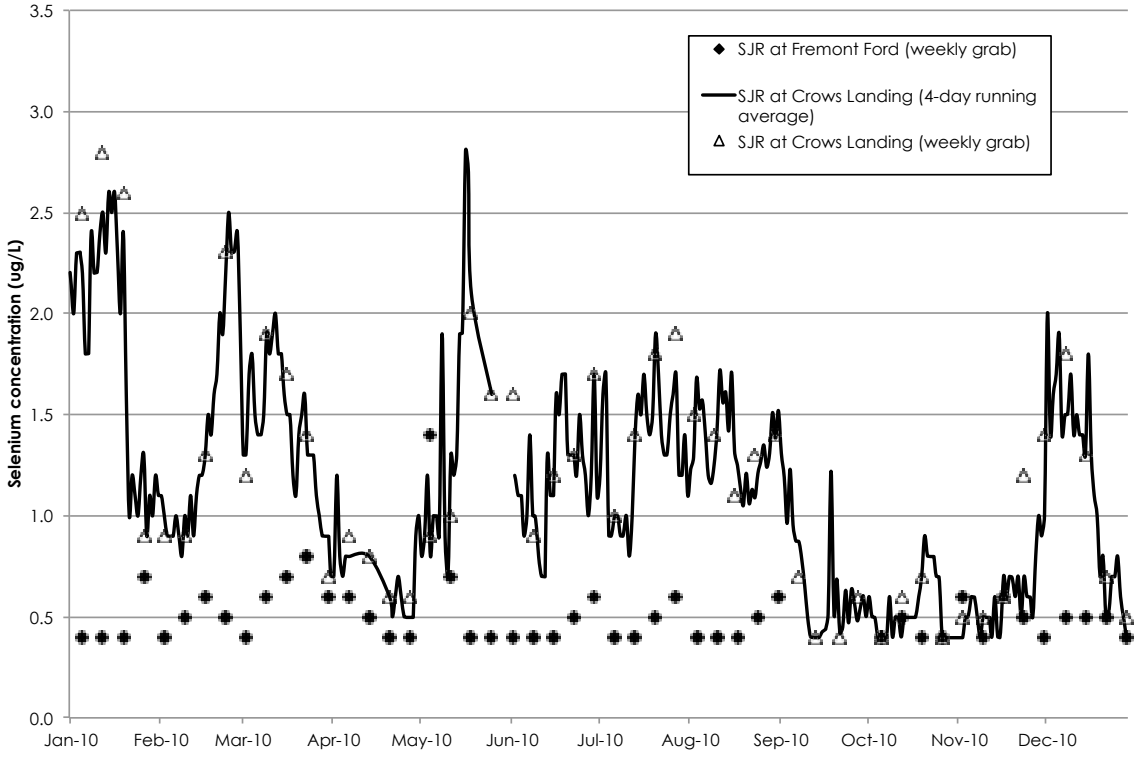


Figure 2. Selenium Concentration in the San Joaquin River 2011

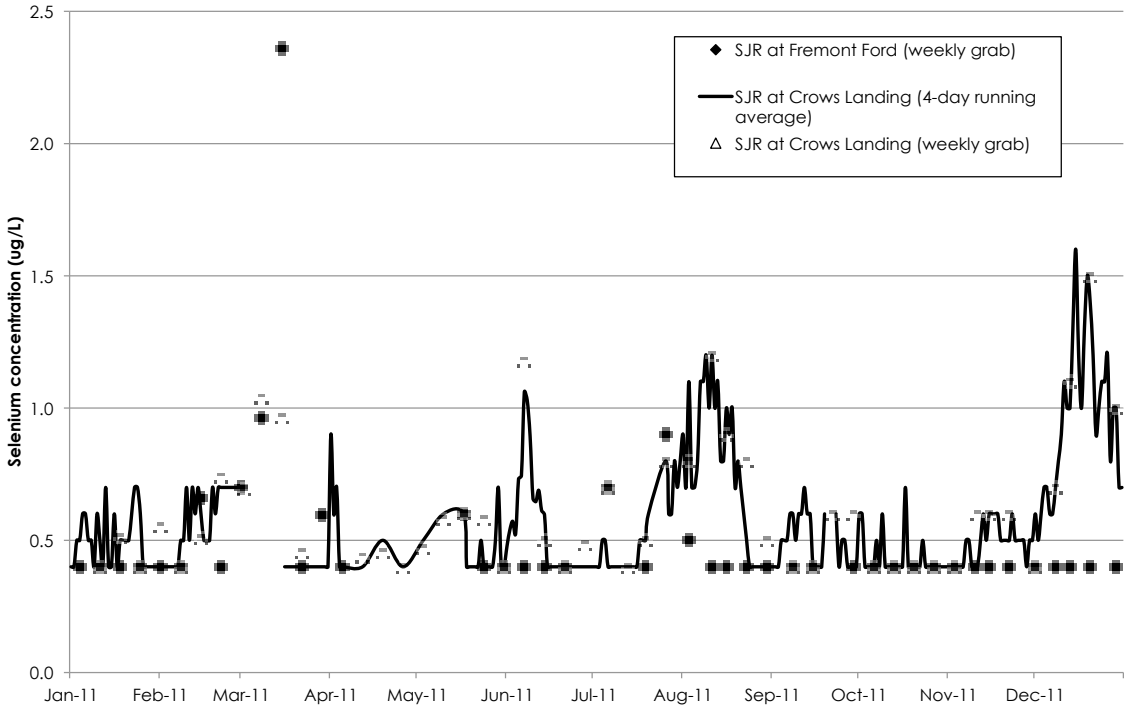


Figure 3. Monthly Mean Selenium Concentration in the San Joaquin River at Crows Landing (Site N) 2010

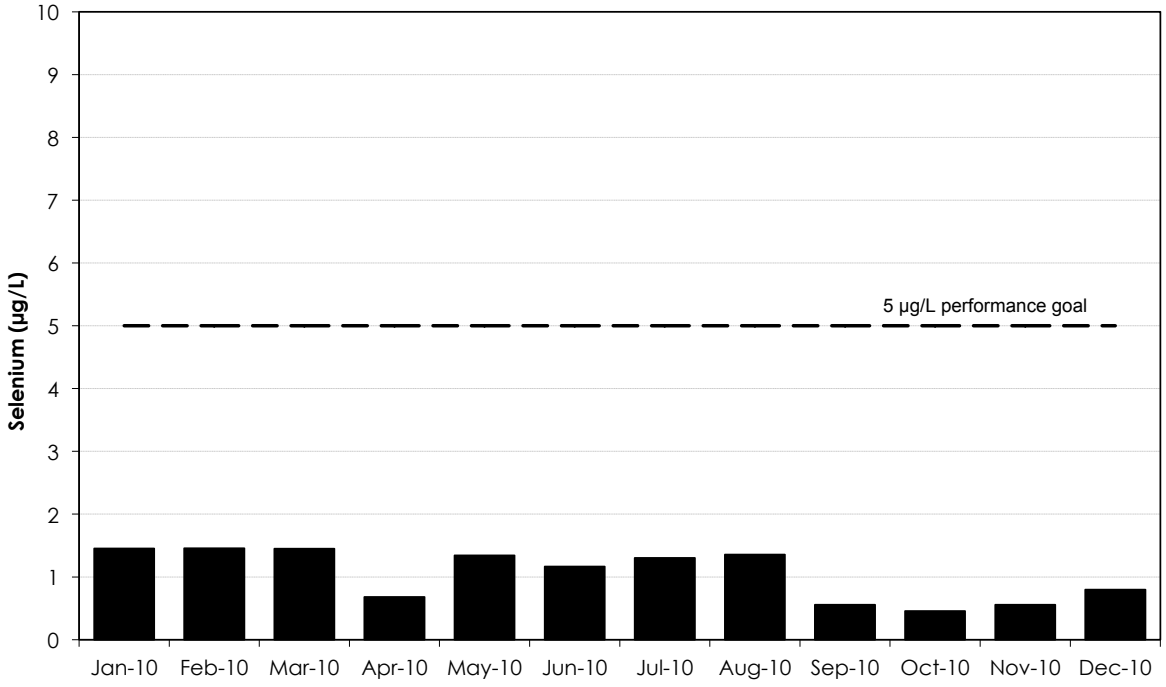


Figure 4. Monthly Mean Selenium Concentration in the San Joaquin River at Crows Landing (Site N) 2011

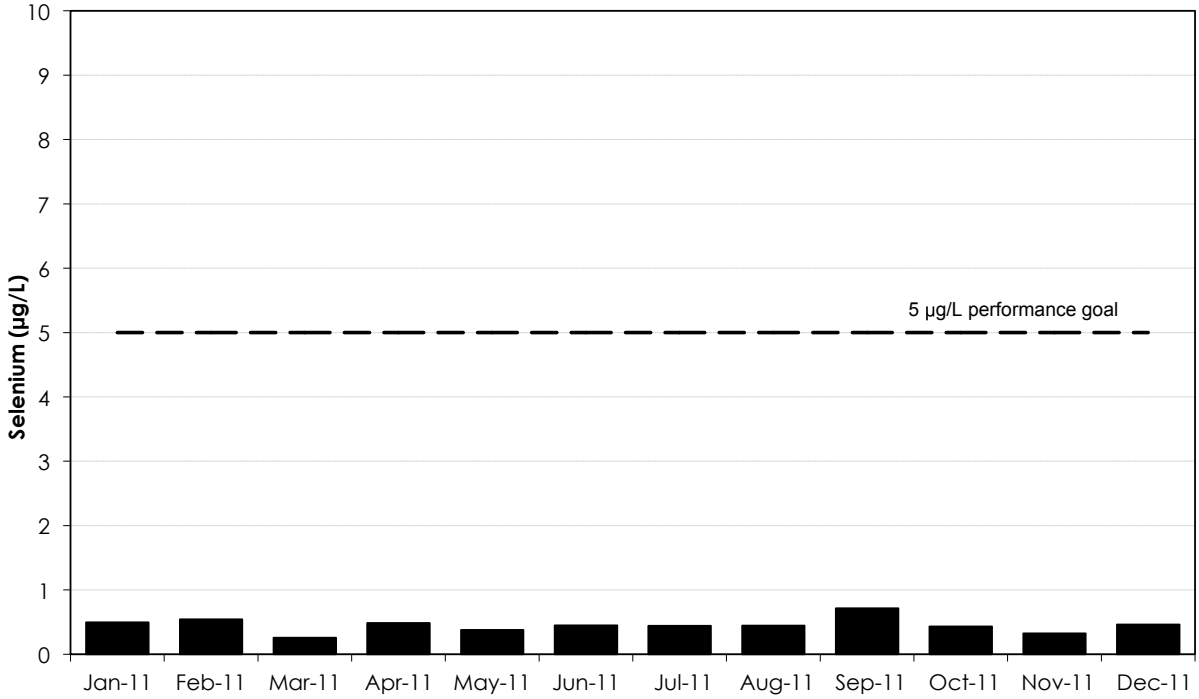


Figure 5. Mean Monthly Selenium Concentration in the Grassland Wetland Supply Channels 2010

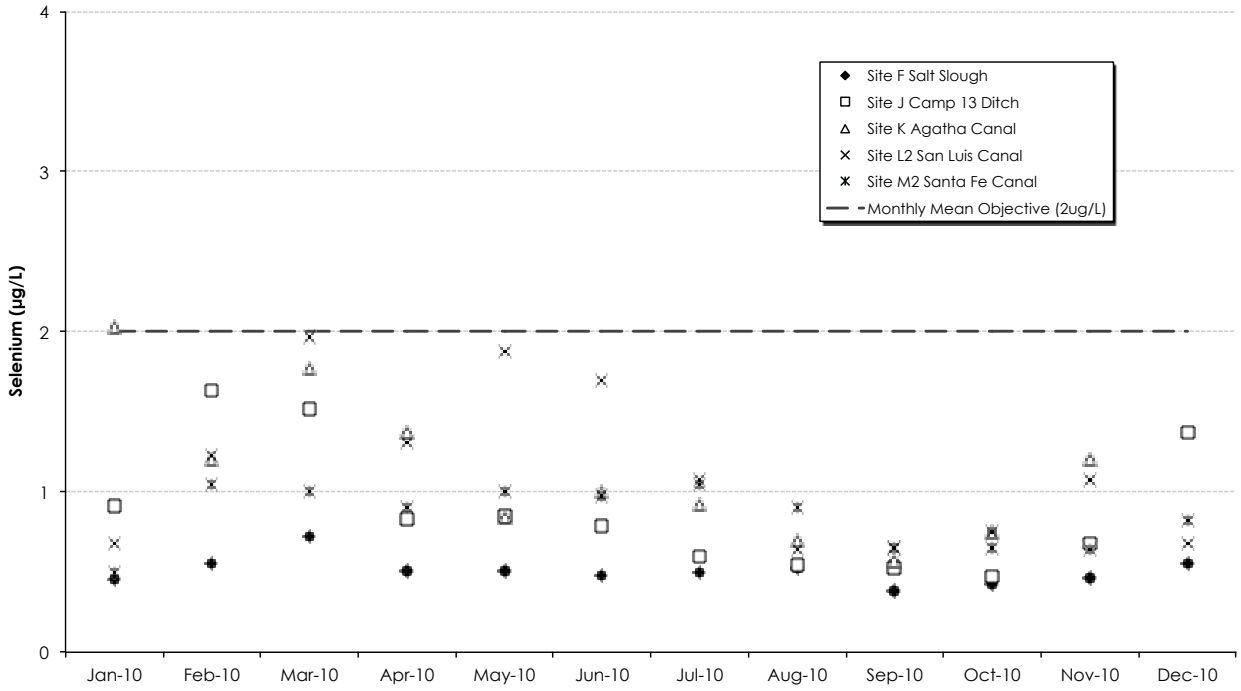


Figure 6. Mean Monthly Selenium Concentration in the Grassland Wetland Supply Channels 2011

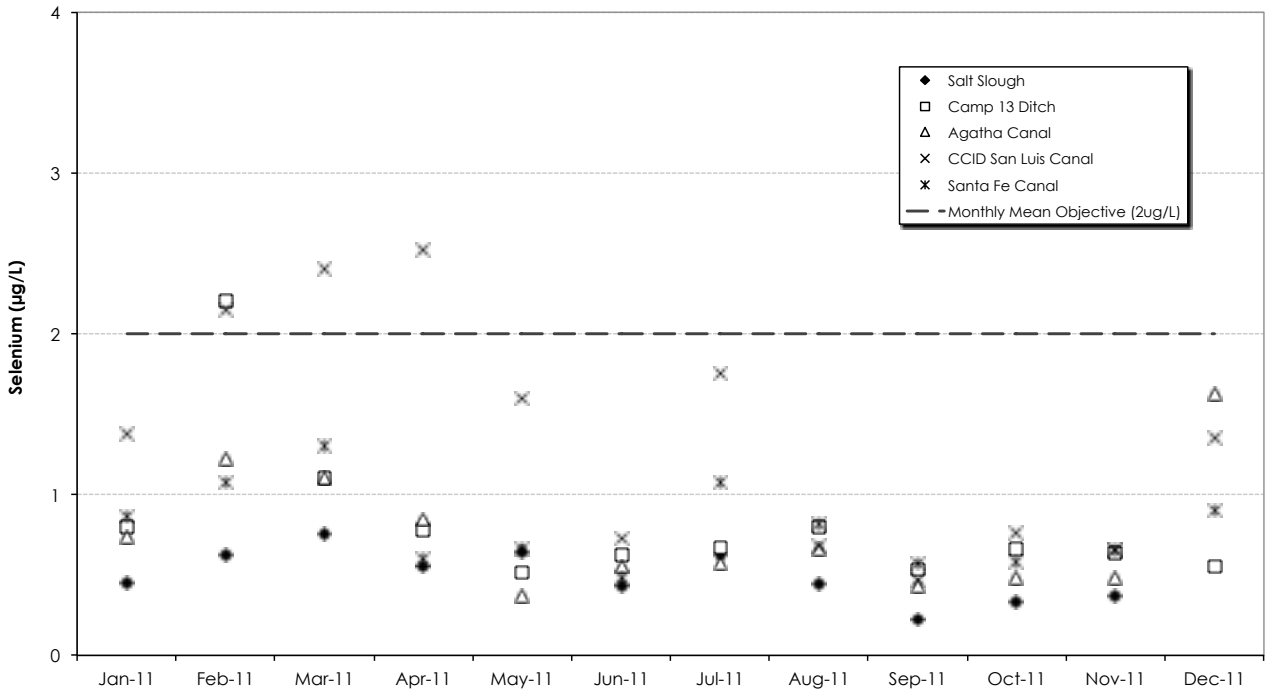


Figure 7. Weekly Grab Selenium Concentration in Mud Slough (north) below San Luis Drain (Site D) 2010 – 2011

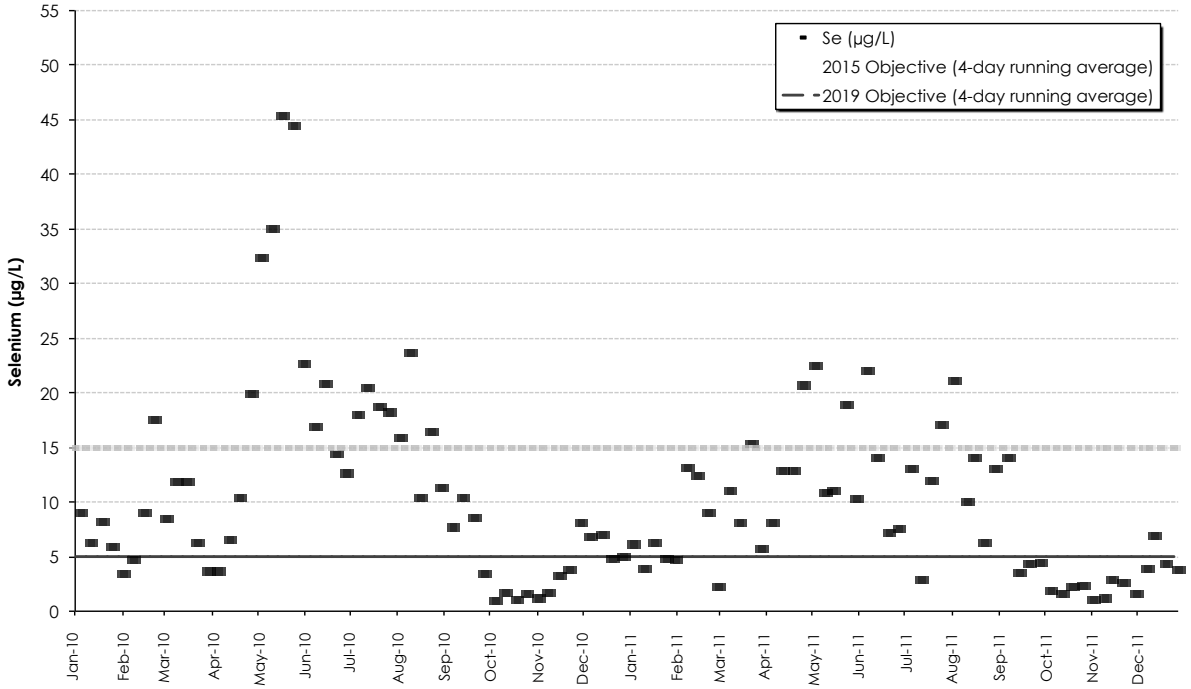


Figure 8. Weekly Grab Selenium Concentration in Mud Slough (north) above San Luis Drain (Site C) 2010 – 2011

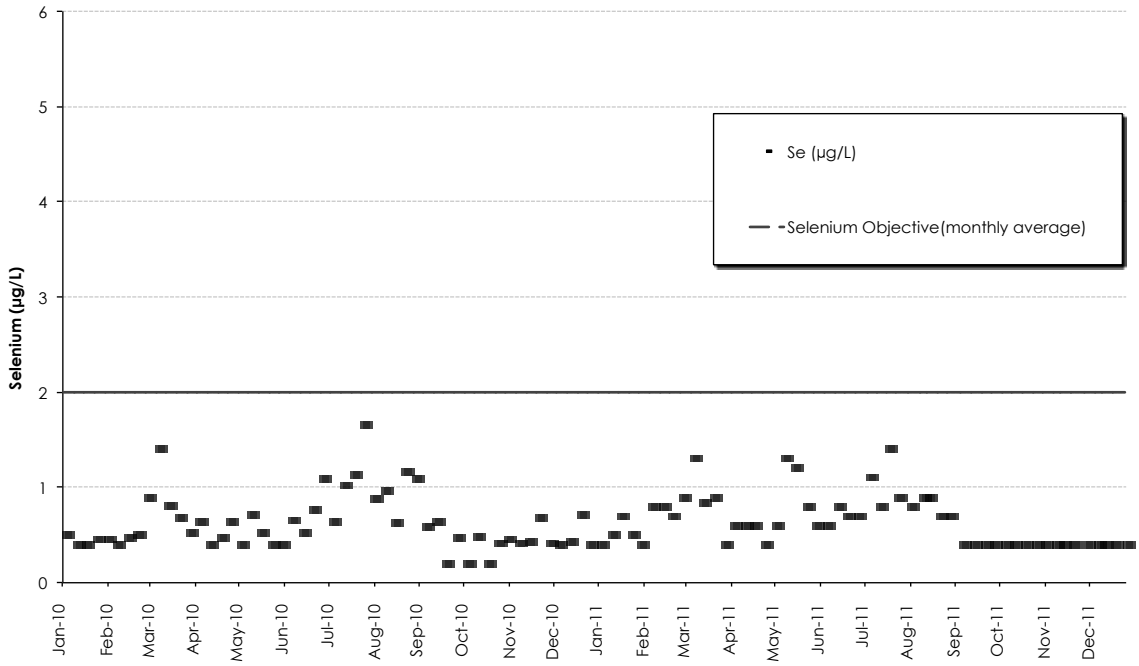


Figure 9. Weekly Grab Selenium Concentration in Salt Slough at Highway 165 (Lander Ave) (Site F) 2010 – 2011

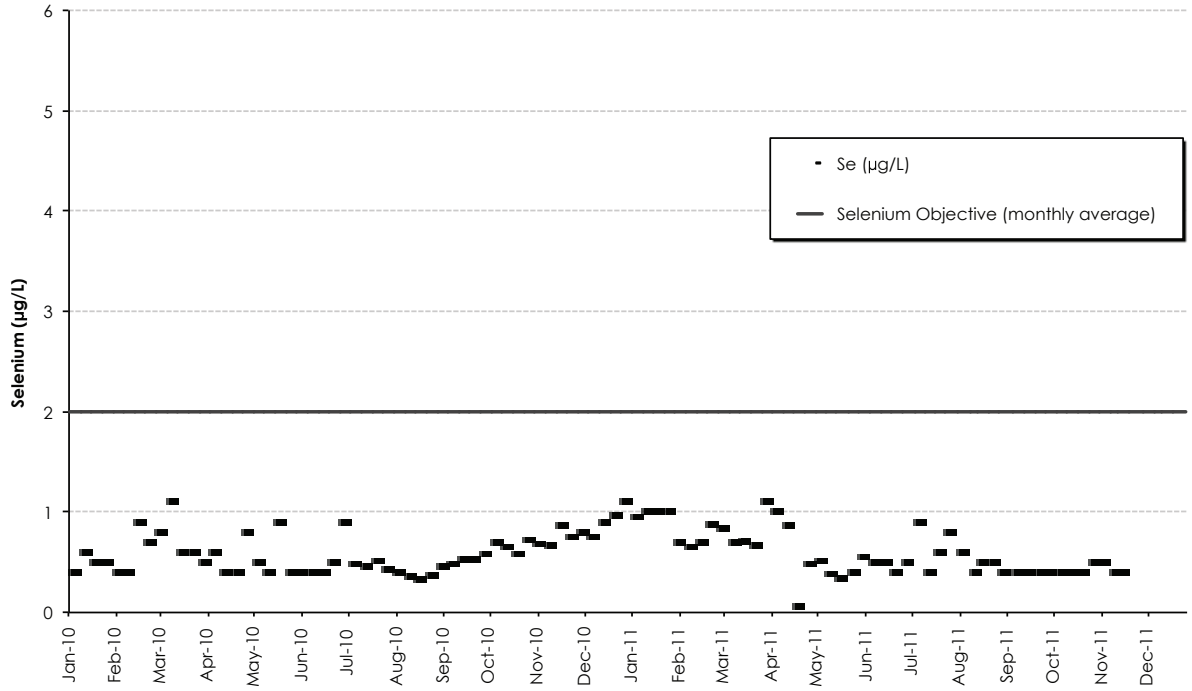
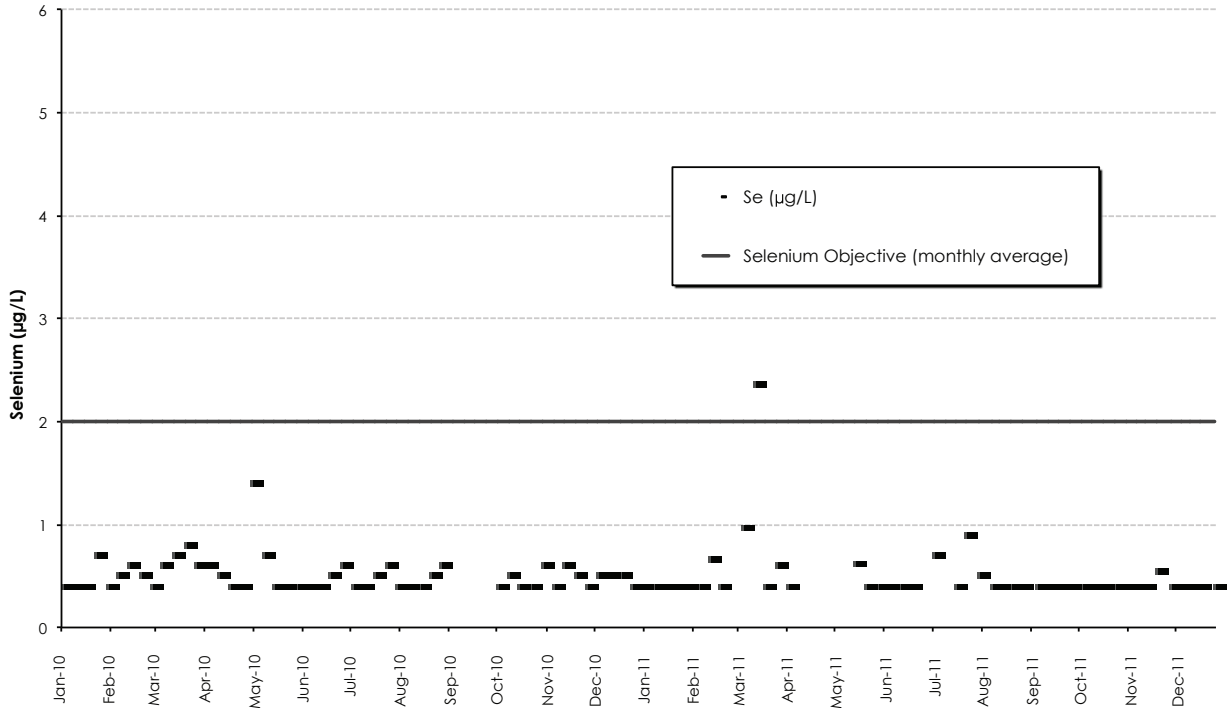


Figure 10. Weekly Grab Selenium Concentration in the San Joaquin River at Fremont Ford (Site G) 2010 – 2011



GBP

CHAPTER 5

Flow, Salt and Selenium Mass Balances in the San Luis Drain

January 1, 2010 – December 31, 2011

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SUMMARY

This chapter includes tables of data which summarize monthly flows, salt loads, and selenium loads that passed Stations A and B during the past two years and for the entire fifteen years of the Project.

Although the 28 mile reach utilized by the Grassland Bypass Project is lined with concrete, water continued to enter the San Luis Drain between Stations A and B during the winter months when wetlands beside the Drain were flooded. There was an increase in flow between the stations during 16 of the 24 months between January 2010 and December 2011. The greatest increase occurred in October 2010 when there was a 51 percent increase in flow between the stations (Table 1a).

For most of the two year span there was a corresponding increase in salt load between the stations as well. The greatest increase occurred in October 2010 when there was a 35 percent increase in salt load between the stations (Table 2a).

Table 3a lists monthly gains and losses of selenium between the stations between January 2010 and December 2011. The loads of selenium increased between five and 15 percent during eight of the 24 months, with largest increases (15 percent) occurring in January 2010. However, the monthly loads decreased during fourteen months; the greatest loss (172 percent) occurred during November 2010. The difference in selenium between the sites may be due to measurement error, microbial uptake, adsorption to sediments, volatilization, or seepage of seleniferous water into or out of the drain between Stations A and B.

Table 4a lists the monthly effects of rainfall and evapotranspiration on the volume of water in the San Luis Drain during 2010 and 2011. Column 9 in this table lists the monthly change in flow between the station that is not the result of rainfall upon, and evaporation from, the water surface of the Drain. These calculations suggest that the seasonal increases in flow in the drain are due to seepage from adjacent wetlands.

Table 5a summarizes the differences in flow, salt load, selenium load, and volume between Stations A and B between January 2010 and December 2011. Table 5b summarizes the differences in flow, salt loads, and selenium loads during the entire fourteen years of the Grassland Bypass Project.

BACKGROUND

Seepage into the San Luis Drain most likely occurs through cracks and one-way weep valves that equalize hydraulic pressure to prevent the concrete lining from buckling. Along the Drain, the water surface elevation of adjacent wetlands, when flooded in the fall and winter, is often higher than the elevation of water in the Drain.

Leakage from the Drain can occur where the concrete lining is fractured or between adjacent concrete panels. Other losses from the Drain include direct evaporation of water and evapotranspiration by algae and aquatic plants.

Flow Differences Between Stations A and B

Table 1a and **Figure 1** compare the monthly flows of water that passed Stations A and B during 2010 and 2011. Note the increases in flow during the autumn and winter months. **Tables 1b and 1c** summarize the difference in the amount of water that flowed past Stations A and B during the entire Project.

The difference in monthly flows between the stations for 2010 through 2011 ranged from a loss of 200 to a gain of 410 acre-feet (**Table 1a**). The largest increases typically occurred between September and March when wetlands beside the Drain were flooded. There was a net annual increase in flow of six percent during 2010 and eleven percent during 2011 (**Tables 1b** and **1c**). The annual net difference in flows between the stations has increased each year (**Tables 1b** and **1c**).

In previous years, we thought that monthly differences in flows were partly the result of cumulative errors from different analytical methods and equipment. Beginning in October 2005, flow at Station B is measured the same way as at Station A using a sharp-crested weir with a precision of ± 5 percent.

In **Table 4a**, we calculate the net water gain or loss in acre-feet per month by taking into account precipitation upon, and evapotranspiration from, the water surface in the Drain. Once precipitation and evapotranspiration are accounted for, the difference in flow between Stations A and B from January 2010 through December 2011 ranges from a loss of 31 percent to a gain of 47 percent. The autumn and winter months (September - March) show large increases in flow.

Salt Mass Balance Between Stations A and B

Table 2a lists the monthly loads of salt in water that passed Stations A and B during 2010 and 2011. **Figure 2** shows the monthly loads of salt in water that passed Stations A and B during the past two years. The change in salt loads between the stations ranged from a loss of 1,920 acre-feet to a gain of 2,380 acre-feet. As with the observed changes in flows, the increases in salt occurred during autumn and winter months when the adjacent wetlands were flooded. In 2010, the annual loads of salt increased by about fifteen percent followed by a one percent increase in 2011 (**Tables 2b** and **2c**).

Since salinity is a conservative chemical constituent, the monthly salt load measured at Station A should be identical to that at Station B. An increase in salt load must infer inflow of saline water into the Drain if other factors such as precipitation and evaporation are taken into account. A decrease in salt load would infer the loss of saline water from the drain.

In previous years, we thought that monthly differences in salt loads were the result of cumulative errors from different analytical methods and equipment. Drift in the EC sensor response can affect the computation of salt load. However, EC is measured with identical sensors and methods at both sites. USGS staff considers the EC sensor at Station B2 to be accurate within three percent. In previous years, algae bio-fouling of the probe at Station B has caused errors of more than 30 percent during summer months, but diligent maintenance prevented this from occurring and kept the rate of error less than ten percent. Over the past two years the flow weighted EC was lower at Station B than Station A for 15 of the 24 months as listed in **Table 2a**.

Selenium Mass Balance Between Stations A and B

A simple mass balance of selenium was calculated to better understand the dynamics of selenium mass transport and mass transfer within the San Luis Drain. Selenium is a non-conservative chemical constituent. The data are presented in **Tables 3a**, **3b**, and **3c**.

Figure 3 shows the monthly loads of selenium at both sites during 2010 and 2011. The differences in selenium load along the San Luis Drain ranged from a loss of 112 pounds (November 2010) to a gain of 28 pounds (January 2010).

DISCUSSION

Table 5a is a summary of monthly differences in flow, salinity, and selenium between Stations A and B. The monthly differences in selenium loads did not correspond to differences in flows and salt loads between the Stations. For example, during October 2010, there was a 51 percent increase in flow, 35 percent increase in salt loads, and a 18 percent reduction in selenium load.

The monthly differences in selenium loads may be caused by the different frequency of collecting water quality samples at each station. Flow data, when combined with continuous and discrete selenium data, are used to compute this mass balance. As mentioned before, flow is measured the same way at each site, but selenium sampling does not occur at the same frequency at both Stations A and B.

Selenium samples were collected by auto-samplers at both sites. At Station B, several samples were collected each day; the composite of each day's samples were analyzed in the laboratory. At Station A, seven daily samples were mixed to produce a single weekly composite for analysis by the laboratory.

CONCLUSION

In the past two years of the Grassland Bypass Project, there were increases in the flow of water in the San Luis Drain during autumn and winter months when adjacent wetlands were flooded. The monthly increases in flow (**Table 1a**) did not correspond with local rainfall or evapotranspiration (**Table 4a**). The annual changes in flows have ranged from a loss of one percent to a gain of sixteen percent (**Tables 1b** and **1c**).

The loads of salt have varied each month from a loss of 56 percent to a gain of 35, with gains typically occurring between September and February while adjacent wetlands have been flooded (**Table 2a**). The net annual change in salt loads has ranged from a loss of five percent to a gain of sixteen percent (**Tables 2b** and **2c**).

The monthly loads of selenium varied from a loss of 172 percent to a gain of 15 percent (**Table 3a**). These differences do not correspond to the observed gain of flows during the autumn and early winter. The differences in selenium loads, due to natural processes, cannot be determined under the current monitoring program.

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Table 1c. Comparison of Flow Measurements, Calendar Years 1997 - 2011
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Figure 2. Comparison of Salt Loads in the San Luis Drain
Figure 3. Comparison of Selenium Loads in the San Luis Drain

Table 1a. Comparison of Flow Measurements in the San Luis Drain

	Monthly Average Flow		Total Flow			Difference as	Rainfall
	Station A	Station B	Station A	Station B		Percent of	
	cfs	cfs	acre-feet/month	acre-feet/month	Difference	Station B	Inches
January 2010	18.0	23.3	1,100	1,430	330	23%	2.04
February 2010	24.0	28.5	1,330	1,580	250	16%	1.99
March 2010	25.4	30.1	1,560	1,850	290	16%	0.51
April 2010	16.5	16.0	980	950	-30	-3%	1.39
May 2010	28.6	26.6	1,760	1,630	-130	-8%	0.00
June 2010	22.0	20.3	1,310	1,210	-100	-8%	0.00
July 2010	17.5	14.2	1,070	870	-200	-23%	0.00
August 2010	18.3	15.1	1,120	930	-190	-20%	0.00
September 2010	11.3	11.8	670	700	30	4%	0.00
October 2010	5.4	11.0	330	680	350	51%	0.32
November 2010	20.5	18.0	1,220	1,070	-150	-14%	1.19
December 2010	22.8	29.4	1,400	1,810	410	23%	2.02
January 2011	20.2	26.0	1,240	1,600	360	23%	0.86
February 2011	34.7	39.5	1,930	2,190	260	12%	1.52
March 2011	44.0	48.9	2,700	3,010	310	10%	1.85
April 2011	30.8	33.7	1,840	2,000	160	8%	0.11
May 2011	26.2	27.3	1,610	1,680	70	4%	0.47
June 2011	25.8	27.0	1,540	1,610	70	4%	0.63
July 2011	16.4	15.9	1,010	980	-30	-3%	0.00
August 2011	17.0	17.1	1,040	1,050	10	1%	0.00
September 2011	11.4	13.9	680	830	150	18%	0.00
October 2011	10.3	15.9	630	980	350	36%	0.16
November 2011	10.3	16.5	610	980	370	38%	0.86
December 2011	13.3	18.0	820	1,110	290	26%	0.07

Data sources: Station A - San Luis & Delta-Mendota Water Authority
Station B2 - San Luis & Delta-Mendota Water Authority
Rainfall measured at Panoche WD

Table 1b. Comparison of Flow Measurements, Water Years 1997 – 2011

	Monthly Average Flow		Total Flow			
	Station A cfs	Station B cfs	Station A acre-feet	Station B acre-feet	Difference	Difference as Percent of Station B
WY 1997	52.3	52.0	37,800	37,560	-240	-1%
WY 1998	60.6	63.9	43,570	45,950	2,380	5%
WY 1999	42.2	44.7	30,510	32,310	1,800	6%
WY 2000	40.5	43.1	29,330	31,260	1,930	6%
WY 2001	37.4	39.1	27,050	28,250	1,200	4%
WY 2002	35.7	39.3	25,820	28,400	2,580	9%
WY 2003	35.0	37.5	25,250	27,270	2,020	7%
WY 2004	35.1	38.2	25,370	27,700	2,330	8%
WY 2005	38.1	41.8	27,540	30,160	2,620	9%
WY 2006	32.0	36.0	23,080	25,970	2,890	11%
WY 2007	22.9	25.7	16,480	18,540	2,060	11%
WY 2008	18.2	21.6	13,230	15,670	2,440	16%
WY 2009	17.2	18.3	12,340	13,160	820	6%
WY 2010	18.9	20.1	13,610	14,520	910	6%
WY 2011	22.9	25.7	16,540	18,510	1,970	11%

Table 1c. Comparison of Flow Measurements, Calendar Years 1997 – 2011

	Monthly Average Flow		Total Flow			
	Station A cfs	Station B cfs	Station A acre-feet	Station B acre-feet	Difference	Difference as Percent of Station B
1997	50.7	51.9	36,590	37,490	900	2%
1998	61.5	64.3	44,220	46,240	2,020	4%
1999	41.4	44.6	29,910	32,250	2,340	7%
2000	39.9	41.7	28,920	30,210	1,290	4%
2001	36.3	38.8	26,190	28,010	1,820	6%
2002	36.7	39.3	26,520	28,460	1,940	7%
2003	35.1	38.0	25,360	27,550	2,190	8%
2004	35.5	39.0	25,730	28,290	2,560	9%
2005	37.2	41.1	26,870	29,610	2,740	9%
2006	32.1	35.8	23,180	25,890	2,710	10%
2007	21.9	25.0	15,760	17,990	2,230	12%
2008	19.1	21.9	13,880	15,860	1,980	12%
2009	17.2	17.9	12,340	12,920	580	4%
2010	19.2	20.3	13,850	14,710	860	6%
2011	21.7	25.0	15,650	18,020	2,370	13%

Table 2a. Comparison of Salinity and Salt Loads in the San Luis Drain

	Flow-weighted Electrical Conductivity		Salt Loads			Difference as
	Station A µS/cm	Station B µS/cm	Station A tons per month	Station B tons per month	Difference	Percent of Station B
January 2010	4,199	4,704	4,650	6,770	2,120	31%
February 2010	4,068	4,671	5,440	7,430	1,990	27%
March 2010	4,396	4,982	6,900	9,280	2,380	26%
April 2010	3,778	4,954	3,730	4,740	1,010	21%
May 2010	4,208	4,585	7,440	7,510	70	1%
June 2010	4,177	4,371	5,510	5,320	-190	-4%
July 2010	5,005	5,102	5,380	4,470	-910	-20%
August 2010	4,916	5,216	5,540	4,880	-660	-14%
September 2010	4,901	4,399	3,310	3,100	-210	-7%
October 2010	4,919	3,694	1,630	2,520	890	35%
November 2010	5,131	4,063	6,300	4,380	-1,920	-44%
December 2010	4,974	4,254	7,010	7,750	740	10%
January 2011	5,440	4,793	6,800	7,720	920	12%
February 2011	5,174	5,140	10,050	11,320	1,270	11%
March 2011	4,943	4,941	13,440	14,980	1,540	10%
April 2011	5,490	5,582	10,160	11,230	1,070	10%
May 2011	5,212	5,138	8,450	8,680	230	3%
June 2011	5,052	4,780	7,830	7,750	-80	-1%
July 2011	5,447	4,333	5,540	4,280	-1,260	-29%
August 2011	5,202	3,858	5,450	4,070	-1,380	-34%
September 2011	5,543	3,402	3,790	2,840	-950	-33%
October 2011	5,744	2,996	3,640	2,960	-680	-23%
November 2011	5,436	2,566	3,330	2,530	-800	-32%
December 2011	6,197	2,934	5,120	3,280	-1,840	-56%

Data sources: Station A - San Luis & Delta-Mendota Water Authority
Station B - US Geological Survey Site 11262895

Table 2b. Comparison of Salinity and Salt Loads, Water Years 1997 – 2011

	Flow-weighted Electrical Conductivity		Salt Loads			Difference as
	Station A µS/cm	Station B µS/cm	Station A tons	Station B tons	Difference	Percent of Station B
WY 1997	4,477	4,257	176,700	167,830	-8,870	-5%
WY 1998	4,625	4,439	211,330	205,110	-6,220	-3%
WY 1999	4,821	4,650	143,880	149,140	5,260	4%
WY 2000	4,478	4,301	135,260	135,010	-250	0%
WY 2001	4,634	4,191	125,100	120,030	-5,070	-4%
WY 2002	4,427	4,069	111,200	116,190	4,990	4%
WY 2003	4,552	4,318	113,630	118,760	5,130	4%
WY 2004	4,446	4,173	110,630	116,350	5,720	5%
WY 2005	4,583	4,316	127,030	132,560	5,530	4%
WY 2006	4,782	4,605	111,070	121,020	9,950	8%
WY 2007	4,660	4,235	77,140	79,700	2,560	3%
WY 2008	4,151	4,120	55,350	65,930	10,580	16%
WY 2009	3,827	4,254	47,840	55,590	7,750	14%
WY 2010	4,266	4,617	58,460	67,670	9,210	14%
WY 2011	5,211	4,498	86,450	87,520	1,070	1%

Table 2c. Comparison of Salinity and Salt Loads, Calendar Years 1997 – 2011

	Flow-weighted Electrical Conductivity		Salt Loads			Difference as
	Station A µS/cm	Station B µS/cm	Station A tons	Station B tons	Difference	Percent of Station B
1997	4,627	4,354	174,250	169,330	-4,920	-3%
1998	4,699	4,563	214,730	208,860	-5,870	-3%
1999	4,767	4,532	138,620	146,580	7,960	5%
2000	4,379	4,189	133,360	128,600	-4,760	-4%
2001	4,661	4,200	121,460	119,210	-2,250	-2%
2002	4,469	4,155	115,030	117,760	2,730	2%
2003	4,559	4,281	114,240	119,330	5,090	4%
2004	4,404	4,129	111,860	118,000	6,140	5%
2005	4,581	4,422	123,670	132,060	8,390	6%
2006	4,923	4,589	113,260	120,500	7,240	6%
2007	4,460	4,096	71,600	75,550	3,950	5%
2008	3,975	4,096	56,480	66,200	9,720	15%
2009	3,843	4,367	48,020	56,280	8,260	15%
2010	4,556	4,583	62,840	68,150	5,310	8%
2011	5,407	4,205	83,600	81,640	-1,960	-2%

Data source: Calculated from data published by the San Francisco Estuary Institute

Table 3a. Comparison of Selenium Measurements in the San Luis Drain

	Flow-weighted Selenium Concentration (1)		Total Selenium Loads			Difference
	Station A µg/L	Station B µg/L	Station A (2) pounds	Station B (3) pounds	Difference	as Percent of Station B
January 2010	54.8	49.4	164	192	28	15%
February 2010	41.8	37.2	151	160	9	5%
March 2010	59.0	49.9	250	251	1	0%
April 2010	41.3	33.7	110	87	-23	-27%
May 2010	53.6	54.5	257	242	-15	-6%
June 2010	41.6	41.5	148	137	-11	-8%
July 2010	42.2	38.4	123	91	-32	-35%
August 2010	36.6	37.4	111	94	-17	-19%
September 2010	29.2	22.5	53	43	-10	-24%
October 2010	22.3	9.4	20	17	-3	-18%
November 2010	53.3	18.5	177	65	-112	-172%
December 2010	47.0	34.7	179	176	-3	-2%
January 2011	46.3	36.8	156	160	4	3%
February 2011	52.8	46.6	277	278	0	0%
March 2011	49.4	46.3	363	379	16	4%
April 2011	51.4	49.6	257	270	13	5%
May 2011	50.5	51.5	221	235	14	6%
June 2011	52.0	50.2	218	220	2	1%
July 2011	41.5	47.2	114	123	9	7%
August 2011	35.4	33.5	100	96	-4	-5%
September 2011	30.9	21.9	57	50	-8	-15%
October 2011	28.8	16.6	49	44	-5	-12%
November 2011	33.7	18.5	56	49	-7	-14%
December 2011	44.8	29.9	100	93	-7	-8%

Data Sources: Station A - Calculated from Regional Board weekly composite samples at Site MER562s
Station B - Published by San Francisco Estuary Institute
(1) Flow-weighted concentrations and loads calculated by USBR SCC-107
(2) Selenium load calculated by USBR SCC-107
(3) Selenium load published by San Francisco Estuary Institute

Table 3b. Comparison of Selenium Measurements Water Years 1997 – 2011

	Average Flow-weighted Concentration		Total Selenium Loads			Difference
	Station A µg/L	Station B µg/L	Station A pounds	Station B pounds	Difference	as Percent of Station B
WY 1997	67.5	62.8	7,418	6,964	-454	-7%
WY 1998	70.6	66.5	8,436	8,774	338	4%
WY 1999	65.3	59.3	5,178	5,129	-49	-1%
WY 2000	61.3	54.0	4,685	4,889	204	4%
WY 2001	62.8	56.1	4,509	4,823	314	7%
WY 2002	58.3	50.6	3,815	3,941	126	3%
WY 2003	61.6	55.6	3,865	4,025	160	4%
WY 2004	60.9	52.7	3,813	3,873	60	2%
WY 2005	49.0	49.6	3,701	4,312	611	14%
WY 2006	58.2	48.9	3,612	3,563	-49	-1%
WY 2007	57.3	47.5	2,581	2,549	-32	-1%
WY 2008	46.6	37.1	1,743	1,738	-5	-0.3%
WY 2009	38.3	32.5	1,350	1,252	-97	-7.8%
WY 2010	43.7	37.7	1,686	1,576	-109	-6.9%
WY 2011	44.4	37.2	2,140	2,068	-72	-3.5%

Table 3c. Comparison of Selenium Measurements Calendar Years 1997 – 2011

	Average Flow-weighted Concentration		Total Selenium Loads			Difference
	Station A µg/L	Station B µg/L	Station A pounds	Station B pounds	Difference	as Percent of Station B
1997	67.4	60.8	7,173	6,854	-319	-5%
1998	71.1	67.9	8,567	8,877	310	3%
1999	64.0	57.1	5,018	4,992	-26	-1%
2000	62.0	54.6	4,646	4,507	-139	-3%
2001	63.0	54.9	4,360	4,299	-61	-1%
2002	63.1	56.2	4,089	4,176	87	2%
2003	60.8	54.0	3,868	4,007	139	3%
2004	53.3	46.8	3,621	3,672	51	1%
2005	52.0	50.8	3,686	4,286	600	14%
2006	63.5	52.6	3,795	3,718	-77	-2%
2007	49.7	41.7	2,267	2,275	8	0.4%
2008	42.6	35.8	1,707	1,686	-21	-1.2%
2009	38.5	32.9	1,359	1,249	-110	-8.8%
2010	43.6	35.6	1,744	1,555	-189	-12.2%
2011	43.1	37.4	1,969	1,997	27	1.4%

Data source: Flow-weighted concentrations and loads calculated by USBR SCC-107

Table 4a. Gain or Loss due to Precipitation and Evapotranspiration

	Precipitation			Evapotranspiration										
	Three Site Average Precip	Three Site Average Precip	Water Gain from Precip on San Luis Drain	Three Site Average ETo	Three Site Average ETo	Water lost to Evap. From San Luis Drain	Gain or Loss from Water Surface of San Luis Drain	Flow passing Station A	Flow passing Station B	Difference in flow passing Stations A and B	Net Water Gain/Loss not due to Precip or ETO	Equivalent Flow rate	Net Water Gain/Loss as Percent of Site B flow
	inches	feet	acre feet	inches	feet	acre feet	acre feet	acre feet	acre feet	acre feet	acre feet	cfs	percent
	(1)	(2)	(2)	(3)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Jan 2010	1.54	0.13	13	0.98	0.08	-8	5	1,100	1,430	330	335	5.4	23%
Feb 2010	1.38	0.12	12	1.71	0.14	-14	-3	1,330	1,580	250	247	4.5	16%
Mar 2010	0.43	0.04	4	4.09	0.34	-35	-31	1,560	1,850	290	259	4.2	14%
Apr 2010	1.76	0.15	15	4.85	0.40	-41	-26	980	950	-30	-56	-0.9	-6%
May 2010	0.18	0.01	1	7.56	0.63	-64	-63	1,760	1,630	-130	-193	-3.1	-12%
Jun 2010	0.02	0.00	0	9.03	0.75	-77	-76	1,310	1,210	-100	-176	-3.0	-15%
Jul 2010	0.00	0.00	0	8.64	0.72	-73	-73	1,070	870	-200	-273	-4.4	-31%
Aug 2010	0.00	0.00	0	7.33	0.61	-62	-62	1,120	930	-190	-252	-4.1	-27%
Sep 2010	0.00	0.00	0	5.80	0.48	-49	-49	670	700	30	-19	-0.3	-3%
Oct 2010	0.26	0.02	2	3.45	0.29	-29	-27	330	680	350	323	5.3	47%
Nov 2010	1.31	0.11	11	1.91	0.16	-16	-5	1,220	1,070	-150	-155	-2.6	-14%
Dec 2010	2.20	0.18	19	0.83	0.07	-7	12	1,400	1,810	410	422	6.9	23%
Jan 2011	1.07	0.09	9	0.75	0.06	-6	3	1,240	1,600	360	363	5.9	23%
Feb 2011	1.48	0.12	13	2.28	0.19	-19	-7	1,930	2,190	260	253	4.6	12%
Mar 2011	2.00	0.17	17	3.24	0.27	-27	-10	2,700	3,010	310	300	4.9	10%
Apr 2011	0.18	0.02	2	5.73	0.48	-49	-47	1,840	2,000	160	113	1.9	6%
May 2011	0.43	0.04	4	7.18	0.60	-61	-57	1,610	1,680	70	13	0.2	1%
Jun 2011	0.69	0.06	6	7.83	0.65	-66	-61	1,540	1,610	70	9	0.2	1%
Jul 2011	0.00	0.00	0	7.90	0.66	-67	-67	1,010	980	-30	-97	-1.6	-1t0%
Aug 2011	0.00	0.00	0	7.46	0.62	-63	-63	1,040	1,050	10	-53	-0.9	-5%
Sep 2011	0.00	0.00	0	5.76	0.48	-49	-49	680	830	150	101	1.7	12%
Oct 2011	0.76	0.06	6	3.65	0.30	-31	-24	630	980	350	326	5.3	33%
Nov 2011	0.85	0.07	7	1.74	0.15	-15	-8	610	980	370	362	6.1	37%
Dec 2011	0.10	0.01	1	1.64	0.14	-14	-13	820	1,110	290	277	4.5	25%

Notes:

(1) California Irrigation Management Information System - Average preciptiation for Stations 007, 056, and 124

(2) Total rainfall x SLD surface area. SLD surface area = 28 mi x 30' top width = 101.8 ac

(3) California Irrigation Management Information System - Average Eto for Stations 007, 056, and 124

(4) Total evapotranspiration from the SLD surface area (101.8 acres)

(5) Sum of rainfall and evapotransipiration from the SLD

(6) Flow passing Station A (from Table 1)

(7) Flow passing Station B (from Table 1)

(8) Flow at Station B - Flow at Station A

(9) Column (8) - (5) = Net water volume gained from or lost

(10) Average daily flow (cfs) of the Net Water Gain/Loss

(11) Difference in flow (6)/ Station B flow x 100%

Table 4b. Gain or Loss Due to Precipitation and Evapotranspiration, Water Year Totals

	CIMIS Precipitation			CIMIS Evapotranspiration									
	Three Site Average Precip	Three Site Average Precip	Water Gain from Precip on San Luis Drain	Three Site Average ETo	Three Site Average ETo	Water lost to Evap. From San Luis Drain	Gain or Loss from Water Surface	Flow passing Station A	Flow passing Station B	Differences in flows passing Stations A and B	Net Water Gain/Loss not due to Precip or ETO	Equivalent Flow rate	Net Water Gain/Loss as Percent of Site B flow
	inches	feet	acre feet	inches	feet	acre feet	acre feet	acre feet	acre feet	acre feet	acre feet	cfs	percent
WY 1997	10.40	0.87	88	58.69	4.89	-498	-410	37,800	37,560	-240	-650	-0.90	-2%
WY 1998	17.73	1.48	150	52.36	4.36	-444	-294	43,570	45,950	2,380	2,086	2.88	5%
WY 1999	7.77	0.65	66	56.73	4.73	-481	-415	30,510	32,310	1,800	1,385	1.91	4%
WY 2000	5.62	0.47	48	57.78	4.82	-490	-442	29,330	31,260	1,930	1,488	2.05	5%
WY 2001	7.35	0.61	62	59.67	4.97	-506	-444	27,050	28,250	1,200	756	1.04	3%
WY 2002	5.79	0.48	49	58.32	4.86	-495	-446	25,820	28,400	2,580	2,134	2.95	8%
WY 2003	7.60	0.63	65	56.48	4.71	-479	-415	25,250	27,270	2,020	1,605	2.22	6%
WY 2004	5.72	0.48	49	60.10	5.01	-510	-461	25,370	27,700	2,330	1,869	2.58	7%
WY 2005	12.11	1.01	103	52.71	4.39	-447	-344	25,940	28,370	2,430	2,086	2.88	7%
WY 2006	11.20	0.93	95	55.03	4.59	-467	-372	23,080	25,970	2,890	2,518	3.48	10%
WY 2007	4.00	0.33	34	56.35	4.70	-478	-444	16,480	18,540	2,060	1,616	2.23	9%
WY 2008	4.72	0.39	40	61.31	5.11	-520	-480	13,230	15,670	2,440	1,960	2.71	13%
WY 2009	4.24	0.35	36	60.57	5.05	-514	-478	12,340	13,160	820	342	0.47	3%
WY 2010	6.80	0.57	58	57.66	4.80	-489	-431	13,610	14,520	910	479	0.66	3%
WY 2011	9.62	0.80	82	54.32	4.53	-461	-379	16,540	18,510	1,970	1,591	2.20	9%

Table 4c. Gain or Loss Due to Precipitation and Evapotranspiration, Calendar Year Totals

	CIMIS Precipitation			CIMIS Evapotranspiration									
	Three Site Average Precip	Three Site Average Precip	Water Gain from Precip on San Luis Drain	Three Site Average ETo	Three Site Average ETo	Water lost to Evap. From San Luis Drain	Gain or Loss from Water Surface	Flow passing Station A	Flow passing Station B	Differences in flows passing Stations A and B	Net Water Gain/Loss not due to Precip or ETO	Equivalent Flow rate	Net Water Gain/Loss as Percent of Site B flow
	inches	feet	acre feet	inches	feet	acre feet	acre feet	acre feet	acre feet	acre feet	acre feet	cfs	percent
1997	10.30	0.86	87	59.25	4.94	-503	-415	36,590	37,490	900	485	0.67	1%
1998	14.76	1.23	125	52.42	4.37	-445	-319	44,220	46,240	2,020	1,701	2.35	4%
1999	6.45	0.54	55	57.72	4.81	-490	-435	29,910	32,250	2,340	1,905	2.63	6%
2000	7.02	0.59	60	56.37	4.70	-478	-419	28,920	30,210	1,290	871	1.20	3%
2001	8.97	0.75	76	59.82	4.99	-507	-431	26,190	28,010	1,820	1,389	1.92	5%
2002	6.00	0.50	51	58.55	4.88	-497	-446	26,520	28,460	1,940	1,494	2.06	5%
2003	6.09	0.51	52	56.90	4.74	-483	-431	25,360	27,550	2,190	1,759	2.43	6%
2004	7.90	0.66	67	58.35	4.86	-495	-428	25,730	28,290	2,560	2,132	2.94	8%
2005	10.72	0.89	91	53.88	4.49	-457	-366	26,870	29,610	2,740	2,374	3.28	8%
2006	9.31	0.78	79	51.19	4.27	-434	-355	23,180	25,890	2,710	2,355	3.25	9%
2007	3.94	0.33	33	57.29	4.77	-486	-453	15,760	17,990	2,230	1,777	2.45	10%
2008	4.28	0.36	36	61.38	5.11	-521	-484	13,880	15,860	1,980	1,496	2.07	9%
2009	4.76	0.40	40	60.82	5.07	-516	-476	12,340	13,160	820	344	0.48	3%
2010	9.08	0.76	77	56.18	4.68	-477	-400	13,610	14,520	910	510	0.71	4%
2011	7.56	0.63	64	55.16	4.60	-468	-404	15,650	18,020	2,370	1,966	2.72	11%

Table 5a. Mass Balance in the San Luis Drain

	Difference in flow between Sites A and B	Difference in Salt Load between Sites A and B	Difference in Selenium Load between Sites A and B	Difference in Flow not due to Rain or Evapotranspiration
	Table 1a	Table 2a	Table 3a	Table 4a
January 2010	23%	31%	15%	23%
February 2010	16%	27%	5%	16%
March 2010	16%	26%	0%	14%
April 2010	-3%	21%	-27%	-6%
May 2010	-8%	1%	-6%	-12%
June 2010	-8%	-4%	-8%	-15%
July 2010	-23%	-20%	-35%	-31%
August 2010	-20%	-14%	-19%	-27%
September 2010	4%	-7%	-24%	-3%
October 2010	51%	35%	-18%	47%
November 2010	-14%	-44%	-172%	-14%
December 2010	23%	10%	-2%	23%
January 2011	23%	12%	3%	23%
February 2011	12%	11%	0%	12%
March 2011	10%	10%	4%	10%
April 2011	8%	10%	5%	6%
May 2011	4%	3%	6%	1%
June 2011	4%	-1%	1%	1%
July 2011	-3%	-29%	7%	-10%
August 2011	1%	-34%	-5%	-5%
September 2011	18%	-33%	-15%	12%
October 2011	36%	-23%	-12%	33%
November 2011	38%	-32%	-14%	37%
December 2011	26%	-56%	-8%	25%

Table 5b. San Luis Drain Mass Balance - Summary Statistics 1996 – 2011

	Difference in flow between Sites A and B	Difference in Salt Load between Sites A and B	Difference in Selenium Load between Sites A and B	Difference in Flow not due to Rain or Evapotranspiration
Maximum	52%	40%	52%	49%
Month	Oct-07	Oct-99	May-05	Oct-07
Minimum	-23%	-56%	-172%	-31%
Month	May-09	Feb-98	Aug-09	May-09
Median	6%	4%	-0.5%	4%
Average	10%	5%	-3.1%	8%
Count	183	183	183	183

Figure 1. Comparison of Flows in the San Luis Drain

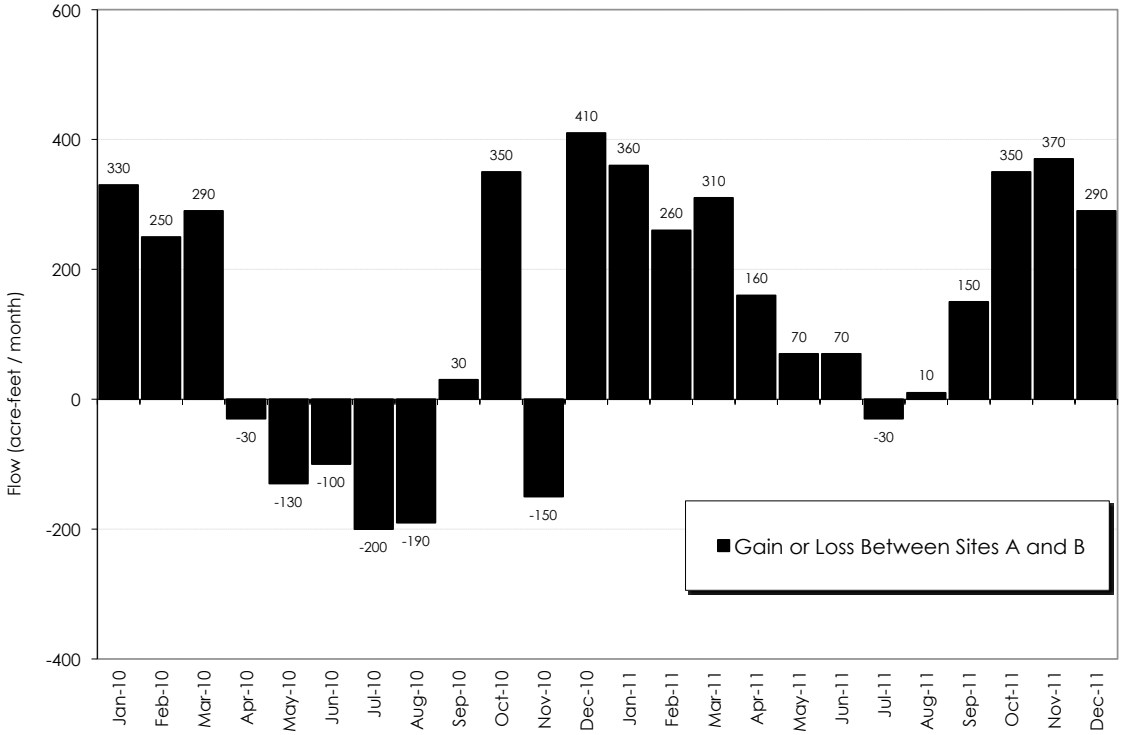


Figure 2. Comparison of Salt Loads in the San Luis Drain

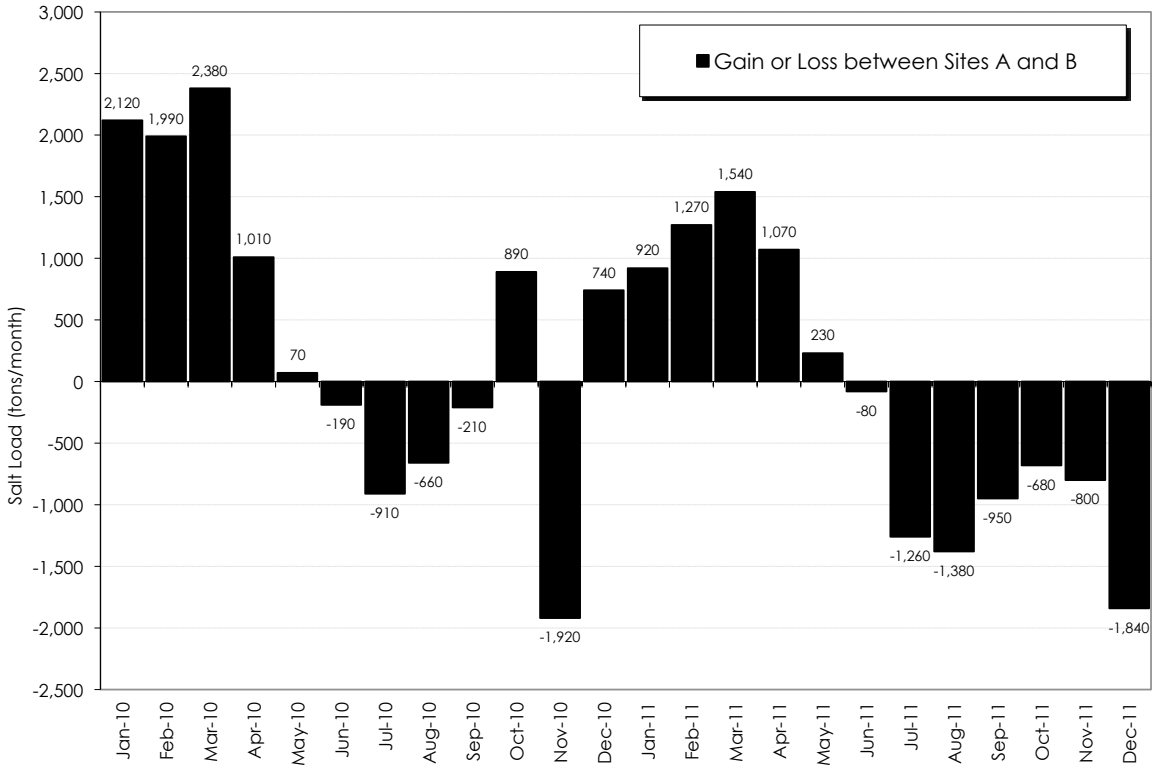
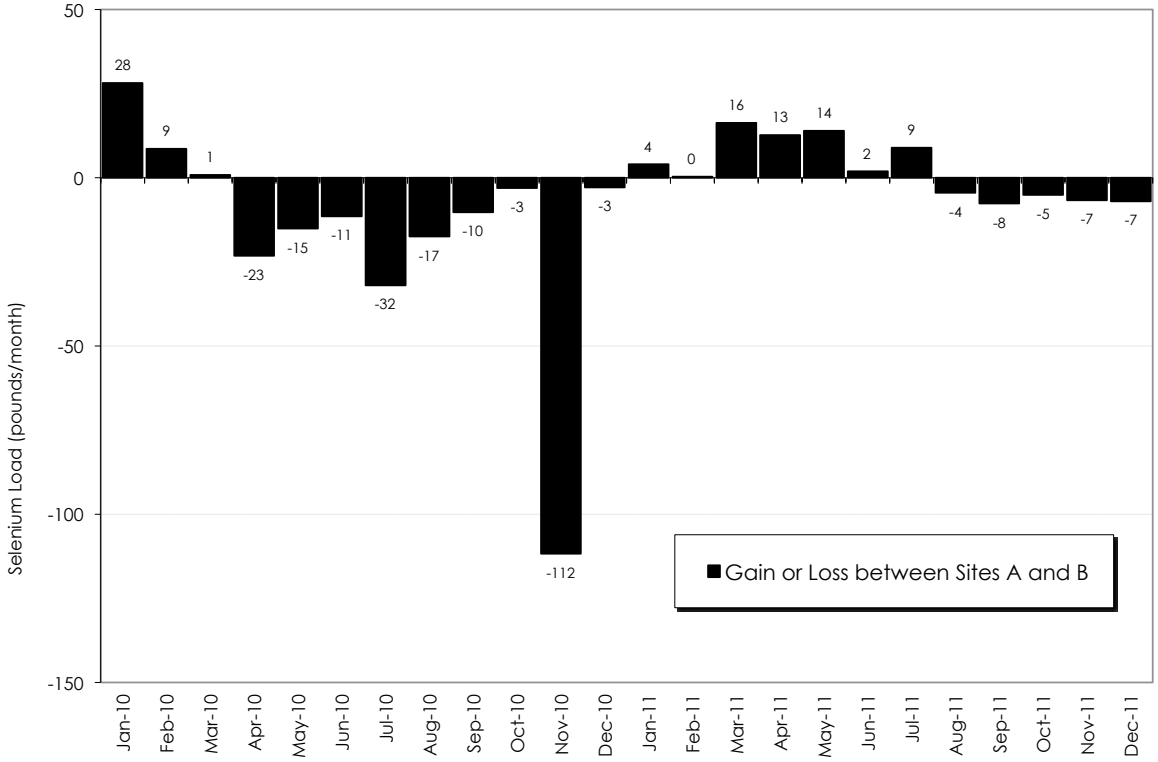
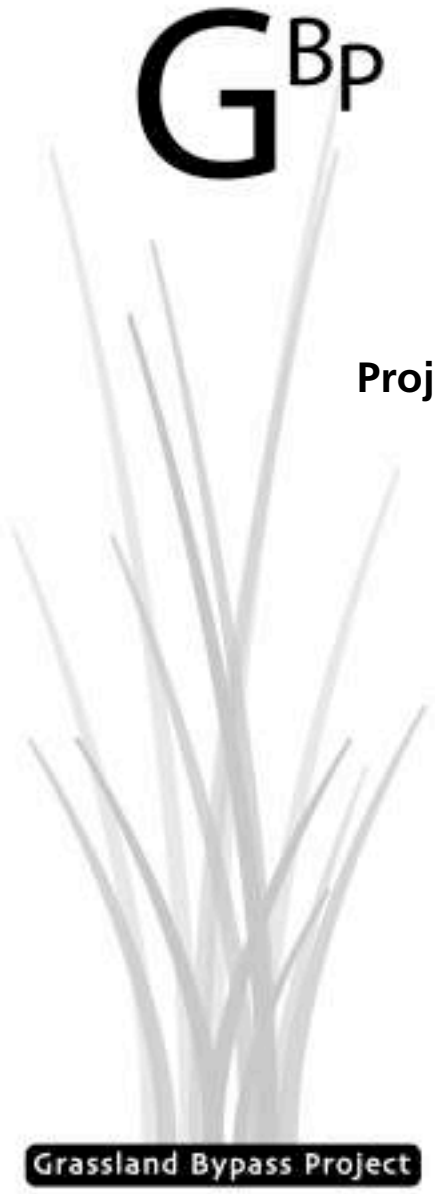


Figure 3. Comparison of Selenium Loads in the San Luis Drain





CHAPTER 6

Project Impacts on the San Joaquin River

January 1, 2010 – December 31, 2011

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INTRODUCTION

The purpose of this chapter is to compare the loads of salt discharged by the Grassland Bypass Project (GBP) with loads that might exist in the absence of the project. This comparison uses flow and salinity data for stations in the San Luis Drain, Mud Slough, Salt Slough, and the San Joaquin River from October 1985 to December 2011. Two methods are used:

- simple comparison of flow and salt loads as percentages, and

- theoretical dilution analysis.

The theoretical dilution analysis was agreed upon in meetings involving the US Bureau of Reclamation (Reclamation), the South Delta Water Agency and its legal counsel, and the California Regional Water Quality Control Board, as a means of demonstrating that the Project was not causing adverse downstream impacts.

Section D of the 2009 Use Agreement[4] includes the following statement:

"It is the intention and objective of RECLAMATION and the AUTHORITY, among other things, to ensure that continued use of the Drain as provided in this Agreement results in improvement in water quality and environmental conditions in the San Joaquin River, delta, and estuary relative to the quality that existed prior to the term of this Agreement, insofar as such quality or conditions may be affected by drainage discharges from the Drainage Area (as hereinafter defined), and to ensure that such continued use of the Drain does not reduce the ability to meet the salinity standard at Vernalis compared to the ability to meet the salinity standard that existed prior to the term of this Agreement."

COMPARISON OF FLOW AND SALT LOADS AS PERCENTAGES

Table 1a compares the monthly flows and loads of salt discharged by the Project (measured at Station B) with those in the San Joaquin River at Crows Landing (Station N) during 2010 and 2011. During 2010, the Project contributed 2 percent of the flow passing Crows Landing, and 12 percent of the monthly salt load in the river, and 1 percent of the flows and 10 percent of the monthly salt load in 2011. During the entire fifteen years of the Project, annual discharge from the Project was between 1 and 5 percent of the annual flow and up to 22 percent of the salt load in the river as measured at Crows Landing (**Tables 1b and 1c**).

Table 2 compares the volumes of water discharged from the 97,000 acre Grassland Drainage Area (GDA) with flows in the Grasslands watershed, as measured in Mud and Salt Sloughs. Prior to Water Year[5] 1997, the volume of water discharged from the GDA was 20 to 32 percent of the regional flow. The Project has reduced the GDA flow to 16 percent of the regional flow.

4 U.S. Bureau of Reclamation and the San Luis and Delta-Mendota Water Authority, December 22, 2009. Agreement for Continued Use of the San Luis Drain. Agreement No. 10-WC-20-3975.

5 Water Year = October 1 – September 30

Table 3 compares the loads of salts discharged from the GDA with the salts in water in Mud and Salt Sloughs. Prior to WY 1997, the GDA discharged 41 to 59 percent of the regional salt load. The Grassland Bypass Project has reduced the salt load to an average of 31 percent, ranging from 40 percent during WY 1997 (wet) and 24 percent during WY 2010 (above normal) and WY 2011 (wet).

THEORETICAL DILUTION OF GBP DISCHARGES TO MEET VERNALIS STANDARDS

In order to assess the effect of GBP on salinity in the San Joaquin River, an analysis was developed to theoretically isolate the effects of GBP from other activities potentially affecting salinity concentrations in the river. Drainage from GBP was assumed as the only drainage relevant to project related changes in salt load on the San Joaquin River. The analysis was cast in terms of theoretical dilution water needed to bring the GBP discharges to the Vernalis seasonal salinity objectives.

The salinity objectives for Vernalis are 1,000 µS/cm[6] (640 mg/L[7] Total Dissolved Solids) in the winter months (September - March) and 700 µS/cm (448 mg/L TDS) in the summer months (April - August). **Table 4** lists the theoretical volume of water that would be needed each year to dilute the combined salt loads from the GDA, measured at Station A, and the Grasslands Watershed, drained by Mud Slough and Salt Slough (Stations D & F), to meet the Vernalis standards. This analysis does not take into account any of the other operational criteria, nor does it consider salinity contributions to the River other than those derived from the GDA. The value of the analysis is that it permits a "with" and "without" project comparison with prior year hydrology, in terms (water quality releases from a reservoir) meaningful to water users and managers.

The assimilative capacity analysis considers the total volume of dilution water (assumed to have a salinity of 100 mg/L) that would be needed to reduce the drainage water alone to the salinity objective. Note that the monthly volume of dilution water is highly dependent on the 100 mg/L assumption. Note also that the relation between dilution water quality and required volume is non-linear.

Figure 1 shows the monthly theoretical dilution requirements for October 1985 through December 2011. **Figure 2** shows the total theoretical dilution requirement for Water Years 1986 - 2011. The unshaded areas in **Figures 1 and 2** represent the theoretical dilution requirements for salt loads generated by the Grasslands Watershed which includes the GDA and other agricultural areas, wetlands, and uncontrolled runoff from the Coast Range watersheds. The shaded area in both figures shows the theoretical dilution requirements for salt loads discharged from only the GDA.

The data for **Figure 2** are summarized in **Table 4**. Prior to WY 1997, about 273,440 acre-feet would have been required to dilute the average annual volume of drainage water discharged from the GDA to meet the Vernalis standard. During the fifteen years of the Project, the theoretical annual volume of water needed to dilute the GDA drainage water was reduced 42 percent to less than 230,000 acre-feet. In comparison, the average annual volume of water needed to dilute the regional flows before WY 1997 was about 358,000 acre-feet, and about 294,000 during the Grassland Bypass Project through WY 2011; a reduction of only eighteen percent.

6 µS/cm = microSiemens per centimeter, equivalent to micromhos per centimeter

7 mg/L = milligrams per liter, equivalent to parts per million

These percentages should be put into context of the 1987 – 1994 drought and the initiation of CVPIA water deliveries to wetlands (private, State and Federal) in the Grasslands Basin that preceded the authorization of the Grassland Bypass Project. The latter has profoundly affected the hydrology of the Grasslands Basin and has affected the timing of salt loading to the San Joaquin River.

Though WY 2010 and 2011 were classified as above normal and wet, , the theoretical volumes of water needed to dilute the drainage water from the GDA was less than the theoretical volumes needed during the dry and critical drought years of 1987 – 1994 (**Table 4 and Figure 2**). Note that the theoretical dilution for WY 2010 and 2011 were less than that needed for WY 1992, a critical year.

Data for several more years will be necessary before the impact of the GBP on the San Joaquin River, as measured by dilution requirements for GDA discharges (Station A) and for the regional watershed, can be quantified with confidence. Preliminary results show a decreasing dilution requirement for discharges from the GDA since 1997, and an increasing requirement for the regional watershed.

CALCULATIONS

The formula for theoretical dilution is: $Q2 = Q1(C3-C1)/(C2-C3)$

Q1 = Drainwater discharge in acre-feet per month

Q2 = Volume of water needed to dilute Q1 to meet Vernalis standards in acre-feet per month

C1 = Measured concentration of GBP drainage water in parts per million (mg/L)

C2 = Assumed concentration of dilution water = 100 mg/L

C3 = Vernalis standard concentration = 448 mg/L April - August

= 640 mg/L September – March

References

U.S. Bureau of Reclamation, et al. June 2002. Monitoring Program for the Operation of the Grassland Bypass Project. Prepared by the Grassland Bypass Project Data Collection and Review Team.

U.S. Bureau of Reclamation, et al. August 22, 2002. Quality Assurance Project Plan for the Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project.

Tables

Table 1a. Comparison of Flows and Salt Loads Discharged to the San Joaquin River

Table 1b. Comparison of Flows and Salt Loads Discharged to the San Joaquin River, Water Years 1997 – 2011

Table 1c. Comparison of Flows and Salt Loads Discharged to the San Joaquin River, Calendar Years 1997 - 2011

Table 2. Annual Volume of Water Discharged from the Grassland Drainage Area and Mud/Salt Slough Watershed

Table 3. Annual Loads of Salt Discharged from the Grassland Drainage Area and Mud/Salt Slough Watershed

Table 4. Theoretical Annual Volumes of Dilution Water Needed to Meet Vernalis Standards

Figures

Figure 1. Theoretical Monthly Volumes of Water Needed to Dilute Drainage Water from the Grasslands Drainage Area and the Regional Watershed to Meet Vernalis

Figure 2. Theoretical Annual Volumes of Water Needed to Dilute Drainage from the Grassland Drainage Area and the Regional Watershed to Meet Vernalis

Table 1a. Comparison of Flows and Salt Loads Discharged to the San Joaquin River

	Monthly Flow			Monthly Salt Load		
	Grassland Bypass Project Station B acre-feet	San Joaquin River at Crows Landing Station N acre-feet	B as % of N	Grassland Bypass Project Station B tons	San Joaquin River at Crows Landing Station N tons	B as % of N
January 2010	1,430	63,300	2%	6,770	54,940	12%
February 2010	1,580	51,460	3%	7,430	55,740	13%
March 2010	1,850	104,530	2%	9,280	88,750	10%
April 2010	950	101,480	1%	4,740	59,010	8%
May 2010	1,630	91,560	2%	7,510	49,790	15%
June 2010	1,210	67,370	2%	5,320	42,240	13%
July 2010	870	33,910	3%	4,470	30,470	15%
August 2010	930	32,060	3%	4,880	26,310	19%
September 2010	700	55,700	1%	3,100	26,530	12%
October 2010	680	50,370	1%	2,520	31,470	8%
November 2010	1,070	49,380	2%	4,380	40,420	11%
December 2010	1,810	123,110	1%	7,750	80,170	10%
January 2011	1,600	370,000	0.4%	7,720	104,290	7%
February 2011	2,190	254,880	1%	11,320	81,950	14%
March 2011	3,010	449,980	1%	14,980	130,900	11%
April 2011	2,000	842,590	0.2%	11,230	145,640	8%
May 2011	1,680	409,990	0.4%	8,680	58,370	15%
June 2011	1,610	256,030	1%	7,750	57,260	14%
July 2011	980	251,350	0.4%	4,280	55,040	8%
August 2011	1,050	73,470	1%	4,070	36,810	11%
September 2011	830	61,340	1%	2,840	28,320	10%
October 2011	980	100,150	1%	2,960	37,370	8%
November 2011	980	66,770	1%	2,530	41,540	6%
December 2011	1,110	41,440	3%	3,280	46,060	7%

Data Sources: Station B - US Geological Survey Site 11262895
Station N - US Geological Survey Site 11274550

Table 1b. Comparison of Flows and Salt Loads Discharged to the San Joaquin River, Water Years 1997 – 2011

	Total Flow			Total Salt Load		
	Grassland Bypass Project Station B acre-feet	San Joaquin River at Crows Landing Station N acre-feet	B as % of N	Grassland Bypass Project Station B tons	San Joaquin River at Crows Landing Station N tons	B as % of N
WY 1997	37,560	3,844,610	1%	167,830	1,067,030	16%
WY 1998	45,950	4,904,910	1%	205,110	1,493,450	14%
WY 1999	32,310	1,015,480	3%	149,140	680,840	22%
WY 2000	31,260	1,027,440	3%	135,010	706,370	19%
WY 2001	28,250	653,430	4%	120,030	623,060	19%
WY 2002	28,400	533,960	5%	116,190	518,580	22%
WY 2003	27,270	546,130	5%	118,760	575,350	21%
WY 2004	27,700	554,550	5%	116,350	563,890	21%
WY 2005	30,160	1,721,000	2%	132,560	882,230	15%
WY 2006	25,970	3,437,650	1%	119,700	952,840	13%
WY 2007	18,540	606,360	3%	77,400	523,580	15%
WY 2008	15,670	586,030	3%	65,930	496,050	13%
WY 2009	13,160	336,670	4%	55,590	361,510	15%
WY 2010	14,520	709,070	2%	67,670	531,320	13%
WY 2011	18,510	3,192,490	1%	87,520	850,640	10%

Table 1c. Comparison of Flows and Salt Loads Discharged to the San Joaquin River, Calendar Years 1997 – 2011

	Total Flow			Total Salt Load		
	Grassland Bypass Project Station B acre-feet	San Joaquin River at Crows Landing Station N acre-feet	B as % of N	Grassland Bypass Project Station B tons	San Joaquin River at Crows Landing Station N tons	B as % of N
1997	37,490	3,590,680	1%	169,330	1,060,870	16%
1998	46,240	5,064,330	1%	208,860	1,497,060	14%
1999	32,250	864,600	4%	146,580	665,970	22%
2000	30,210	1,059,180	3%	128,600	692,060	19%
2001	28,010	638,210	4%	119,210	623,700	19%
2002	28,460	523,240	5%	117,760	528,650	22%
2003	27,550	521,480	5%	119,330	558,560	21%
2004	28,290	573,270	5%	118,000	575,090	21%
2005	29,610	1,755,440	2%	132,060	892,950	15%
2006	25,890	3,463,050	1%	116,890	952,470	12%
2007	17,990	550,850	3%	75,510	497,770	15%
2008	15,860	523,470	3%	66,200	467,340	14%
2009	12,920	356,380	4%	56,280	378,910	15%
2010	14,710	824,230	2%	68,150	585,840	12%
2011	18,020	3,177,990	1%	81,640	823,550	10%

Table 2. Annual Volume of Water Discharged from the Grassland Drainage Area and Mud/Salt Slough Watershed

Water Year (1)	Water Year Type	Water discharged from Grassland Drainage Area (2) acre-feet	Water discharged from Mud and Salt Sloughs (3) acre-feet	GDA discharge as percent of discharge from the Sloughs
WY 1986	Wet	67,010	284,320	24%
WY 1987	Critical	74,900	233,840	32%
WY 1988	Critical	65,330	230,450	28%
WY 1989	Critical	54,190	211,390	26%
WY 1990	Critical	41,660	194,660	21%
WY 1991	Critical	29,290	102,160	29%
WY 1992	Critical	24,530	85,430	29%
WY 1993	Wet	41,200	167,960	25%
WY 1994	Critical	38,670	183,550	21%
WY 1995	Wet	57,570	263,770	22%
WY 1996	Wet	52,980	267,950	20%
WY 1997	Wet	37,560	287,010	13%
WY 1998	Wet	45,950	378,670	12%
WY 1999	Above Normal	32,310	253,130	13%
WY 2000	Above Normal	31,260	235,490	13%
WY 2001	Dry	28,250	226,750	12%
WY 2002	Dry	28,400	180,160	16%
WY 2003	Below Normal	27,270	216,140	13%
WY 2004	Dry	27,700	210,520	13%
WY 2005	Wet	30,160	265,880	11%
WY 2006	Wet	25,970	285,000	9%
WY 2007	Critical	18,540	178,330	10%
WY 2008	Critical	15,670	152,670	10%
WY 2009	Below Normal	13,160	109,510	12%
WY 2010	Above Normal	14,520	165,580	9%
WY 2011	Wet	18,510	243,270	8%

Notes:
Pre-project data compiled by Nigel Quinn (LBNL) from CVRWQCB and USGS reports.
(1) Water Year - October 1 - September 30
(2) Grassland Drainage Area
GDA WY 1986 - 1996: CVRWQCB data
GDA WY 1997 - 2011: Station B - San Luis Drain, LBL, USGS, and SLDMWA data
(3) Mud and Salt Sloughs
Station D - Mud Slough near Gustine, US Geological Survey Site 11262900
Station F - Salt Slough at Hwy 165, US Geological Survey Site 11361100
(4) Below Normal, Critical, and Dry Water Years: 1987 - 1992, 1994, 2001, 2002, 2004, 2007, 2008, 2009
(5) Above Normal and Wet Water Years: WY 1986, 1993, 1995 - 2000, 2003, 2005, 2006, 2010, 2011

Table 3. Annual Loads of Salt Discharged from the Grassland Drainage Area and Mud/Salt Slough Watershed

Water Year (1)	Water Year Type	Salt discharged from Grassland Drainage Area (2) tons	Salt discharged from Mud and Salt Sloughs (3) tons	GDA salt discharge as percent of discharge from the Sloughs
WY 1986	Wet	214,250	494,540	43%
WY 1987	Critical	241,526	438,900	55%
WY 1988	Critical	236,301	455,960	52%
WY 1989	Critical	202,420	389,330	52%
WY 1990	Critical	171,265	380,560	45%
WY 1991	Critical	129,899	221,540	59%
WY 1992	Critical	110,327	197,350	56%
WY 1993	Wet	183,021	336,520	54%
WY 1994	Critical	171,495	379,410	45%
WY 1995	Wet	237,530	499,340	48%
WY 1996	Wet	197,526	477,730	41%
WY 1997	Wet	167,830	446,700	38%
WY 1998	Wet	205,100	627,660	33%
WY 1999	Above Normal	149,150	401,620	37%
WY 2000	Above Normal	135,010	372,430	36%
WY 2001	Dry	120,020	383,150	31%
WY 2002	Dry	116,190	327,350	35%
WY 2003	Below Normal	118,750	373,930	32%
WY 2004	Dry	116,350	350,500	33%
WY 2005	Wet	132,560	436,440	30%
WY 2006	Wet	121,070	436,860	28%
WY 2007	Critical	79,680	269,590	30%
WY 2008	Critical	65,920	262,040	25%
WY 2009	Below Normal	55,580	194,420	29%
WY 2010	Above Normal	67,660	278,360	24%
WY 2011	Wet	87,520	359,310	24%

Notes:
Pre-project data compiled by Nigel Quinn (LBNL) from CVRWQCB and USGS reports.
(1) Water Year - October 1 - September 30
(2) Grassland Drainage Area
GDA WY 1986 - 1996: CVRWQCB data
GDA WY 1997 - 2011: Station B - San Luis Drain, LBL, USGS, and SLDMWA data
(3) Mud and Salt Sloughs
Station D - Mud Slough near Gustine, US Geological Survey Site 11262900
Station F - Salt Slough at Hwy 165, US Geological Survey Site 11361100
(4) Below Normal, Critical, and Dry Water Years: 1987 - 1992, 1994, 2001, 2002, 2004, 2007, 2008, 2009
(5) Above Normal and Wet Water Years: WY 1986, 1993, 1995 - 2000, 2003, 2005, 2006, 2010, 2011

Table 4. Theoretical Annual Volumes of Dilution Water Needed to Meet Vernalis Standards

Water Year (1)	Water Year Type	Theoretical Annual Volume of Water Needed to Dilute GDA Discharge to Meet Vernalis Standard (2) acre-feet	Theoretical Annual Volume Water Needed to Dilute Regional Discharge to Meet Vernalis Standard (3) acre-feet
WY 1986	Wet	303,360	426,150
WY 1987	Critical	332,190	406,130
WY 1988	Critical	335,150	424,450
WY 1989	Critical	294,830	350,410
WY 1990	Critical	245,170	341,300
WY 1991	Critical	186,450	235,850
WY 1992	Critical	160,420	191,070
WY 1993	Wet	272,850	325,960
WY 1994	Critical	249,060	363,090
WY 1995	Wet	344,980	451,510
WY 1996	Wet	283,340	418,390
WY 1997	Wet	243,890	342,720
WY 1998	Wet	294,200	517,350
WY 1999	Above Normal	201,500	321,520
WY 2000	Above Normal	190,230	297,220
WY 2001	Dry	174,570	322,700
WY 2002	Dry	154,950	293,060
WY 2003	Below Normal	158,270	312,370
WY 2004	Dry	151,040	285,940
WY 2005	Wet	172,110	349,960
WY 2006	Wet	153,410	339,330
WY 2007	Critical	104,410	155,730
WY 2008	Critical	73,880	216,920
WY 2009	Below Normal	60,580	163,150
WY 2010	Above Normal	80,440	229,830
WY 2011	Wet	118,990	263,310

Notes:
Pre-project data compiled by Nigel Quinn (LBNL) from CVRWQCB and USGS reports.
(1) Water Year - October 1 - September 30
(2) Grassland Drainage Area
GDA WY 1986 - 1996: CVRWQCB data
GDA WY 1997 - 2011: Station B - San Luis Drain, LBL, USGS, and SLDMWA data
(3) Mud and Salt Sloughs
Station D - Mud Slough near Gustine, US Geological Survey Site 11262900
Station F - Salt Slough at Hwy 165, US Geological Survey Site 11361100
(4) Below Normal, Critical, and Dry Water Years: 1987 - 1992, 1994, 2001, 2002, 2004, 2007, 2008, 2009
(5) Above Normal and Wet Water Years: WY 1986, 1993, 1995 - 2000, 2003, 2005, 2006, 2010, 2011

Figure 1. Theoretical Monthly Volumes of Water Needed to Dilute Drainage Water from the Grasslands Drainage Area and the Regional Watershed to Meet Vernalis

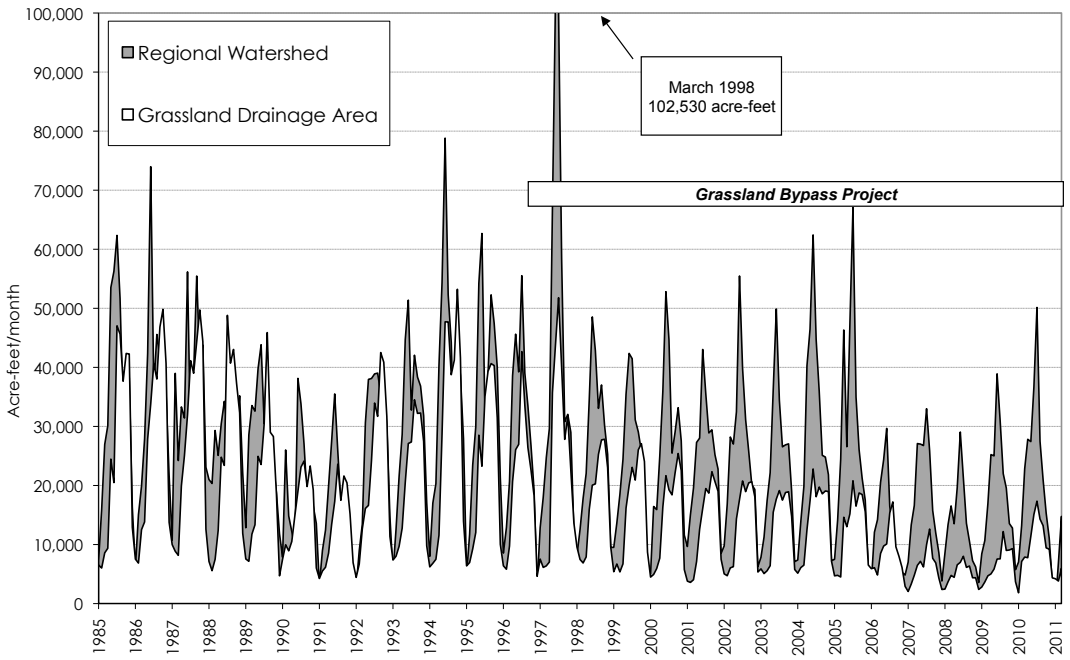
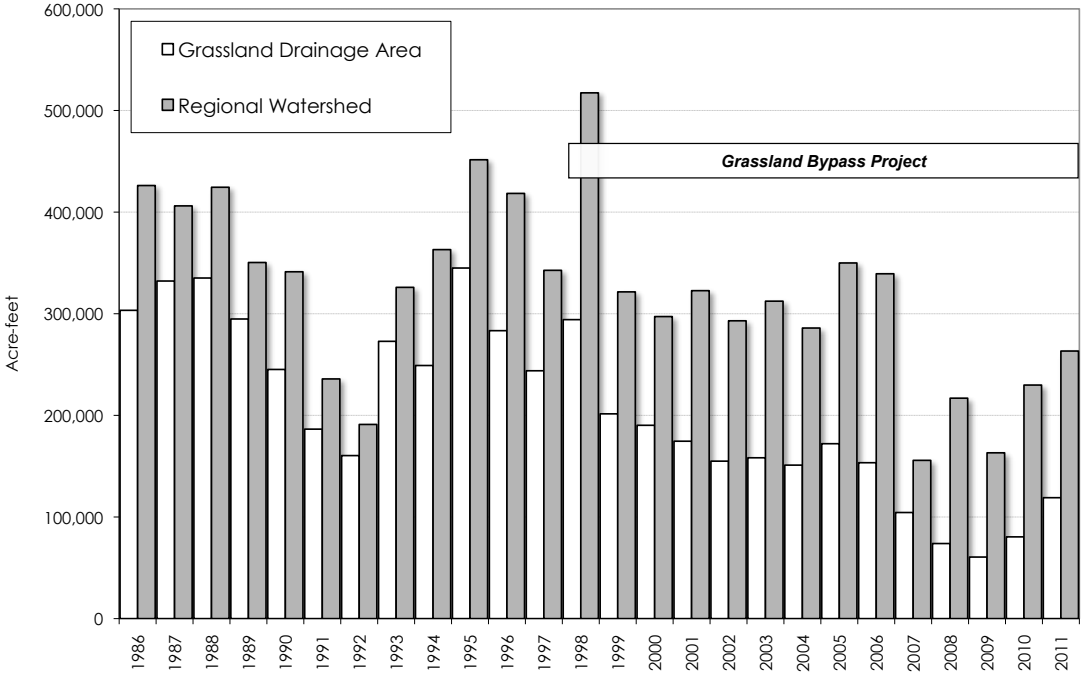
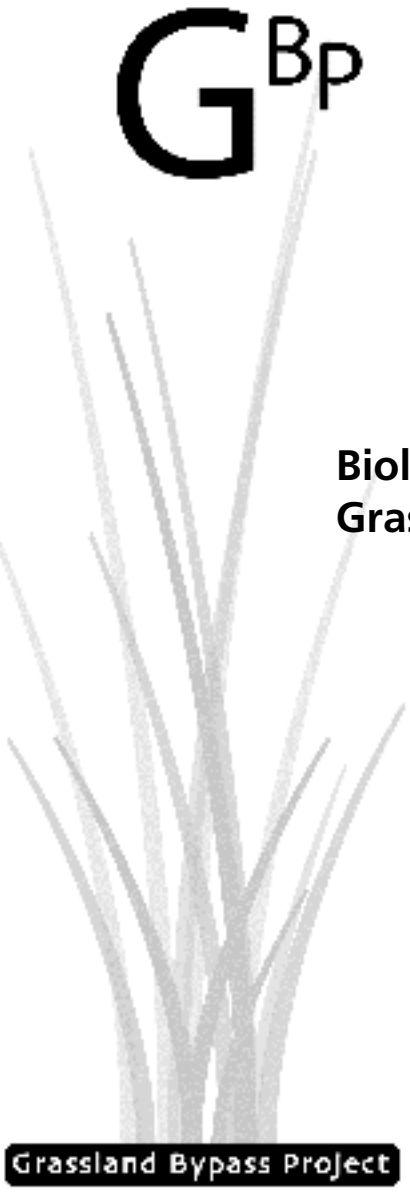


Figure 2. Theoretical Annual Volumes of Water Needed to Dilute Drainage from the Grassland Drainage Area and the Regional Watershed to Meet Vernalis





CHAPTER 7

Biological Effects of the Grassland Bypass Project

January 1, 2010 – December 31, 2011

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Abstract

In its fourteenth and fifteenth years of operation, the Grassland Bypass Project continued to reduce the risk of selenium toxicity in the ecosystem from which the Project removed agricultural subsurface drainwater. However, it also continued to cause elevated risk in the waterway into which the drainwater has been diverted by the Project. In Salt Slough, where drainwater has been removed by the Project, selenium concentrations in fish and invertebrates , after continuing to decline for several years, appeared to "bottom out", rising slightly in 2010-2011, but remaining almost entirely below thresholds of concern. The overall selenium hazard (Lemly index) to the Salt Slough ecosystem remained low in 2010 and 2011. (**Table 4b**)

In Mud Slough (north) below the outfall of the San Luis Drain (SLD), selenium concentrations in fish and invertebrates continued to exceed generally thresholds of concern; average concentrations in these organisms generally have not decreased as loads and concentrations of selenium in water in Mud Slough (north) have declined. The Lemly index of selenium hazard to the aquatic ecosystem remained "high" in this area. (**Table 4a**)

Selenium concentrations did not exceed the 2 µg/g (wet weight) Human Health Screening Level in six composite samples of carp muscle tissue collected in 2010 and 2011 from Mud Slough (north) and two places in the San Joaquin River.

No biota samples were collected from Mud Slough (north) at Highway 140 (Site E), San Joaquin River at Fremont Ford (Site G), and the San Joaquin River at Hills Ferry (Site H) during 2010 and most of 2011. Samples of fish and invertebrates were collected in December 2011 at these sites. No vegetation samples were collected from these sites during 2010 and 2011.

Abundance of the invasive Siberian freshwater shrimp (Exopalaemon modestus), appeared to have rebounded somewhat since 2008. Numbers of this non-native species had exploded after it first appeared in Grassland sloughs in 2003, but had declined by 2006-2007. This species evidently bioconcentrates selenium more efficiently than other aquatic invertebrates, and may have contributed to the persistence of elevated concentrations of selenium in the biota through 2011 as loads of selenium discharged into Mud Slough were generally declining.

The concentration of selenium in two composite samples of whole-body Mosquitofish (*Gambusia affinis*) collected during December 2011 at Mud Slough at Highway 140 were 5.7 and 5.8 µg/g (dry weight), exceeding the 4 µg/g (dry weight) level of concern for warm water fish, but below the toxicity threshold of 9 µg/g (dry weight). In the San Joaquin River at Fremont Ford, selenium concentrations in two composite samples of whole body fish were below the 3 µg/g (dry weight) threshold of concern. The only composite sample collected from the river at Hills Ferry had a selenium concentration of 3.2 µg/g (dry weight), slightly above the threshold of concern.

In 2010 and 2011, selenium concentrations in all seed samples collected along Salt Slough and along Mud Slough remained entirely below levels of concern as diet for waterbirds. Boron concentrations in one seed sample collected from along Salt Slough was above the threshold of concern as diet for waterbirds; along Mud Slough, concentrations of boron were at or above the threshold of concern in all of the seed samples collected in 2010-2011. No vegetation samples were collected in 2010

and 2011 from Mud Slough (north) at Highway 140, the San Joaquin River near Fremont Ford, and the San Joaquin River at Hills Ferry.

Introduction

Project History

In 1985, the San Luis Drain (SLD) was closed due to deaths and developmental abnormalities of waterbirds at a reservoir in the Kesterson National Wildlife Refuge at the terminus of the SLD. The SLD, constructed by the U.S. Bureau of Reclamation (USBR), had been conceived as a means to dispose of agricultural drainwater generated from irrigation with water supplied by the federal Central Valley Water Project. However, due to environmental concerns and budget constraints, the SLD had never been completed as originally planned. The constructed portion of the SLD had been used only to convey agricultural drainwater from Westlands Water District in the western San Joaquin Valley.

Farms in the adjacent Grassland Drainage Area (GDA) never used the SLD, but discharged agricultural drainwater through wetland channels in the Grassland Water District, San LuisNational Wildlife Refuge Complex, and the China Island Unit of the North Grasslands Wildlife Area (Refuges) to the San Joaquin River. This drainwater contains elevated concentrations of selenium, boron, chromium, and molybdenum, and high concentrations of various salts (CEPA, 2000) that disrupt the normal ionic balance of affected aquatic ecosystems (SJVDP, 1990b).

Discharge of agricultural drainwater from GDA farms was unaffected by the closure of the SLD, and drainage continued to contaminate Refuge water delivery channels after the closure of the SLD and Kesterson Reservoir in 1986. To address this problem, a proposal to use a portion of the SLD and extend it to Mud Slough, a natural waterway in the Refuges, was implemented by the USBR in September 1996 with support from other federal and state agencies (USBR and SLDMWA, 1995). This project, known as the Grassland Bypass Project (GBP), diverts agricultural drainwater from GDA farms into the lower 28 miles of the SLD and thence into the lower portion of Mud Slough (about six miles). The GBP has removed drainwater from more than 90 miles of wetland water supply channels, including Salt Slough, and allows the Refuges full use of water rights to create and restore wetlands on the Refuges.

The GBP continues to contaminate the northernmost six miles of Mud Slough and the reach of the San Joaquin River between Mud Slough and the Merced River. However, as phased-in load reduction goals are achieved by GDA farmers, these effects are expected to be reduced.

An essential component of the GBP is a monitoring program that tracks contaminant levels and effects in water, sediment, and biota to ensure that the overall effect of the GBP is not a net deterioration of the ecosystems in the area affected by the GBP.

Contaminants of Concern

In the aftermath of the deaths and developmental abnormalities of birds at Kesterson Reservoir in the early 1980s, studies definitively traced the cause to selenium in the agricultural drainwater in the reservoir (Suter, 1993). Because of this, and because of the well-known history of death, teratogenesis, and reproductive impairment caused by selenium in agricultural drainwater elsewhere (reviewed in Skorupa, 1998), the primary contaminant of concern in this monitoring program is selenium. Other

inorganic constituents of potential toxicological concern in drainage water include boron, molybdenum, arsenic, chromium (Klasing and Pilch, 1988; SJVDP, 1990a;CRWQCBCVR, 1998) and mercury.

Selenium Ecological Risk Guidelines

The assessment of the risks that selenium poses to fish and wildlife can be difficult due to the complex nature of selenium cycling in aquatic ecosystems (Lemly and Smith, 1987). Early assessments developed avian risk thresholds through evaluating bird egg concentrations and relating those to levels of teratogenesis (developmental abnormalities) and reproductive impairment (Skorupa and Ohlendorf, 1991). In 1993, to evaluate the risks of the proposed Grassland Bypass Project on biotic resources in Mud and Salt Sloughs, a set of Ecological Risk Guidelines based on selenium in water, sediment, and residues in several biotic tissues were developed by a subcommittee of the San Luis Drain Re-Use Technical Advisory Committee (CAST, 1994; Engberg, et.al., 1998). These guidelines (as recently modified: **Table 1**) are based on a large number of laboratory and field studies, most of which are summarized in Skorupa et al. (1996) and Lemly (1993). In areas where the potential for selenium exposure to fish and wildlife resources exists, these selenium risk guidelines can be used to trigger appropriate actions by resource managers, regulatory agencies, and dischargers. For the GBP the selenium risk guidelines have been divided into three threshold levels: No Effect, Concern, and Toxicity.

In the No Effect range risks to sensitive species are not likely. As new information becomes available it should be evaluated to determine if the No Effect level should be adjusted. Since the potential for selenium exposure exists, periodic monitoring of water and biota is appropriate.

Within the Concern range there may be risk to species sensitive to elevated contaminant concentrations in water, sediment, and biota, and should be monitored on a regular basis. Immediate actions to prevent selenium concentrations from increasing should be evaluated and implemented if appropriate. Long-term actions to reduce selenium risks should be developed and implemented. Research on effects on sensitive or listed species may be appropriate.

Within the Toxicity range, adverse affects are more likely across a broader range of species, and sensitive or listed species would be at greater risk. These conditions will warrant immediate action to reduce selenium exposure through disruption of pathways, reduction of selenium loads, or other appropriate actions. More detailed monitoring, studies on site-specific effects, and studies of pathways of selenium contamination may be appropriate and necessary. Long-term actions to reduce selenium risks should be developed and implemented.

Warmwater Fish

The warmwater fish guidelines (**Table 1**) refer to concentrations of selenium in warmwater fish that adversely affect the fish themselves. Nearly all of the fish routinely sampled by the GBP monitoring program are warmwater fish.

The concern threshold for warmwater fish has been kept at 4 µg/g (all fish data are whole body, dry weight). Experimental data reported in the literature may be interpreted to support a range of thresholds around this value. In particular, bluegill sunfish dietary exposure data in Cleveland et al. (1993) and Lemly (1993) support warmwater fish concern thresholds ranging from 2.5 to 3.9 µg/g. Bluegill sunfish are warmwater fish that are found in the sloughs in the GBP area.

Cleveland et al. (1993) found no adverse effects after 59 days of exposure to a concentration of dietary selenium (nominally 3.3 µg/g wet weight) that resulted in a bluegill tissue concentration of 2.6 µg/g (whole body dry weight). Fifty nine days of exposure to dietary concentrations that resulted in tissue concentrations of 4.3 µg/g (whole body dry weight) caused a significant increase in mortality relative to controls. Therefore the No Observable Effect Concentration (NOEC) is 2.6 µg/g, and the Lowest Observable Effect Concentration (LOEC) is 4.3 µg/g. Following a standard US EPA method (Stephan et al., 1985), the tissue threshold is calculated as the geometric mean of the NOEC and the LOEC. Application of this procedure to these data yields a threshold of 3.3 µg/g.

Other data in Cleveland et al. (1993) support a threshold closer to 4 µg/g. After 90 days of dietary exposure bluegill with a tissue selenium concentration of 3.2 µg/g did not exhibit adverse effects that were significantly greater than controls (NOEC), but bluegill with a tissue concentration of 4.7 µg/g experienced significantly increased mortality (LOEC). The corresponding threshold is 3.9 µg/g (geometric mean of 3.2 µg/g and 4.7 µg/g). Analysis of these data (Cleveland et al., 1993: 90 day) using the logit procedure (linear regression using logit- transformed effect data) yields an LC10 of 2.81 µg/g whole body dry weight (**Figure 1c).**

In an experiment reported by Lemly (1993) juvenile bluegill exposed to dietary selenium (5.16 µg/g dry weight) in the form of seleno-L-methonine for 180 days, while being subjected to certain conditions (cold temperature and short photoperiod) simulating the onset and about 4 months duration of winter, reached whole body selenium concentrations of 5.8 µg/g (dry weight) at 60 days (beginning of full winter: 4 degrees C water temperature) and 7.9 µg/g (dry weight) at 180 days, and suffered 33.8% mortality at 180 days. Controls (diet: 0.82 µg/g dry weight) subject to the same winter-onset conditions reached whole body selenium concentrations of 1.1 µg/g (dry weight) at 60 days (beginning of full winter) and 1.4 µg/g (dry weight) at 180 days, and suffered 2.8% mortality at 180 days. If this 2.8% control mortality is assumed to be due to causes other than selenium, then the NOEC is 1.4 µg/g and LOEC (causing 31% mortality) is 7.9 µg/g at 180 days. By the standard US EPA method (Stephan et al., 1985), the tissue threshold is then 3.3 µg/g whole body dry weight (geomean of 1.4 and 7.9 µg/g). However, concentrations of selenium at 180 days were magnified by loss of lipid during winter stress (Lemly, 1993; US EPA, 2004). If the concentrations at 60 days are used as an indication of summer-fall concentrations of bluegill that will reach the 180 day concentrations at the end of winter (US EPA, 2004), then the tissue threshold should be 2.5 µg/g (geometric mean of 1.1 and 5.8 µg/g, the whole-bodyconcentrations of the control and exposed treatment groups respectively at 60 days).

Considering that these data do not include adverse effects on reproduction, which may occur at lower concentrations, these thresholds (2.5 to 3.9 µg/g whole body dry weight) may not be fully protective of sensitive warmwater fish species.

Coldwater Fish

Salmonids (salmon and trout), which are known as "coldwater fish", are evidently more sensitive to selenium than other freshwater fish such as sunfish and carp, which are known as "warmwater fish". This accords with the greater sensitivity of trout and salmon to a wide range of other contaminants (Teather and Parrott 2006.). Application of a biphasic model (Beckon *et al*. 2008) to a study of juvenile

fall run Chinook salmon (*Oncorhynchus tshawytscha*) from the Merced River Hatchery (Hamilton *et a*l. 1990) indicates that ten percent mortality attributable to selenium (LC10) is associated with a whole body selenium tissue concentration of 1.84 µg/g dry weight (**Figure 1D**). Deforest *et al.* (1999) analyzed these data using the alternative probit and logit methods. Both procedures yielded LC10s of 1.7 µg/g (whole body dry weight).

These LC10s are in good agreement with 10 percent effect level (EC10) for rainbow trout (*Oncorhynchus mykiss*), another salmonid species. Analysis of a study (Hilton *et al*., 1980) of juvenile rainbow trout (average initial weight: 1.28 g) exposed for 140 days to dietary selenium in the form of sodium selenite indicates that a 10 percent reduction in weight (from optimum weight) is associated with a selenium concentration of 2.19 µg/g in trout tissue (whole body dry weight; **Figure 1E**).

These findings are consistent with the more recent study by Vidal *et al.*(2005) in which larval rainbow trout (24 days old initially) were exposed for 90 days to dietary selenium in the form of seleno-L-methionine. Rainbow trout that had been fed a diet spiked with 4.6 µg/g selenium reached an average tissue concentration of 0.58 µg/g whole body wet weight (reported), or 2.64 µg/g whole body dry weight (calculated from wet weight using 75.84% moisture – US EPA 2004) and weighed an average of 3.54 g. This is significantly less than the average weight of controls (5.17 g, diet: 0.23 µg/g dry weight), which had an average tissue concentration of 0.31 µg/g whole body wet weight, or 1.41 µg/g whole body dry weight. Thus the LOEC and NOEC are 2.64 µg/g and 1.41 µg/g respectively, and the US EPA method of Stephan *et al.* (1985) yields a tissue threshold of 1.76 µg/g whole body dry weight (geometric mean of LOEC and NOEC).

The analyses above focus on growth and mortality. Reproductive impairment may occur at lower selenium concentrations, but too few data are available to do similar analyses of reproductive effects. Therefore, sensitive coldwater fish species may not be fully protected by any of the thresholds derived from these analyses.

Although the fish community in the sloughs affected by the GBP principally consists of warmwater species, anadromous coldwater fish migrate through the portion of the San Joaquin River into which these sloughs discharge. A study by Saiki *et al.* (1991) showed that migrating juvenile coldwater fish (Chinook salmon) in the reach of the San Joaquin River just below the discharge of Mud Slough bioaccumulated selenium to concentrations of about 3 µg/g (whole body dry weight), levels at which substantial mortality could occur (**Figure 1D**).

Vegetation and Invertebrates

The guidelines for vegetation (as diet) and invertebrates (as diet) refer to selenium concentrations in plants and invertebrates affecting birds that eat these items. These guidelines are mainly based on experiments in which seleniferous grain or artificial diets spiked with selenomethionine were fed to chickens, quail or ducks resulting in reproductive impairment (Wilber, 1980; Martin, 1988; Heinz, 1996). The Concern threshold for vegetation is 3 µg/g (dry weight) and the Toxicity threshold is 7 µg/g. The invertebrate concern threshold and toxicity threshold are the same as those for vegetation.

Water

Fish and wildlife are much more sensitive to selenium through dietary exposure from the aquatic food chain than by direct waterborne exposure. Therefore the guidelines for water reflect water

concentrations associated with threshold levels of food chain exposure (Hermanutz *et al.*, 1990; Maier and Knight, 1994), rather than concentrations of selenium in water that directly affect fish and wildlife. The concern threshold is 2 µg/L and the toxicity threshold is 5 µg/L.

Sediment

As with water, the principal risk of sediment to fish and wildlife is via the aquatic food chain. Therefore the sediment guidelines are based on sediment concentrations as predictors of adverse biological effects through the food chain (USFWS, 1990; Van Derveer and Canton, 1997). The concern threshold for sediment (dry weight) is 2 µg/g and the toxicity threshold is 4 µg/g.

Bird Eggs

Bird eggs are particularly good indicators of selenium contamination in local ecosystems (Heinz, 1996). However, the interpretation of selenium concentrations in bird eggs in the GBP area is complicated by the proximity of contaminated and uncontaminated sites and by the variation in foraging ranges among bird species. Relative to the guidelines originally used for the GBP, the guidelines used here for individual bird eggs have been revised upward based on recent studies of hatchability of ibis, mallard, and stilt eggs (Henny and Herron, 1989; Heinz, 1996; Skorupa, 1998). The concern threshold has been raised from 3 to 6 µg/g dry weight, and the toxicity threshold has been raised from 8 to 10 µg/g dry weight.

Selenium Ecological Risk Index

Several years after the risk guidelines were developed for the GBP, Lemly (1995, 1996) published a risk index designed to provide an estimate of ecosystem-level effects of selenium. Lemly's assessment procedure sums the effects of selenium on various ecosystem components to yield a characterization of overall hazard to aquatic life. The procedure involves determining an index of toxicity for each component, then adding these indexes together to yield a single index, often known as the Lemly Index. In contrast to the ecological risk guidelines outlined in **Table 1**, the component indexes of the Lemly Index are based on maximum contaminant concentrations rather than means. Therefore, the Lemly Index is sensitive to brief spikes in contaminant levels, but is unaffected by prevailing contaminant levels. Furthermore, the Lemly Index is strongly dependent on sampling periods and sampling frequency, yet Lemly provided no sampling protocol. For these reasons, there is a need to develop a new protocol and index that replaces Lemly's categorical rating format (low, medium, high) with a direct estimate of the probability of adverse effects (e.g.10%+ probability of reproductive impairment). Despite the weaknesses of the Lemly Index, we continue to use it for comparative purposes as long as it remains the best available overall index of the ecological risk of selenium.

Boron Ecological Risk Guidelines

The dietary and tissue concentrations of boron associated with toxic effects on fish and wildlife are not as well known as for selenium. The effects of dietary exposures and waterborne exposures (without dietary exposures) are known for some taxa (**Table 2**), but there are as yet no definitive data associating tissue concentrations with adverse effects in fish and invertebrates. Boron concentrations as low as 0.1 mg/L in water may adversely affect reproduction of sensitive fish species (review in NIWQP, 1998).

Methods

Agency Responsibilities

The role of the California Department of Fish and Wildlife (CDFW) [formerly California Department of Fish and Game (CDFG] and the United States Fish and Wildlife Service (USFWS) in this interagency program is to implement the bio-monitoring portion of the Compliance Monitoring Program. The methods used by the CDFW and USFWS are described in the Quality Assurance Project Plan for Use and Operation of the Grassland Bypass Project (USBR 2001). These methods are also based on standard operating procedures described in Standard Operation Procedures for Environmental Contaminant Operations (USFWS, 1995) and standards used by the other agencies participating in the compliance monitoring program. Deviations from the QAPP that have occurred since 1996 will be discussed later in this section.

To obtain baseline data for this Project, the USFWS began sampling in March 1992, after the reuse of the SLD was initially proposed by the USBR in 1991. The CDFW began sampling in August of 1993. USFWS and CDFW sampling plans before the reopening of the SLD and the early drafts of the monitoring plan were mutually influencing. Therefore, methods used by both agencies before the final approval of the QAPP are, except for a few minor differences, identical to the methods ultimately approved by the Data Collection and Reporting Team. The sampling schedule, though, as discussed below, now follows a regular timetable.

Matrices Sampled

Samples of the biota were collected at each site and analyzed for selenium and boron. Aquatic specimens were collected with hand nets, seine nets, and by electro fishing. Mosquitofish (*Gambusia affinis*), inland silversides (*Menidia beryllina*), red shiners (*Cyprinella lutrensis*), fathead minnows (*Pimephales promelas*), carp (*Cyprinus carpio*), white catfish (*Ameiurus catus*), and green sunfish (*Lepomis cyanellus*) were the principal species of fish collected. Waterboatmen (family: Corixidae), backswimmers (family: Notonectidae), red swam crayfish (*Procambarus clarkii*), and Siberian freshwater shrimp (*Exopalaemon modestus*) were the principal invertebrates collected.

Separation of biological samples from unwanted material also collected in the nets was accomplished by using stainless steel or Teflon sieves, and glass (or enamel) pans pre-rinsed with de-ionized water then native water. To the extent possible, three replicate, composite samples (minimum 5 individuals totaling at least 2 grams for each composite) of each primary species listed above were collected, but other species were also collected. Fish species were analyzed as composite whole body samples except as noted below. Estimates of a conversion factor for relating selenium concentration in skeletal muscle (M) to whole body concentrations (WB) range from M=0.6xWB for many freshwater fish (Lemly and Smith, 1987) to M=0.045+1.23xWB for bluegills and M=-0.39+1.32xWB for largemouth bass (Saiki *et al.*, 1991).

Between 1992 and 1999, frog tadpoles occasionally collected from Mud Slough and Salt Slough sites were archived. In 1999 these archived samples were analyzed. Additional samples have been collected and analyzed from these sites since 2000.

Analyses of fish samples collected from the San Joaquin River (Sites G and H) and Mud Slough (Sites C, D, I2 and E) were prioritized to first meet the objectives of the Compliance Monitoring Plan (Section 4.5.1.4). Supplemental fish samples were analyzed only when baseline biota target species and sample sizes could not be obtained.

The seed heads of wetland plants that provide food for waterfowl were collected along the sloughs in the late summer (August) of each year. This plant material was analyzed for boron as well as selenium.

Waterfowl and/or shorebird eggs, depending on availability, were collected from areas adjacent to Mud Slough and the SLD in the spring of each year since 1996. In addition, in 1992 Snowy Egret and Black-crowned Night Heron eggs were collected at East Big Lake, which has served as a reference sampling site for the USFWS. Bird eggs were analyzed individually, and the results are discussed and displayed below as individual concentrations and geometric means.

Graphs of whole body and avian egg selenium concentrations presented in this report include indications of the threshold concentrations delimiting the risk ranges listed above (**Table 1**). The threshold between the No Effect Zone and the Concern Zone is indicated by a horizontal line of short dashes; the Toxicity threshold is marked on each graph by a horizontal line of long dashes.

All biota samples were kept on ice or on dry ice while in the field then kept frozen to Zero degrees centigrade C during storage and shipment. For all samples, after freeze drying, homogenization, and nitric-perchloric digestion; total selenium was determined by hydride generation atomic absorption spectrophotometry and boron was determined by inductively coupled (argon) plasma spectroscopy.

Sampling Sites

Between 1992 and 1999, biological samples were collected from two sites on Salt Slough, five sites on Mud Slough, two sites in the SLD, two sites on the San Joaquin River, and one reference site that does not receive selenium contaminated drainwater (East Big Lake). Beginning in 1995, sampling efforts were concentrated on the seven sites (**Figure 1**) identified in the Compliance Monitoring Plan: four sites on Mud Slough (C, D, E, and I), one on Salt Slough (F) and two San Joaquin River sites (G and H). Site C is located upstream of where the SLD discharges into Mud Slough. Site D is located immediately downstream of the discharge point. Site I is a small, seasonally flooded backwater area fed by Mud Slough and is located approximately 1 mile downstream from Site D. In March, 2001, biological sampling in Mud Slough was moved from Site I to a new site (Site I2) about 0.5 km upstream of Site I. The new site has a larger, more persistent backwater area.

Site E is located further downstream where Mud Slough crosses State Highway 140. To assess the mitigative effects of drainwater removal from Salt Slough, one sample point, Site F, is located on the San Luis National Wildlife Refuge approximately 2 miles upstream of where State Highway 165 crosses Salt Slough. Site G is located on the San Joaquin River at Fremont Ford, upstream of the Mud Slough confluence, while Site H is located on the San Joaquin River 200 meters upstream of the confluence of the main branch of the Merced River, downstream of Mud Slough confluence. Sites C, D, F, and I2 are monitored by the USFWS while CDFW monitors Sites E, G, and H.

Sampling Times

Baseline sampling conducted by the USFWS occurred monthly during the spring and summer of 1992 and then less frequently during 1993 and 1994. Baseline sampling by CDFW occurred during the summer and fall of 1993 and then resumed in the spring of 1996. Between 1992 and 1995 sampling by either the CDFW and the USFWS occurred at least once every season. Experience and interagency discussions led to the identification of four sampling times based on historic water use and drainage practices and on seasonal use of wetland resources by fish and wildlife. Biota sampling since 1995 has been synchronized to occur during the months of November, March, June, and August. Since 1996, avian eggs have been collected in May and June.

Statistical Analysis

Student's 2-tail t-tests (unpaired samples with unequal variances) were used to compare means of concentrations for groups of samples collected at different times at the sampling sites

Selenium Hazard Assessment

The protocol proposed by Lemly (1995, 1996) was used to estimate the overall hazard of selenium to the ecosystems affected by the GBP. The implementation of the protocol presented here incorporates data for water from Central Valley Regional Water Quality Control Board and data for sediment from the USBR in addition to biological data collected by the USFWS and CDFW. In accordance with Lemly's protocol, the assessments use the highest (rather than the mean) concentrations of selenium found in each of the ecosystem components (**Tables 4a**, **4b**, **5a**, and **5b**).

Data from the biological sampling in November 1996, shortly after GBP initiation, were excluded from the WY 1997 hazard assessments because temporarily extremely high concentrations of selenium in some fish may have been due to those fish having been flushed out of the previously stagnant, evapo-concentrated SLD. Very high levels of selenium in the water associated with storm flows were not excluded because elevated concentrations persisted long enough (especially in February 1998) to potentially affect the ecosystem adversely.

Concentrations of selenium in fish eggs were estimated from whole body concentrations using the conversion factor (fish egg selenium = fish whole body selenium x 3.3) recommended in Lemly (1995, 1996).

Site E (lower Mud Slough) and the San Joaquin River sites (G and H) cannot be rated as to overall hazard of selenium because not all media have been collected to assess these sites.

Departures from the Monitoring Plan and Quality Assurance Project Plan

To ensure reliable and consistent data, the USFWS and the CDFW followed the procedures specified in the Monitoring Plan and the Quality Assurance Project Plan (QAPP) with the exceptions listed below.

External quality assurance samples (QAPP Appendix A, Section 7) were not submitted toanalytical labs with GBP biological samples before January of 1998. External quality assurance

samples are biological materials (e.g. powdered chicken egg, shark liver) with certified concentrations of the analytes of concern (selenium, boron), supplied by third party laboratories. The analyte concentrations in these samples are known to the agencies submitting the samples, but not known to the laboratory doing the analysis. This blind test of laboratory analytical precision supplements the internal quality control procedures of the analytical laboratory. Internal quality control protocols specified in the QAPP (procedural blanks, duplicate samples, and spiked samples) have been followed throughout the history of GBP biological sampling.

The USFWS used stainless steel (rather than Teflon) strainers for sorting small fish (QAPP Appendix A, Section 4.7).

For some species at some locations it has not been practical at times to collect the full target minimum numbers of individuals and/or mass per sample that are specified in the Compliance Monitoring Plan (Section 4.5.1.4) and the QAPP (Appendix A, Section 4.5).

From 1992 through 1997 all biological samples collected by the USFWS (except bird eggs in 1996 and 1997) were analyzed by Environmental Trace Substance Laboratory at the University of Missouri in accordance with the QAPP (Appendix A, Section 6.1). Bird egg samples collected in 1996 and 1997 were analyzed at Trace Element Research Laboratory (TERL) at Texas A & M University, a USFWS contract laboratory. All biological samples collected in 1998 were analyzed at TERL. TERL is subject to the same performance standards as Environmental Trace Substance Laboratory, therefore, the GBP quality assurance objectives (QAPP **Table 1**) apply to analytical results from TERL. All biological samples beginning in 1999 have been analyzed at the Water Pollution Control Laboratory of the CDFW in Rancho Cordova, California, after this laboratory was screened and approved by the GBP Quality Control Officer.

Seine net mesh size was increased from 3/16 inch to 1/4 inch after the first two pre-Project collections in 1993 from sampling sites E, G, and H (QAPP Appendix A, Section 4.6). This change in sampling gear resulted in significant declines in catch abundance of smaller forage fish without altering diversity of representative assemblages. Data collected from 1993 sampling efforts at these sites were not included in making quantitative spatial or temporal comparisons between sites unless otherwise noted. At sites C, D, I, and F, 1/8 inch mesh seines were used from 1992 through 1998. Since 1999, a 3/16 inch mesh bag seine has been used at these sites by the USFWS.

As discussed earlier, biological sampling in Mud Slough was moved from Site I to Site I2, a new site about 0.5 km upstream with a larger, more permanent backwater area.

Results

Salt Slough (Site F)

Salt Slough is a principal wetland water supply channel from which drainwater has been removed by the GBP.

Selenium in fish

Concentrations of selenium in Salt Slough fish composite samples declined rapidly during the first year of operation of the GBP. Concentrations then stabilized at levels generally below the concern threshold for warmwater fish (4 µg/g), but continued to trend downward as concentrations of selenium continued to decline gradually since the first year of the project. During 2010-2011, of the 85 samples of fish collected at this site (mostly composite samples), only three samples (a single black bullhead: 6.05 µg/g; a sample of 5 Mississippi silversides: 5.94 µg/g; and a sample of 5 Splittail: 4.07 µg/g) exceeded the 4 µg/g, concern threshold for warmwater fish (**Figures 2-2E**). The average selenium concentration in all 85 samples was 2.28 µg/g (geometric mean 2.18), well under the 4 µg/g threshold of concern, but significantly (p=0.01) above the average selenium concentration in all 109 fish samples collected in the previous two years (2008-2009: 2.03 µg/g, geometric mean 2.00).

Selenium in invertebrates

Concentrations of selenium in invertebrates in Salt Slough declined abruptly after the cessation of agricultural drainwater discharges into this slough with the implementation of the Grassland Bypass Project in October 1996. Since that initial decline, selenium concentrations in invertebrates as well as ambient water have continued to trend downward despite the invasion of the Siberian freshwater shrimp (**Figure 2F**). The mean concentration of selenium in all invertebrate samples collected during 2010-2011 (1.48 µg/g, geometric mean 1.40, n=23) was above, but not significantly (p=0.26) above the mean concentration of selenium in all invertebrate samples collected during the previous two years (2008-2009: 1.26 µg/g, geometric mean 1.13, n=18), but significantly (p=0.01) below the broader average for the previous 12 year period (1998-2009 (1.81 µg/g, geometric mean 1.64, n=113), and highly significantly (p=8x10-12) below the pre-project average (4.37 µg/g, geometric mean 4.15, n=27). In 2010-2011, selenium concentrations in all of the 23 composite invertebrate samples collected from Salt Slough (**Figure 2f**) were within the range of <3 µg/g concentrations associated with no known adverse effects on wildlife that eat invertebrates.

Selenium in plants

Of the seven composite samples of waterfowl forage plant material (seed heads) that were collected along the banks of Salt Slough in August 2010 and August 2011, only one (swamp timothy) had a selenium concentration sufficient to quantify accurately (1.6 µg/g, **Figure 2G**). All samples were well below the dietary threshold of concern (3 µg/g, see **Table 1**).

Boron in plants

All but one of the seven composite samples of waterfowl forage plant material (seed heads) that were collected along the banks of Salt Slough August 2010 had boron concentrations (**Figure 2H**)

below the dietary threshold of concern (30 µg/g, see **Table 2**). One sample (tule, Schoenoplectus acutus) had a boron concentration an order of magnitude above the threshold of concern (305 µg/g).

Mud Slough upstream of the San Luis Drain discharge (Site C)

This sampling location, about 400 m upstream of the outfall of the SLD, was intended to serve as a kind of reference site, representing the baseline conditions in Mud Slough that would prevail in lower Mud Slough (North) were it not for drainwater discharges into lower Mud Slough due to the Grassland Bypass Project. However, evidence has emerged that this site, though upstream from the SLD discharge, is close enough to the discharge point that fish samples at this site are affected by upstream movement of fish from the downstream drainwater. Evidence for this can be seen in the very high concentrations of selenium in Mosquitofish and silversides sampled at this site as well as Site D (just downstream of the discharge) in the months immediately after the opening of the Grassland Bypass Project in October 1996 (compare **Figures 3a** and **3b** with **Figures 4a** and **4b**). There is no known reason for such a spike in selenium in fish at this site apart from the hypothesis that some selenium-laden fish moved upstream from the discharge of the San Luis Drain.

Selenium in fish

Following the pulse of selenium in fish in the immediate aftermath of the initial discharge of the San Luis Drain into Mud Slough (see above), selenium concentrations in fish at this site stabilized from 1998 through 2009. Except red shiners and fathead minnows, most species of fish remained at levels generally below the threshold of concern for warmwater fish (4 µg/g, **Figures 3-3e**). In 2003, the average selenium concentration in all fish sampled at this site (3.84 µg/g, n=62) rose significantly (p=0.02) above the previous year average (3.21 µg/g, n=57). The increase in average selenium concentration in fish coincided with an increase in selenium in invertebrates evidently due to an invasive species of freshwater shrimp (see below). This suggests that this exotic species has been adversely affecting the aquatic ecosystem due to its greater propensity to bioaccumulate selenium relative to other invertebrates. After the bloom in Siberian freshwater shrimp numbers from 2003 to 2005, numbers and bioaccumulation of selenium in this species evidently declined (see below). This was echoed in a barely significant (p=0.08, i.e., significant at the 90% level, but not significant at the 95% level of confidence) decline in the average selenium in all fish sampled at this site (2003-2005: 3.6 µg/g; 2006-2007: 3.2 µg/g). The lack of significance in the decline may have been due in part to the longer lag time of larger and more predatory fish in response to the invasion of Siberian freshwater shrimp (compare Fig. 3A with Fig. 3D and Fig. 3E). In 2008-2009 the average selenium concentration in all fish (4.0 µg/g, geometric mean 3.5, n=98) rose again significantly (p=0.002) above the average for the previous two years (3.2 µg/g, geometric mean 2.9 µg/g, n=107) despite a continuing gradual decline in water concentrations (**Figure 3**; geometric means: 2006-2007 0.44 µg/L, 2008-2009 0.41 µg/L). This could not be explained by abundance or selenium concentrations in Siberian freshwater shrimp. In 2010-2011, the average selenium concentration in all fish (3.41 µg/g, geometric mean 3.16 µg/g, n=107) declined significantly (p=0.02) compared to the average for the previous two years (2008-2009).

Selenium in invertebrates

Unlike fish, invertebrates at Site C above the discharge of San Luis Drain seem to have been uninfluenced by that discharge (**Figure 3f**: little or no evidence of a spike in selenium concentrations

immediately following the initial discharge highly seleniferous water from the San Luis Drain). This may be because they are more localized than some species of fish.

Selenium concentrations in invertebrates collected at Site C remained generally well below the threshold of concern (3 µg/g) until 2003-2004 when the average of all invertebrate samples rose abruptly and significantly (**Figure 3f**; 1993-2002 average: 1.75 µg/g, geometric mean 1.65, n=91; 2003-2004 average: 2.48, geometric mean 2.13, n=27; p=0.01). This increase appears to have been driven by rapidly increasing numbers of a recently-arrived East Asian palaemonid shrimp known as the Siberian freshwater shrimp (Exopalaemon modestus). After this exotic species appeared in the lower Sacramento River in 2000 (Hieb et al. 2002), populations evidently exploded in rivers upstream of the delta. By 2003 when it was first encountered in the GBP monitoring program, it was already becoming one of the most common invertebrate species seined at this location in Mud Slough. The propensity of the newly-arrived Siberian freshwater shrimp to bioaccumulate selenium was substantially higher than that of other aquatic arthropods in the area (**Figure 3f**).

After the initial population explosion of Siberian freshwater shrimp in 2003-2004, population numbers declined, and the propensity of surviving individuals of this species to bioaccumulate selenium also declined (**Figure 3f**). This has brought down the average selenium concentration of all invertebrates sampled at this site. In 2010-2012 the average invertebrate selenium concentration at this site (2.08 µg/g, geometric mean 1.92, n=12) was not significantly different (p=0.33) from the average concentration during the period of monitoring before the Siberian freshwater shrimp appeared at this site (1993-2002).

Selenium in plants

Selenium concentrations in both of the composite samples of waterfowl forage plant material (seed heads of tule and salt marsh bulrush, Bolboschoenus robustus) that were collected along the banks of Mud Slough at this site in August 2010 (**Figure 3g**) were too low to quantify accurately and well below the dietary threshold of concern (3 µg/g, see **Table 1**).

Boron in plants

Boron concentrations in both of the composite samples of waterfowl forage plant material that were collected along the banks of Mud Slough at Site C in August 2010 (**Figure 3h**) were well above the dietary threshold of concern (30 µg/g, see **Table 2**). The boron concentrations were:

73.1 µg/g (dry weight) in a sample of tule seed heads, and 1590 µg/g (dry weight) in a sample of salt marsh bulrush seed heads. Elevated boron in plants at this site may be due to the proximity of this site to the old Kesterson Reservoir. Site C is within about 50 m of the northern levee of the northern-most cell of the reservoir. Although the reservoir has not been used to store drainwater since it was closed more than 20 years ago, residual boron from historic drainwater storage may still contaminate groundwater in the area.

Mud Slough just below San Luis Drain discharge (Site D)

This sampling location, about 200 m downstream of the outfall of the SLD, was intended to represent the effects of discharged drainwater on the biota of Mud Slough. However, this site is even closer than the upstream site (Site C) to the point where the San Luis Drain discharges in to Mud

Slough. Therefore, evidence that contaminated fish swim upstream to Site C (see above) also suggests that relatively clean fish from above the discharge point swim downstream and are likely to be included among the fish seined at Site D. Consequently, composite samples collected at this site are effectively diluted by clean fish, and do not represent the full effects of drainwater discharged by the Grassland Bypass Project.

Selenium in fish

Prior to the commencement of the Grassland Bypass Project in the fall of 2006, a "flip-flop" system of agricultural drainwater management was in operation, which alternately routed drainwater through Mud Slough and Salt Slough. This management pattern is reflected in pre- project sampling of fish at this site: higher selenium concentrations in fish in 1992 and early 1993 followed by lower concentrations from late 1993 to 1996 (**Figures 4-4e**). Immediately following the opening of the SLD, selenium concentrations in Mosquitofish and silversides reached very high levels (**Figures 4a** and **4b**), probably as a result of the discharge of some individuals of these species from the SLD itself when the first conveyance of Grassland Area drainwater flushed previously stagnant resident water from the SLD. Over the next several months in 1997, selenium concentrations in composite fish samples declined rapidly, evidently as a consequence of death, dispersal and depuration of these highly contaminated individuals. Thereafter, selenium concentrations in fish stabilized at this site, remaining approximately constant from 1998 through 2007 even while selenium concentrations in water gradually declined (**Figure 4**). In 2008-2009 the average concentration of selenium in all samples of fish at this site (8.01 µg/g, geometric mean 7.36, n=109) rose significantly (p=0.0002) above the average for the previous two years (2006-2007: 6.36 µg/g, geometric mean 5.69, n=78). In 2010-2011 the average in all fish (6.63 µg/g, geometric mean 6.25, n=89) decreased significantly (p=0.0002) below that of the previous two years, while the average selenium concentration in water also decreased slightly (2008-2009 average 11.0 µg/L; 2010-11 average 9.85 µg/L) but not significantly (p=0.33). Despite this short-term decrease in concentrations in fish, selenium concentrations in fish at this site remained slightly (but not significantly; p=0.4) above the longer term average for the previous decade (1998-2007: average 6.40 µg/g). Most fish samples continued to have selenium concentrations at or above levels of concern (4-9 µg/g, see **Table 1**).

The invasion of the Siberian freshwater shrimp has not had as clear of an effect on the fish at this site as it has at the upstream monitoring site (Site C, see above). This may be because of lower populations of the shrimp at this site, suggested by the substantially lower numbers collected here than at Site C (for example, in 2005, 193 individuals were collected at Site C while only 36 individuals were collected at Site D).

Selenium in invertebrates

Invertebrates have been relatively difficult to collect in numbers at Site D since the SLD began discharging drainwater into Mud Slough. The slough in this reach is generally steep-sided, relatively deep, and fast-flowing. Scouring minimizes streamside emergent vegetation, reducing food and cover for invertebrates.

While loads of selenium discharged into Mud Slough from the SLD have declined substantially since the beginning of the GBP (see Chapter 2 of this report), and concentrations of selenium in water at this site have trended downward somewhat (**Figure 4** and see Chapter 4 of this and previous reports), selenium concentrations in invertebrates at this site have not tracked the decline in ambient selenium

(**Figure 4f**). Rather, averages of selenium concentrations in invertebrates have risen significantly (p=0.02) since the first two years of operation of the Grassland Bypass Project (1997-1998 average 2.6 µg/g, geometric mean 2.2, n=11; 2008-2009 average 4.9 µg/g, geometric mean 4.0, n=12). This may be due in part to the invasion of the Siberian freshwater shrimp. The explosion in numbers of this shrimp seems to have occurred later and to a lesser extent at this site than upstream at Site C (see above). A single Siberian freshwater shrimp was collected at this site in March 2003 when 13 were collected at Site C, but not until November 2003 was this species collected here in sufficient numbers to be analyzed for selenium. As elsewhere in the Grassland area, Siberian freshwater shrimp here evidently bioaccumulated selenium to higher levels than other aquatic arthropods (**Figure 4f**). However, the difference between their tendency to bioaccumulate and those of other aquatic arthropods may have been reduced in such sites as this one, where selenium concentrations in the entire aquatic ecosystem are particularly elevated. In the two years following the first collection of Siberian freshwater shrimp in numbers at this site, it evidently caused the average selenium in all samples of invertebrates to rise, but not by a statistically significant amount (1998-Aug 2003: 3.9 µg/g, n=21; Nov 2003-Aug 2005: 4.5 µg/g, n=21; p=0.38). As at Site C upstream, Siberian freshwater shrimp at this site declined in numbers and in selenium concentrations after the initial invasion.

In the two year period (2006-2007) following the first two years of the bloom here (Nov 2003-Aug 2005), the average selenium concentration in all invertebrates declined by a barely significant amount (2006-2007: 3.3 µg/g, geometric mean 2.8, n=11, p=0.10, i.e. significant at the 90% level of confidence, but not at the 95% level). However, in the following two-year period (2008-2009), the average selenium concentration in invertebrates (4.9 µg/g, geometric mean 4.0, n=12) rose again but not significantly (p=0.13, 2-tail t-test). In 2010-11, the average selenium concentration in invertebrates (5.04 µg/g, geometric mean 4.54, n=9) did not change significantly (p=0.92, 2-tail t-test) from that of the previous two years.

For all invertebrate samples analyzed from this site since the beginning of the project (November 1996 through 2011, n=91) the average selenium concentration was 3.99 µg/g (geometric mean 3.29), which is above the concern threshold (3 µg/g) for dietary exposure of fish and wildlife.

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Mud Slough backwater 1.5 km below San Luis Drain discharge (Site I/I2)

Site I2 is intended to be a better representation of the adverse effects of bioaccumulative drainwater contaminants than Site D, because it consists of a backwater. Stagnant conditions and evapoconcentration in such backwaters increase selenium assimilation into aquatic food chains. In addition, this site is located farther downstream fr+om the cleaner reach of Mud Slough upstream of the outfall of the SLD. Therefore, the concentrations of contaminants in mobile aquatic organisms collected here are less likely to be diluted effectively by feeding in nearby cleaner water.

Selenium in fish

All but five (four samples of threadfin shad and a single redear sunfish) of the 92 composite samples of fish collected at Site I2 in 2010-2011 had concentrations of selenium (**Figures 5a – 5e**) at levels of concern (4-9 µg/g) or toxicity (>9 µg/g). The average selenium concentration in fish in 2010-2011 (7.75 µg/g, geometric mean 7.18, n=92) was below the toxicity threshold of 9 µg/g and significantly (p=0.00001) below the average for the previous two-year period 2008- 2009 (9.72 µg/g, geometric mean 9.23, n=94).

Selenium in invertebrates

Selenium concentrations in invertebrates at this site have not declined as selenium loads and concentrations in the water of Mud Slough have trended downward since the start of the GBP **(Figure 5f).** The average selenium concentration in invertebrates in 2010-1012 (5.01 µg/g, geometric mean 4.54, n=23) was not significantly different (p=0.58) from the average for the previous two-year period 2008-2009 (5.47 µg/g, geometric mean 5.03, n=11) and not significantly different (p=0.54) from the average for the two-year period before that (2006-2007: 5.48 µg/g, geometric mean 4.78, n=20).

Compared to upstream sampling sites, at this site the lack of improvement in selenium concentrations cannot be attributed so clearly to the adverse effects of the invasion of the Siberian freshwater shrimp. The bloom in shrimp numbers seems to have occurred later and had less pronounced effects at this site than at upstream sites (see above). Siberian freshwater shrimp were not collected here in sufficient numbers to analyze until March 2004, one year after comparable numbers were collected at Site C, above the SLD outfall. In the two years (2004- 2005) following first sampling of shrimp at this site the average selenium concentration in all invertebrates sampled did not rise significantly from the previous three years (2001-2003) of collection at this specific site (2001-2003 average 5.5 µg/g, geometric mean 5.1, n=31; 2004- 2005 average 5.6 µg/g, geometric mean 5.1, n=29, p=0.85). In the following two years (2006- 2007), as the shrimp bloom faded (see above) average selenium concentrations in all invertebrates collected at this site did not decline significantly (2006-2007 average 5.5 µg/g, n=20, p=0.90) from shrimp bloom (2004-2005) levels.

Of the 23 invertebrate samples collected at this site in 2010, all but four had selenium concentrations above the threshold of concern for birds that might forage on these invertebrates (3 µg/g). Three samples had selenium concentrations above the dietary toxicity threshold of 7 µg/g (one

sample of red swamp crayfish 8.52 µg/g, and two samples of Siberian freshwater shrimp 9.46 and 10.5 µg/g).

Selenium in plants

Selenium concentrations in all seven composite samples of waterfowl forage plant material (seed heads) that were collected along the banks of Mud Slough near the backwater at Site I2 in August 2010 and August 2011 (**Figure 5g**) were well below the dietary threshold of concern (3 µg/g, see **Table 1**).

Boron in plants

Boron concentrations in all seven composite samples of waterfowl forage plant material (seed heads) that were collected along the banks of Mud Slough near the backwater at Site I2 in August 2010 and August 2011 (**Figure 5h**) were above the dietary threshold of concern (30 µg/g, see **Table 2**). This site is downslope from the old Kesterson Reservoir, and may be influenced by a plume of residual boron, a legacy of the boron-enriched, evapoconcentrated drainwater previously stored in the reservoir.

Mud Slough (north) at Highway 140 (Site E)

Site E is located in lower Mud Slough (north) downstream from Sites D and I2 but upstream from the confluence with the San Joaquin River. This site represents the lower reach of the slough that is contaminated by the operation of the Project. This point along the Slough is within the flood- plain of the San Joaquin River, so flows are slower and more spread out. Flood waters of the San Joaquin River periodically back up into the slough, providing some flushing. High flows in the river occurred during the winter and the spring of 2010 and 2011.

Selenium in Fish

No fish were collected from this site during 2010 and most of 2011. One sampling trip was conducted in December 2011. The concentrations of selenium in two composite samples of whole-body Mosquitofish (Gambusia affinis) collected during December 2011 were 5.7 and 5.8 µg/g (dry weight), exceeding the 4 µg/g (dry weight) level of concern for warm water fish, but below the toxicity threshold of 9 µg/g (dry weight) (**Figure 8a – 8c**).

The 2011 concentration of selenium was significantly higher than the concentration of samples collected before the Grassland Bypass Project began in 1996 ($n=19$, $\mu=2.49$, $p<0.001$).

Selenium in Invertebrates

No invertebrates were collected from this site during 2010 and most of 2011. In December 2011, the concentration of selenium measured in a single red swamp crayfish (Procambarus clarkii) was 2.3 µg/g (dry weight); one Siberian freshwater shrimp (Exopalaemon modestus) was collected with selenium concentration of 4.2 µg/g (dry weight), above the 3 µg/g (dry weight) level of concern, but well below the toxicity threshold of 7 µg/g (dry weight) (**Figure 8d**).

San Joaquin River at Fremont Ford (Site G)

Site G is located at Fremont Ford on the San Joaquin River upstream of the Mud Slough confluence. This site represents the reach of the San Joaquin River that is no longer contaminated with agricultural drainwater from the Grassland Drainage Area as a result of the GBP.

Selenium in Fish

No fish were collected from this site during 2010 and most of 2011. Two composite samples of inland silversides (Menidia beryllina) fish were collected in December 2011 with selenium concentrations of 1.25 and 1.27 µg/g (dry weight), well below the 4 µg/g (dry weight) level of concern for warm water fish.

Similar to all years of GBP operation, selenium concentrations in composite samples of fish collected from this site during 2011 continued to reflect removal of selenium laden drain water and delivery of cleaner CVPIA (Central Valley Project Improvement Act) water. The average concentration of selenium in 2011 is significantly less than the pre-project average concentration of selenium of 5.4 µg/g (dry weight) measured in 24 samples ($p<0.001$). Selenium concentrations in whole-body fish have consistently been below the 4 µg/g (dry weight) threshold of concern since the GBP began September 1996 (**Figure 9a – 9c**).

Selenium in Invertebrates

No invertebrates were collected from this site during 2010 and 2011.

Selenium concentrations in all invertebrates collected from this site through 2009 were well below the 3 µg/g (dry weight) threshold of concern for invertebrates as prey items (**Figure 9d**).

San Joaquin River Below Mud Slough (Site H)

Site H is located at Hills Ferry on the San Joaquin River about two miles downstream of the Mud Slough confluence. This site represents the reach of the San Joaquin River most strongly influenced by agricultural drain water discharged by the GBP. One of the environmental commitments of the GBP is that it will not worsen water quality in the San Joaquin River. For practical reasons of year-round accessibility, the site was located just upstream of the Merced River confluence; Merced River waters have relatively low concentrations of selenium. It is possible that some of the fish and invertebrates collected at Site H have moved into this area after foraging within the Merced River and other less contaminated reaches of the San Joaquin River.

Additionally, seasonally high flows in the Merced River can enter the San Joaquin River upstream of Site H, temporarily diluting the load of contaminants there. Due to these confounding influences on selenium body burdens, selenium concentrations in fish and invertebrate tissues collected at this site may not be well correlated with water concentrations of selenium at this site.

Selenium in Fish

No fish were collected from this site during 2010 and most of 2011. One composite sample of red shiners (Cyprinella lutrensis) was collected in December 2011 with a selenium concentration of

3.2 µg/g (dry weight), below the 4 µg/g (dry weight) threshold of concern for warm water fish.

The average selenium concentrations in composite samples throughout the all years of GBP operation have generally remained below the 4 µg/g (dry weight) concern threshold (**Figures 10a-10c**). The 2011 measurement of selenium was slightly less than the 3.45 µg/g (dry weight) average selenium concentration in Mosquitofish collected before the GBP began in 1996 (n=15).

Selenium in Invertebrates

No invertebrates were collected from this site during 2010 and most of 2011. Two composite samples of Siberian freshwater shrimp (Exopalaemon modestus) were collected in December 2011 with selenium concentrations of 3.1 and 3.5 µg/g (dry weight), above the 3 µg/g (dry weight) concern threshold for invertebrates as prey (**Figure 10d**).

The methods and results of a special invertebrate sampling that was conducted at Site H in August 2011 can be found at the end of this chapter.

Fish Community Assessment

Fish community assessments are conducted to describe species richness, abundance and community structure. Fish populations were sampled in Mud Slough at Highway 140, the San Joaquin River at Fremont Ford, and the San Joaquin River below Mud Slough. Fish assemblages from these sites were compared both spatially and temporally to see if conditions for fish species in the San Joaquin River improved and conditions in Mud Slough degraded. As the Grassland Bypass Project began operation in September 1996, this sampling schedule provided a before- and-after picture of the fish communities at these sites. Only data collected with standardized sampling methodologies and effort were analyzed.

No fish were collected from this site during 2010 and most of 2011. One assessment was conducted at each site in December 2011.

Table 3 is a list of the 52 fish species (n =40,278), that have been collected at these sites between March 2001 and December 2011. Eight species of native fish have been caught, representing less than one percent of the catch by number (n = 164). The native species were Sacramento blackfish (*Orthodon macrolepidotus*), Splittail (*Pogonichthys macrolepidotus*), Sacramento sucker (*Catostomus occidentalis*), Prickly sculpin (*Cottus asper*), Chinook salmon (*Oncorhynchus tshawystcha*), Sacramento pikeminnow (*Ptychocheilus grandis*), Hitch (*Lavinia exilicauda*), California roach (*Hesperoleucus symmetricus*), Tule perch (*Hysteocarpus traski*), and Hardhead (*Mylopharodon conocephalus*). Sacramento blackfish were the most abundant native fish at the three sites throughout the study. The most common non-native fish are Mosquitofish (*Gambusia affinis*), inland silversides (*Menidia beryllina*), carp (*Cyprinus carpio*), and fathead minnow (*Pimephales promelas*).

No time trends are apparent in fish species assemblages during the period 1993 to 2011 at Sites E, G, and H (**Figures 11**, **12**, and **13**). No time trend is evident in total anomalies for the various groups of fishes at each site (**Figures 14**, **15**, 1**6**).

After fifteen years of Project operation, no clear pattern of temporal or geographic variation in fish community structure attributable to the Project has emerged. However, current methods of assessing fish species assemblages may lack the power to detect all but the most pronounced alterations in community structure.

Assessment of Risk to Public Health from Consumption of Fish

A public health advisory on consumption of fish is in effect for the Grasslands area (OEHHA 2001):

> *Because of elevated selenium levels, no one should eat more than four ounces of fish from the Grassland area, in any two-week period. Women who are pregnant or may become pregnant, nursing mothers, and children age 15 and under should not any eat fish from this area.*

To assess current human health risks due to selenium in gamefish, carp (Cyprinus cario) were collected from Mud Slough (Site E) and the San Joaquin River (Sites G and H). Samples of skinless fillets from these fish were analyzed for selenium and compared with the 2 µg/g wet weight interim internal guidance and screening level for selenium established by the Office of Environmental Health Hazard Assessment (OEHHA).

The concentration of selenium in two composite samples of carp collected at Site E during December 2011 ranged from 0.40 to 1.32 µg/g (wet weight), well below the 2 µg/g (wet weight) health screening level for selenium. This indicates that selenium in carp in Mud Slough below the outfall of the SLD may not represent a risk for human consumption (**Figure 17**). During all years of GBP operation, 17 samples of carp muscle collected at Site E exceeded the 2 µg/g (wet weight) screening level, whereas none of the 11 samples of carp tissue collected at this site E before October 1996 exceeded the screening level.

2011 (0.86 µg/g (wet weight)) was slightly less than the average of eleven samples collected prior to the beginning of the project in 1996 (0.74 µg/g(wet weight)).

The concentrations of selenium in muscle tissue in Largemouth bass collected at Site G and carp collected at H in 2011 remained well below the 2 µg/g (wet weight) health screening level (**Figures 18** and 19).

Selenium in amphibians

Selenium concentrations (**Figure 6**) in bullfrog tadpoles (Rana catesbeiana) have followed approximately the same trends exhibited by fish (**Figure 2** and **Figure 2F**). At sites from which drainwater was removed by the Grassland Bypass Project (Sites C and F), concentrations rose somewhat in 2010-2011 but not by enough to reverse a longer term downward trend. The average selenium concentration in all six composite samples of tadpoles collected from these sites in 2010-2011 (2.20 µg/g, geometric mean 2.11) was higher (but not significantly: p=0.14) than the average for the previous two years (2008-2009: 1.68 µg/g, geometric mean 1.66, n=8), but lower (not quit significantly at the 95% level: p=0.06, 2-tailed t-test) than the average concentration in all samples collected in the previous 12 years (1998-2009: 2.95 µg/g, geometric mean 2.72, n=43). Even though selenium loads and concentrations have declined in discharged drainwater, selenium concentrations in tadpoles at Mud Slough sites downstream of the drainwater discharge (Sites D and I) have not declined. The two bullfrog tadpoles collected from these sites in 2010-2011 had selenium concentrations (3.86 µg/g and 3.96 µg/g) that exceeded the threshold of concern as diet for birds (3 µg/g) and the average of these two concentrations (3.91 µg/g) was not significantly (p=0.19) different from the average of all bullfrog tadpole samples collected from these sites in the previous decade (2000-2009: 4.34 µg/g, standard deviation =1.25, geometric mean 4.18, n=16).

Selenim in bird eggs

Of the 35 bird eggs collected in the Grassland area in 2010-2011 (**Figure 7**), two (both kildeer, Charadrius vociferus: 7.41 µg/g, collected May 19, 2010, near Site D, and 7.59 µg/g, collected April 12, 2011, along the SLD) exceeded the concern threshold for avian eggs (6 µg/g; see **Table 1**). The selenium concentrations in eggs collected in the vicinity of the San Luis Drain and Mud Slough below the drain discharge (average 3.35 µg/g, geometric mean 3.05, n=28) were significantly (p=0.0002) higher than the concentrations in the general vicinity of Salt Slough (average 1.60 µg/g, geometric mean 1.40, n=7).

Aquatic Hazard Assessment of Selenium

To provide an estimate of ecosystem-level effects of selenium, Lemly (1995, 1996) developed an aquatic hazard assessment procedure that sums the effects of selenium on various ecosystem components to yield a single characterization of overall hazard to aquatic life. Because the Lemly index is based on maximum concentrations, it is strongly influenced by data "outliers." However, it remains the best selenium hazard index available at this time.

Lemly's procedure applied to Mud Slough downstream of the SLD outfall indicated that the hazard to aquatic life continued to be "high" in 2010 and 2011 (**Table 4a**). In the Salt Slough area, the Lemly index dropped to "minimal" in 2010, for the first time since the Grassland Bypass Project commenced, but rose again slightly to "low" in 2011 (**Table 4b**).

A Lemly index was not determined for San Joaquin River sites due to lack of sufficient sample of invertebrates and because bird eggs, one component of the index, were not sampled there.

Special Invertebrate Sampling Event at Site H[7]

Methods

On August 18, 2011 H. T. Harvey and Associates under contract with the Grassland Basin Drainers sampled for invertebrates at Site H. All samples were collected, handled, and analyzed in accordance with the GBP Monitoring Program and associated Quality Assurance Project Plan. Invertebrate samples were analyzed by Olson Agriculture Analytical Services Laboratory at South Dakota State University.

Site H (San Joaquin River at Hills Ferry, as delineated by Chris Eacock with the U.S. Bureau of Reclamation (USBR)) was sampled for invertebrates on 18 August 2011, with Chris Eacock and Jennifer Lewis (USBR), using ¼ inch dip nets, a kick net, and a small plankton net. Three separate locations at Site H were sampled, with replicate samples conducted at each location. Opportunistic sampling was conducted in adjacent areas (within 200 feet of Site H) where the river was shallow and slow enough to sample (i.e., west bank only). Invertebrate samples were collected and tested for selenium concentrations in 1 sample of backswimmers (*Notonectidae*) and 2 samples of red crayfish (*Procambarus clarkia*). Samples were frozen on dry ice and shipped to the laboratory on 22 August 2011, and results were received from the laboratory on 7 October 2011.

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Results

Invertebrate sampling efforts resulted in the following collections: backswimmers (n=1) and red crayfish (n=2). Replicate sampling efforts at the three locations delineated by the USBR did not result in captures of any target species. All target species were captured at adjacent areas where the river was slower and shallower. The results are shown in **Figure 10d**.

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Table 1. Recommended Ecological Risk Guidelines for Selenium Concentrations

Medium	Effects on	Units	No Effect	Concern	Toxicity
Water (total recoverable selenium)	fish and bird reproduction	µg/L	**< 2**	**2 -- 5**	**> 5**
Sediment	fish and bird reproduction	µg/g (dry weight)	**< 2**	**2 -- 4**	**> 4**
Invertebrates (as diet)	bird reproduction	µg/g (dry weight)	**< 3**	**3 -- 7**	**> 7**
Warmwater Fish (whole body)	fish growth/condition/survival	µg/g (dry weight)	**< 4**	**4 -- 9**	**> 9**
Avian egg	egg hatchability (via foodchain)	µg/g (dry weight)	**< 6**	**6 -- 10**	**> 10**
Vegetation (as diet)	bird reproduction	µg/g (dry weight)	**< 3**	**3 -- 7**	**> 7**

Notes:

1/ These guidelines, except those for avian eggs, are intended to be population based. Thus, trends in means over time should be evaluated. Guidelines for avian eggs are based on individual level response thresholds (e.g., Heinz, 1996; Skorupa, 1998)

2/ A tiered approach is suggested with whole body fish being the most meaningful in assessment of ecological risk in a flowing system.

3/ The warmwater fish (whole body) concern threshold is based on adverse effects on the survival of juvenile bluegill sunfish experimentally fed selenium enriched diets for 90 days (Cleveland *et al.*, 1993). It is the geometric mean of the "no observable effect level" and the "lowest observable effect level."

4/ The toxicity threshold for warmwater fish (whole body) is the concentration at which 10% of juvenile fish are killed (DeForest *et al.*, 1999).

5/ The guidelines for vegetation and invertebrates are based on dietary effects on reproduction in chickens, quail and ducks (Wilber, 1980; Martin, 1988; Heinz, 1996).

6/ If invertebrate selenium concentrations exceed 6 mg/kg then avian eggs should be monitored (Heinz *et al.*, 1989; Stanley *et al.*, 1996).

Table 2. Recommended Ecological Risk Guidelines for Boron Concentrations

Medium	Effects on	Units	No Effect	Concern	Toxicity
Water	fish (catfish and trout embryos)	mg/L	**< 5**	**5 -- 25**	**> 25**
Water	invertebrates (*Daphnia*)	mg/L	**< 6**	**6 -- 13**	**> 13**
Water	vegetation (crops and aquatic plants)	mg/L	**< 0.5**	**0.5 -- 10**	**> 10**
Waterfowl diet	duckling growth	µg/g (dry weight)		**> 30**	
Waterfowl egg	embryo mortality	µg/g (dry weight)	**<1**	**> 10**	**>30**

Notes:

1/ Water guidelines for invertebrates are based on the "no observed adverse effects level" and "lowest observed adverse effects level" for *Daphnia magna* (Lewis and Valentine 1981; Gersich 1984).

2/ Waterfowl diet guidelines are based on mallard ducks (Smith and Anders 1989).

3/ The waterfowl egg no effect level is based on poultry data from Romanoff and Romanoff (1949) and San Joaquin Valley field data for reference sites (R. L. Hothem and Welsh; J. P. Skorupa *et al.*).

4/ The waterfowl egg concern and toxicity thresholds are based on Smith and Anders (1989), Stanley *et al.* (1996), and the "order-of-magnitude rule of thumb" (toxicity at about 10 times background concentrations).

5/ The US Environmental Protection Agency's suggested no adverse response level for drinking water is 0.6 mg/L.

Table 3. Community Assessment of Fish Caught By CDFW 2001 – 2011, Mud Slough at Highway 140 (Site E)

Common Name	Scientific name	Origin	Trophic	Tolerance to Degradation	Life Style*	Status*	From	Moyle Reference	Mud Slough at HWY 140 (Site E) Total Sampled	SJR at Fremont Ford (Site G) Total Sampled	SJR at Hills Ferry (Site H) Total Sampled
American shad	Alosa sapidissima	I	I	M	AN	IID	E USA	pp.117-120	-	-	-
Bigscale logperch	Percina macrolepida	I	I	T	F	IID	SW USA	pp.409-411	-	29	24
Black bullhead	Ameiurus melas	I	I/P	T	F	IID	E USA	pp.208-210	7	2	0
Black crappie	Pomoxis nigromaculatus	I	I/P	M	F	IID	M USA	pp.395-397	5	23	27
Bluegill	Lepomis macrochirus	I	I	T	F	IID	M USA	pp.381-384	44	623	429
Bluegill x Redear		I	I	T	F	IID	M USA	pp.381-384	-	-	1
Brown bullhead	Ameiurus nebulosus	I	I/P	T	F	IID	M USA	pp.210-212	21	4	-
Bullfrog	Rana catesbeiana	I	O	T		IIE			-	33	18
California roach	Hesperoleucus symmetricus symmetricus	N	I	M	F	ID		pp.139-144	5	2	-
Carp	Cyprinus carpio	I	O	T	F	IIE	Europe	pp.172-175	1,100	839	830
Channel catfish	Ictalurus punctatus	I	I/P	M	F	IID	M USA	pp.216-218	10	131	54
Chinook salmon	Oncorhynchus tshawytscha	N	I	I	AN, F	IB		pp.251-263	-	1	1
Fathead minnow	Pimephales promelas	I	O	T	F	IIE	M USA	pp.166-168	82	112	36
Golden Shiner	Notemigonus crysoleucas	I	I	M	F	IIE	E USA	pp.164-166	9	0	3
Goldfish	Carrrassius auratus	I	O	T	F	IID	Japan	pp.170-172	206	195	223
Green sunfish	Lepomis cyanellus	I	I/P	T	F	IID	M USA	pp.389-391	26	157	57
Green x Redear	Lepomis ssp.	I	I	M	F	IID			-	1	2
Hardhead	Mylopharodon conocephalus	N	O	M	F	IC		pp.151-154	6	-	-
Hitch	Lavinia exilicauda	N	O	M	F	ID		pp.136-139	1	9	-
Hybrid green/bluegill	Lepomis ssp.	I	I	M	F	IID			-	-	-
Inland silverside	Menidia beryllina	I	I	M	F	IIE	SE USA	pp.307-311	148	349	370
Largemouth bass	Micropterus salmoides	I	P	T	F	IID	M USA	pp.397-401	75	453	189
Mirror carp	Cyprinus carpio	I	O	T	F	IIE	Europe	pp.172-175	1	-	1
Mosquitofish	Gambusia affinis	I	I	T	F	IIE	E USA	pp.317-321	9,898	9697	7089
Pacific lamprey	Lampetra tridentata	N	O	T	AN, F	ID		pp.96-99	-	-	-
Pacific staghorn sculpin	Leptocottus armatus	N	I	M	E,F	IE		pp.361-363	-	-	-
Prickly sculpin	Cottus asper	N	I	M	AM,E,F	IE		pp.346-349	11	2	5
Pumpkin seed	Lepomis gibbosus	I	I	T	F	IID		pp.387-389	-	1	-
Red crayfish	Procambarus (Scapulicambarus) clarkii	I	O	T	F	IIE			114	242	36
Red shiner	Cyprinella lutrensis	I	O	T	F	IIE	M USA	pp.168-170	512	802	494
Redear sunfish	Lepomis microlophus	I	I	M	F	IID	SE USA	pp.385-386	9	109	131
Riffle sculpin	Cottus gulosus	N	I	M	F	ID		pp. 350-352	-	-	-
River lamprey	Lampetra ayresi	N	O	M	AN, F	ID		pp.101-103	-	-	-
Sacramento blackfish	Orthodon microlepidotus	N	O	T	F	IE		pp.144-146	18	20	20
Sacramento pikeminnow	Ptychocheilus grandis	N	I/P	M	F	IE		pp.154-158	1	1	5

Table 3. Community Assessment of Fish Caught By CDFW 2001 – 2011, Mud Slough at Highway 140 (Site E) (cont.)

Sacramento Splittail	Pogonichthys macrolepidotus	N	O	M	E,F	IB		pp.146-150	2	6	6
Sacramento sucker	Catostomus occidentalis	N	O	M	F	IF		pp.185-188	1	9	21
Shimofuri goby	Tridentiger bifasciatus	I	O	M	E	IIE	Japan	pp.437-440	-	-	-
Siberian Freshwater Shrimp	Ecopalaemon modestus	I	O	M	E,F	IIE			129	701	1078
Smallmouth bass	Micropterus dolomieui	I	I/P	M	F	IID	M USA	pp.401-404	1	-	2
Snail sp.		I	O						36	-	-
Speckled dace (Sacramento)	Rhinichthys osculus carringtoni	N	I	T	F	IE		pp.160-164	-	-	-
Spotted bass	Micropterus punctulatus	I	P	M	F	IIE	SE USA	pp.404-406	15	92	170
Striped bass	Morone saxatilis	I	P	M	AN	IID	E USA	pp.364-373	3	27	51
Threadfin shad	Dorosama petenese	I	I	M	F	IID	SE USA	pp.114-117	20	186	200
Threespine stickleback	Gasterostreus aculeatus	N	O	M	AN, E, F	IE		pp.338-343	-	-	-
Tule perch	Hysteocarpus traski	N	I	I	E,F	ID		pp.424-429	-	-	11
Turtle, pond		I	O								1
Warmouth	Lepomis gulosus	I	I	M	F	IIC	M USA	pp.392-393	-	3	1
White catfish	Ameiurus catus	I	I/P	T	F	IID	E USA	pp.214-216	133	517	658
White crappie	Pomoxis annularis	I	I/P	T	F	IID	M USA	pp.393-395	3	1	3
Yellowfin goby	Acanthogobius flavimanus	I	O	M	F	IID	E Asia	pp.436-437	-	-	-
Total Samples									12,652	15,379	12,247

Data source: California Department of Fish and Wildlife

Community Assessment of Fish Caught By CDFW 19 Mar 2001 - 01 Dec 2011 (34 trips)

*Adapted from Moyle, Peter, 2002. Inland Fishes of California. University of California Press. Berkeley, California.

Abbreviations

Trophic Level:
- O: omnivorous (includes omnivores, herbivores, general planktivores)
- I: invertivore (includes invertivores, zooplanktivores
- I/P: carnivore (includes piscivores, large invertebrates (crayfish), amphibian, and mammalian predators

Tolerance to Degradation:
- I: intolerant
- M: moderately tolerant
- T: Tolerant

Life Style*:
- AM: amphidromous
- AN: anadromous
- E: estuarine resident
- F: freshwater resident

Status*:
- I. Native species
- A. Extinct/extirpated
- B. Threatened or endangered
- C. Special concern
- D. Watch list
- E. Stable of increasing

Origin:
- N: Native
- I: Introduced

Table 4a. Aquatic Hazard Assessment of Selenium in Mud Slough below San Luis Drain (Lemly Index)

	Units	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale
		BEFORE PROJECT 1995 - Sept. 1996			GRASSLAND BYPASS PROJECT Phase I								
					WY1997			WY1998			WY1999		
Water	µg/L	19	high	5	80	high	5	104.0	high	5	50.7	high	5
Sediment	µg/g	0.4	none	1	0.8	none	1	2.0	low	3	4.8	high	5
Invertebrates	µg/g	1.6	none	1	3.3	low	3	11.0	high	5	7.0	high	5
Fish eggs	µg/g	14.2	moderate	4	56.1	high	5	34.2	high	5	39.6	high	5
Bird eggs	µg/g	3.1	minimal	2	4.4	minimal	2	6.6	low	3	10.0	low	3
TOTAL HAZARD SCORE			Moderate	13		High	16		High	21		High	23
		GRASSLAND BYPASS PROJECT Phase I						GRASSLAND BYPASS PROJECT Phase II					
		WY2000			WY2001			October 1, 2001 - December 31, 2002			Calendar Year 2003		
Water	µg/L	66	high	5	51	high	5	54.9	high	5	48.0	high	5
Sediment	µg/g	4.4	high	5	3.5	moderate	4	8.5	high	5	7.8	high	5
Invertebrates	µg/g	15.3	high	5	7.1	high	5	7.5	high	5	10.5	high	5
Fish eggs	µg/g	46.5	high	5	54.8	high	5	51.5	high	5	53.2	high	5
Bird eggs	µg/g	5.1	low	3	7.0	low	3	3.2	minimal	2	5.6	Low	3
TOTAL HAZARD SCORE			High	23		High	22		High	22		High	23
		GRASSLAND BYPASS PROJECT Phase II											
		Calendar Year 2004			Calendar Year 2005			Calendar Year 2006			Calendar Year 2007		
Water	µg/L	48.9	high	5	36.6	high	5	39.9	high	5	51.2	high	5
Sediment	µg/g	7.5	high	5	6.4	high	5	4.8	high	5	7.9	high	5
Invertebrates	µg/g	12.97	high	5	12.7	high	5	12.6	high	5	8.2	high	5
Fish eggs	µg/g	54.6	high	5	48.8	high	5	42.6	high	5	46.2	high	5
Bird eggs	µg/g	4.74	minimal	2	11.8	Low	3	7.0	Low	3	4.5	minimal	2
TOTAL HAZARD SCORE			High	22		High	23		High	23		High	22
		GRASSLAND BYPASS PROJECT Phase II						GRASSLAND BYPASS PROJECT PHASE III					
		Calendar Year 2008			Calendar Year 2009			Calendar Year 2010			Calendar Year 2011		
Water	µg/L	51.0	high	5	24.6	high	5	45.3	high	5	25	high	5
Sediment	µg/g	1.5	low	3	1.0	low	3	8.4	high	5	6.9	high	5
Invertebrates	µg/g	9	high	5	10.6	high	5	14	high	5	10.5	high	5
Fish eggs	µg/g	53.8	high	5	60.1	high	5	44.9	high	5	42.6	high	5
Bird eggs	µg/g	9.7	low	3	4.3	minimal	2	7.4	Low	3	7.6	Low	3
TOTAL HAZARD SCORE			High	21		High	20		High	23		High	23

Hazard Scale:		TOTAL HAZARD SCORE	
high	5	16 - 25	High
moderate	4	12 - 15	Moderate
low	3	9 - 11	Low
minimal	2	6 - 8	Minimal
none	1	0 - 5	None

Notes: Table prepared by US Fish and Wildlife Service, Sacramento.

Table 4b. Aquatic Hazard Assessment of Selenium in Salt Slough (Lemly Index)

	Units	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale
		BEFORE PROJECT 1995 - Sept. 1996			GRASSLAND BYPASS PROJECT Phase I								
					WY1997			WY1998			WY1999		
Water	µg/L	38	high	5	3	moderate	4	5.1	high	5	1.5	minimal	2
Sediment	µg/g	0.8	none	1	0.9	none	1	2.1	low	3	0.9	none	1
Invertebrates	µg/g	4.7	moderate	4	2.6	minimal	2	3.2	low	3	2.8	minimal	2
Fish eggs	µg/g	28.1	high	5	17.8	moderate	4	12.9	moderate	4	11.2	moderate	4
Bird eggs	µg/g	5.2	low	3	3.6	minimal	2	3.7	minimal	2	2.7	none	1
TOTAL HAZARD SCORE			High	18		Moderate	13		High	17		Low	10
		GRASSLAND BYPASS PROJECT Phase I						GRASSLAND BYPASS PROJECT Phase II					
		WY2000			WY2001			October 1, 2001 - December 31, 2002			Calendar Year 2003		
Water	µg/L	1.7	minimal	2	2.1	low	3	1.1	minimal	2	1.3	minimal	2
Sediment	µg/g	0.7	none	1	0.8	none	1	0.7	none	1	0.8	none	1
Invertebrates	µg/g	2.7	minimal	2	0.7	minimal	2	2.4	minimal	2	2.5	minimal	2
Fish eggs	µg/g	14.5	moderate	4	12.5	moderate	4	13.8	moderate	4	11.6	moderate	4
Bird eggs	µg/g	4.9	minimal	2	4.0	minimal	2	2.7	none	1	1.5	none	1
TOTAL HAZARD SCORE			Low	11		Moderate	12		Low	10		Low	10
		GRASSLAND BYPASS PROJECT Phase II											
		Calendar Year 2004			Calendar Year 2005			Calendar Year 2006			Calendar Year 2007		
Water	µg/L	1.1	minimal	2	1.5	minimal	2	1.0	minimal	2	1.0	minimal	2
Sediment	µg/g	0.64	none	1	1.5	minimal	2	0.7	none	1	0.5	none	1
Invertebrates	µg/g	3.32	Low	3	4.21	moderate	4	2.4	minimal	1	6.1	high	5
Fish eggs	µg/g	10.6	moderate	4	11.6	moderate	4	12.2	moderate	4	14.0	moderate	4
Bird eggs	µg/g	5.00	minimal	2	5.86	low	3	1.4	none	1	1.8	none	1
TOTAL HAZARD SCORE			Moderate	12		Moderate	15		Low	9		Moderate	13
		Grassland Bypass Project Phase II						Grassland Bypass Project Phase III					
		Calendar Year 2008			Calendar Year 2009			Calendar Year 2010			Calendar Year 2011		
Water	µg/L	1.0	minimal	2	1.0	minimal	2	0.9	minimal	2	1.3	minimal	2
Sediment	µg/g	0.7	none	1	0.6	none	1	0.67	none	1	<0.14	none	1
Invertebrates	µg/g	2.1	minimal	2	2.3	minimal	2	2.5	minimal	1	2.7	minimal	1
Fish eggs	µg/g	13.4	moderate	4	9.2	low	3	20	moderate	4	19.6	moderate	4
Bird eggs	µg/g	3.10	minimal	1	3.5	minimal	1	1.4	none	1	2.4	none	1
TOTAL HAZARD SCORE			Low	10		Low	9		Low	9		Low	9

Hazard Scale:	5.0	high	TOTAL HAZARD SCORE	16 - 25	High
	4.0	moderate		12 - 15	Moderate
	3.0	low		9 - 11	Low
	2.0	minimal		6 - 8	Minimal
	1.0	none		0 - 5	None

Notes: Table prepared by US Fish and Wildlife Service, Sacramento.

Table 5a. Maximum contaminant concentration data used for the Lemly Index (Table 4) for Calendar Year 2010

Mud Slough (north) below San Luis Drain

Media	Sample Date	Location	Value	Units	Sample Type	Sample Size	Data Source
Water	18-May-10	Site D, Mud Slough below SLD discharge	45.3	µg/L	weekly grab	1	USBR
Sediment	16-Mar-10	Site I2, backwater below SLD discharge	8.4	µg/g (dry)	0-3 cm Depth	1	USBR
Invertebrates	26-Aug-10	Site I2, main channel near backwater	14.0	µg/g (dry)	Siberian freshwater shrimp	2	USFWS
Fish eggs (*)	26-Aug-10	Site D, Mud Slough below SLD discharge	44.9	µg/g (dry)	largemouth bass	1	USFWS
Bird eggs	19-May-10	Kesterson Unit along San Luis Drain	7.4	µg/g (dry)	killdeer	1	USFWS

(*) fish egg selenium = fish wholebody selenium x 3.3

Salt Slough

Media	Sample Date	Location	Value		Sample Type	Sample Size	Data Source
Water	16-Feb-12	Site F, Salt Slough at Lander Ave	0.9	µg/L	weekly grab	1	CVRWQCB
Sediment	23-Sep-10	Site F, Salt Slough at Lander Ave	0.7	µg/g (dry)	0-3cm Depth	1	USBR
Invertebrates	27-Aug-10	Site F, Salt Slough boat ramp, San Luis Unit	2.5	µg/g (dry)	Siberian freshwater shrimp	8	USFWS
Fish eggs (*)	16-Nov-10	Site F, Salt Slough boat ramp, San Luis Unit	20.0	µg/g (dry)	black bullhead	1	USFWS
Bird eggs	19-May-10	Duck box #2, San Luis Unit	1.4	µg/g (dry)	wood duck	1	USFWS

(*) fish egg selenium = fish wholebody selenium x 3.3

Table 5b. Maximum contaminant concentration data used for the Lemly Index (Table 4) for Calendar Year 2011

Mud Slough (north) below San Luis Drain

Media	Sample Date	Location	Value	Units	Sample Type	Sample Size	Data Source
Water	4-May-11	Site I2, backwater below SLD discharge	25.0	µg/L	weekly grab	1	USBR
Sediment	8-Nov-11	Site I2, backwater below SLD discharge	6.9	µg/g (dry)	whole core	1	USBR
Invertebrates	16-Aug-11	Site I2, main channel near backwater	10.5	µg/g (dry)	Siberian freshwater shrimp	5	USFWS
Fish eggs (*)	23-Jun-11	Site I2, backwater below SLD discharge	42.6	µg/g (dry)	common carp	50	USFWS
Bird eggs	12-Apr-11	Kesterson Unit along San Luis Drain	7.6	µg/g (dry)	killdeer	1	USFWS

(*) fish egg selenium = fish wholebody selenium x 3.3

Salt Slough

Media	Sample Date	Location	Value		Sample Type	Sample Size	Data Source
Water	8-Mar-11	Site F, Salt Slough at Lander Ave	1.3	µg/L	weekly grab	1	CVRWQCB
Sediment	8-Nov-11	Site F, Salt Slough at Lander Ave	<0.14	µg/g (dry)	whole core	1	USBR
Invertebrates	13-Apr-11	Site F, Salt Slough boat ramp, San Luis Unit	2.7	µg/g (dry)	damselfly larvae	20	USFWS
Fish eggs (*)	18-Nov-11	Site F, Salt Slough boat ramp, San Luis Unit	19.6	µg/g (dry)	Mississippi silverside	5	USFWS
Bird eggs	10-May-11	San Luis Unit, Deadman Slough pump platform	2.4	µg/g (dry)	cliff swallow	1	USFWS

(*) fish egg selenium = fish wholebody selenium x 3.3

Figure 1. Grassland Bypass Project Biota Monitoring Sites

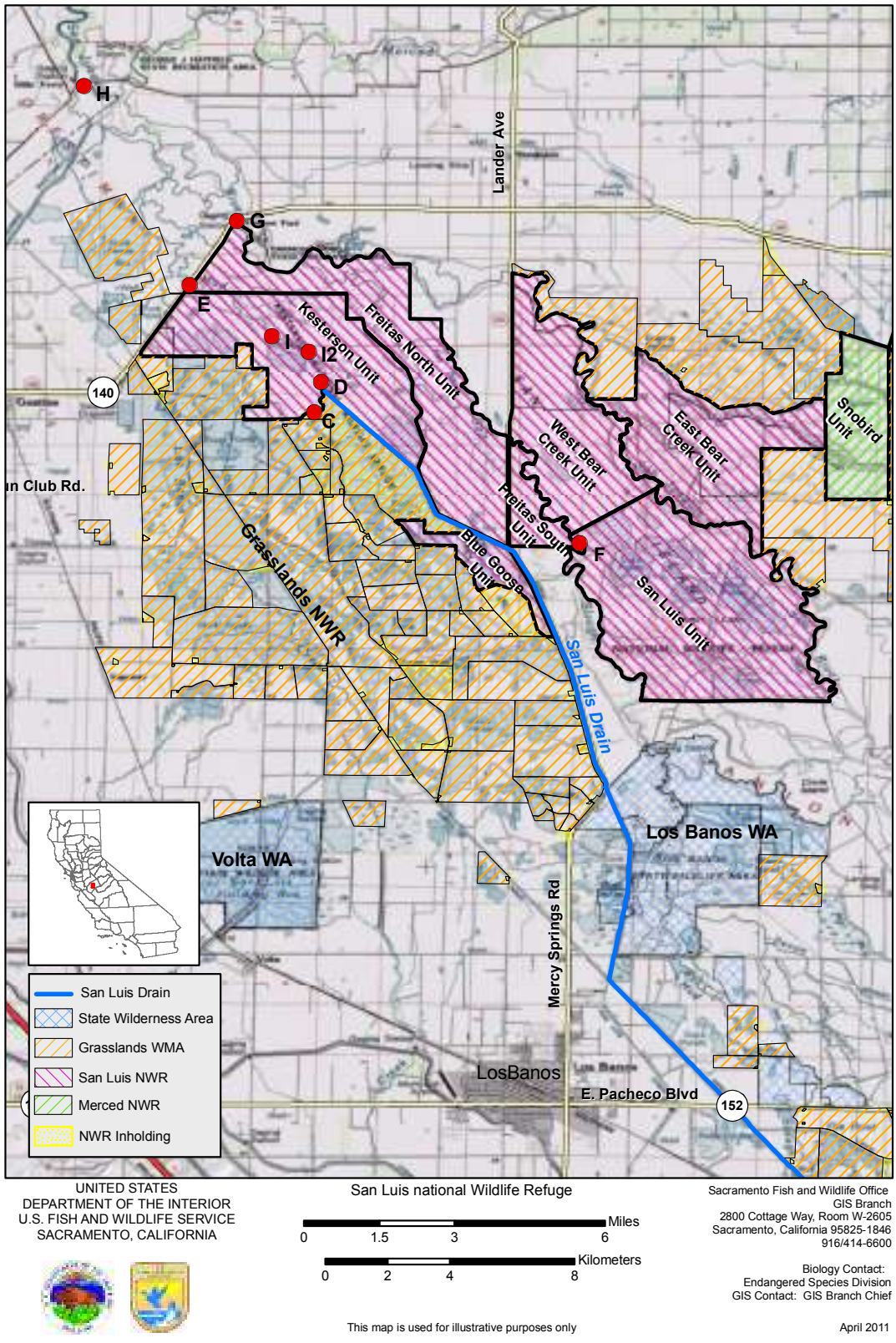


Figure 1b. Numbers of Siberian freshwater shrimp collected at sites in Salt Slough (Site F) and Mud Slough upstream (Site C), just downstream (Site D) and farther downstream (Site I/12) of the San Luis Drain outfall

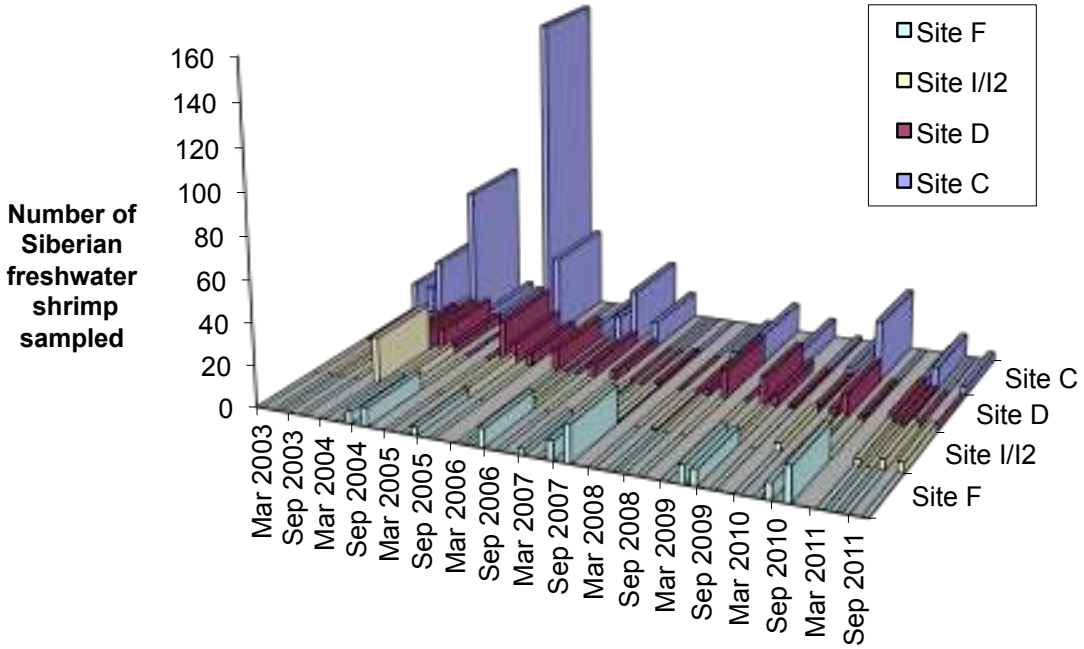


Figure 1c. Relationship between survival of bluegill (logit-transformed) and concentrated of selenium in their tissues after 90 days exposure to dietary selenium in the form of seleno-L-methionine Cleveland et al. 1993)

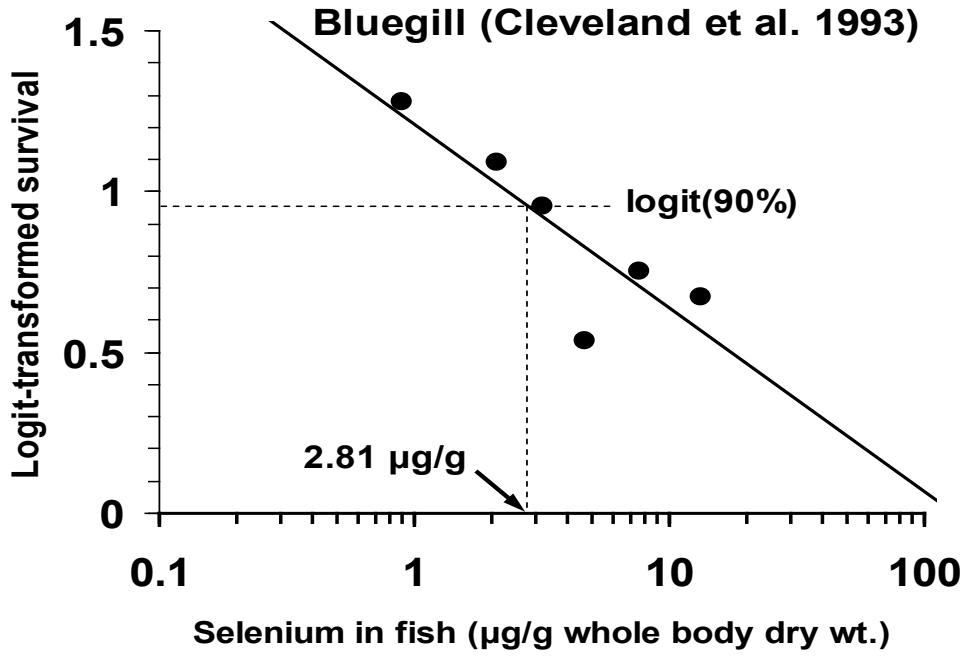


Figure 1d. Relationship between survival of juvenile salmon and concentration of selenium in their tissues after 90 days (Chinook salmon: Hamilton et al .1990) or 45 days (Atlantic salmon: Poston et al . 1976) exposure to dietary selenium. The 10% lethality level (LC10=1.84 µg/g) derived by applying the biphasic model of Brain and Cousens (1989) to only the Chinook salmon data is close to the LC10 (1.85 µg/g) determined by applying the biphasic model of Beckon et al . (2008) to all the salmon data shown. The Chinook salmon data comprises two series of dietary treatments, combined here because the effects on survival are indistinguishable.

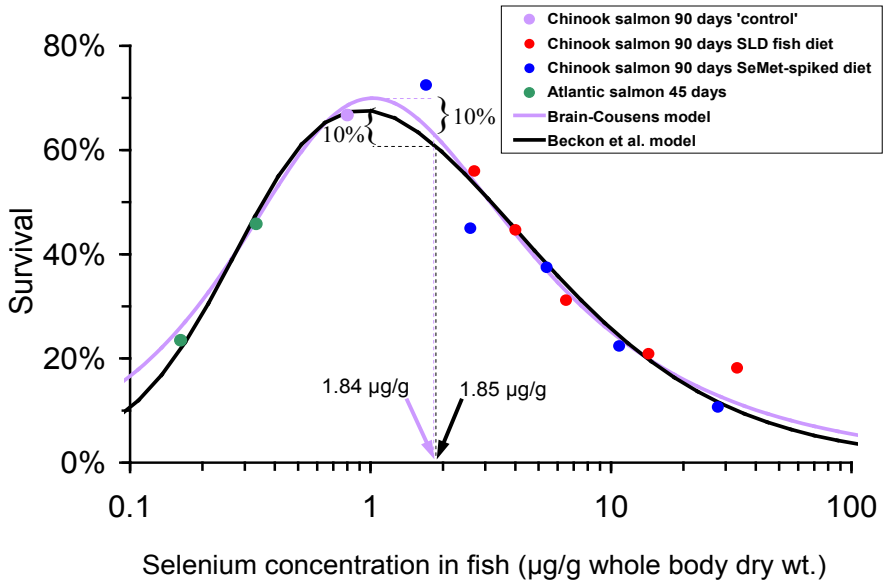


Figure 1e. Relationship between growth of juvenile rainbow trout and concentration of selenium in their tissues after 140 days exposure to dietary selenium in the form of sodium selenite (Hilton et al . 1980). Whole body selenium was calculated from reported concentrations in carcass, kidney and liver.

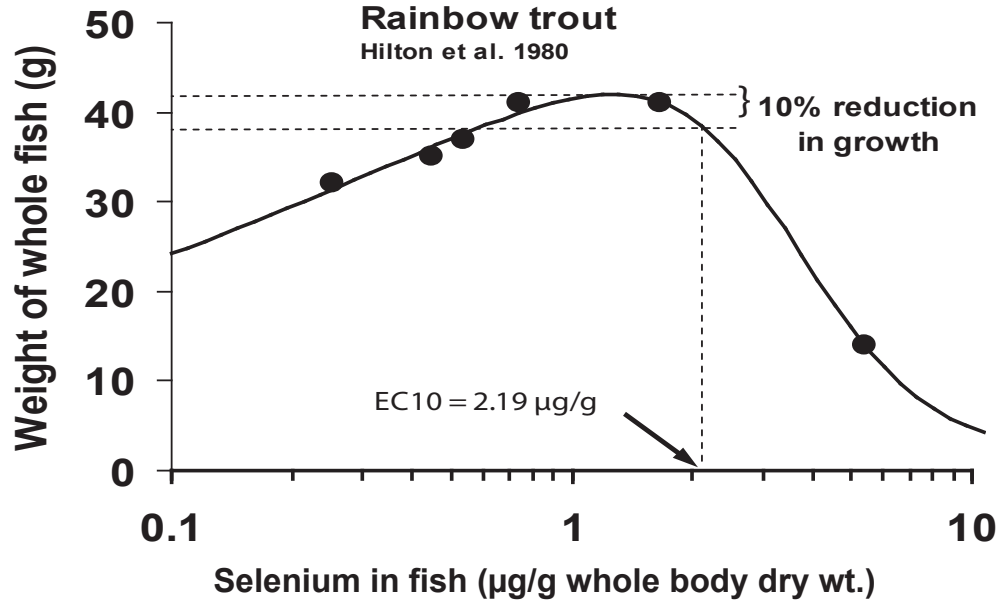


Figure 2. Selenium in all fish in Salt Slough (Site F)

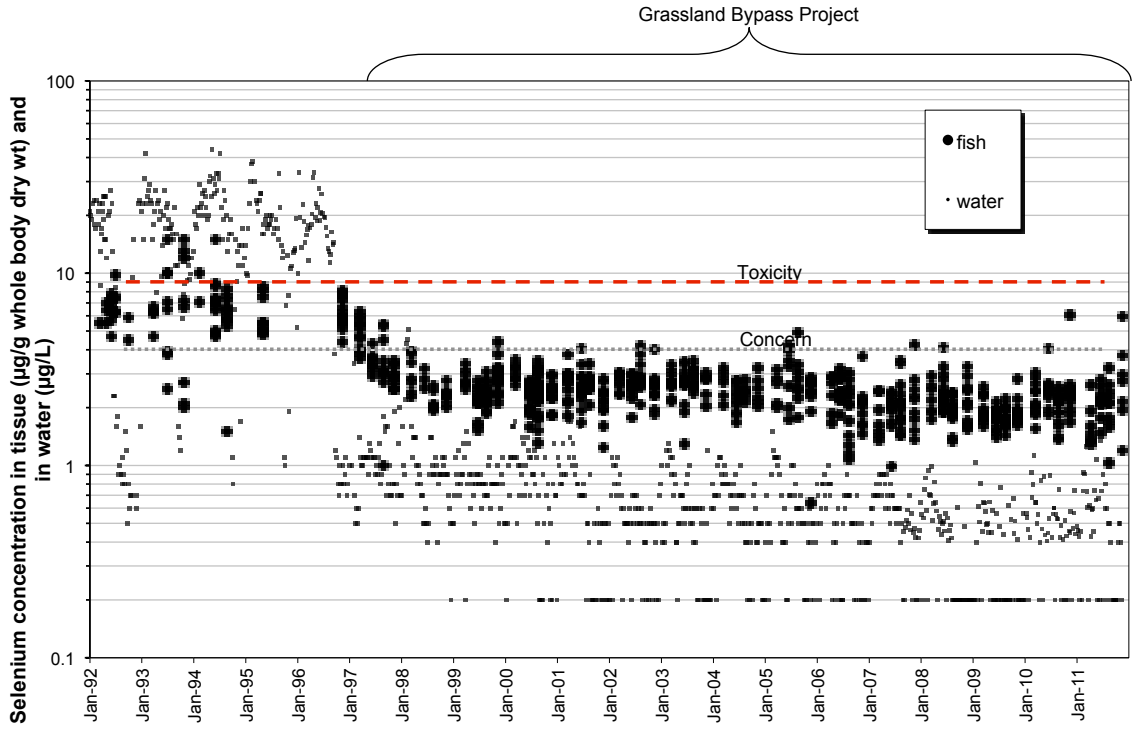


Figure 2a. Selenium in mosquitofish in Salt Slough (Site F)

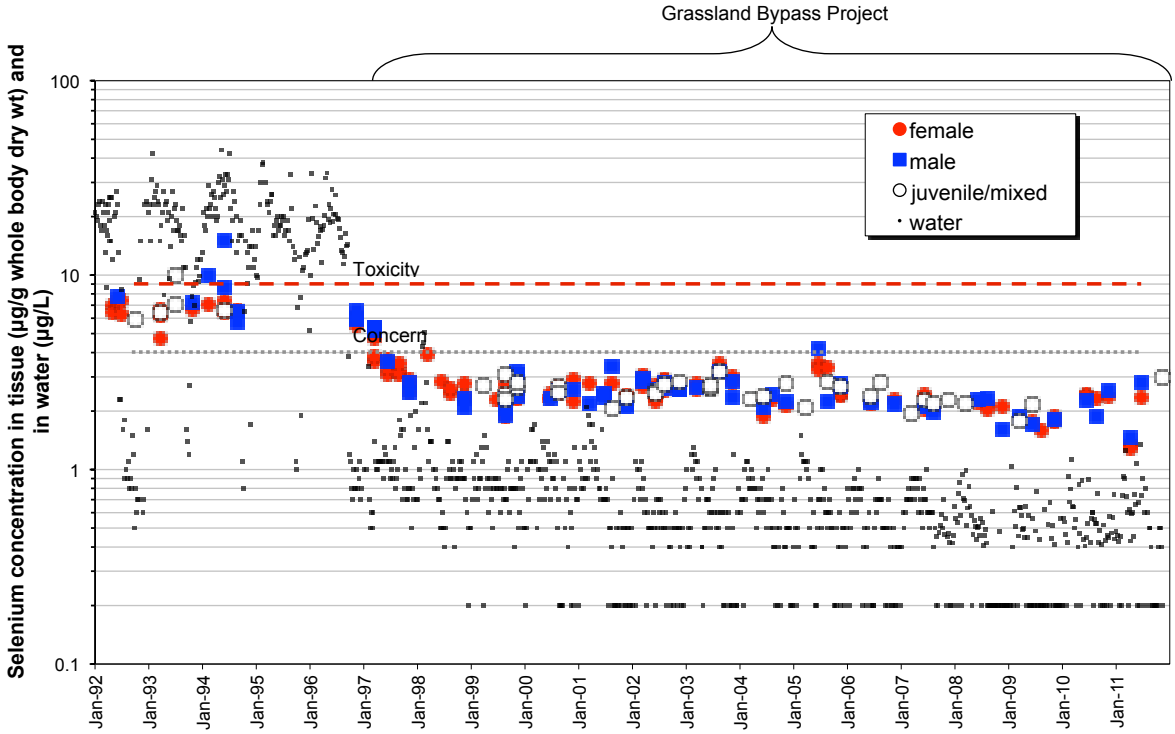


Figure 2b. Selenium in Mississippi silversides in Salt Slough (Site F)

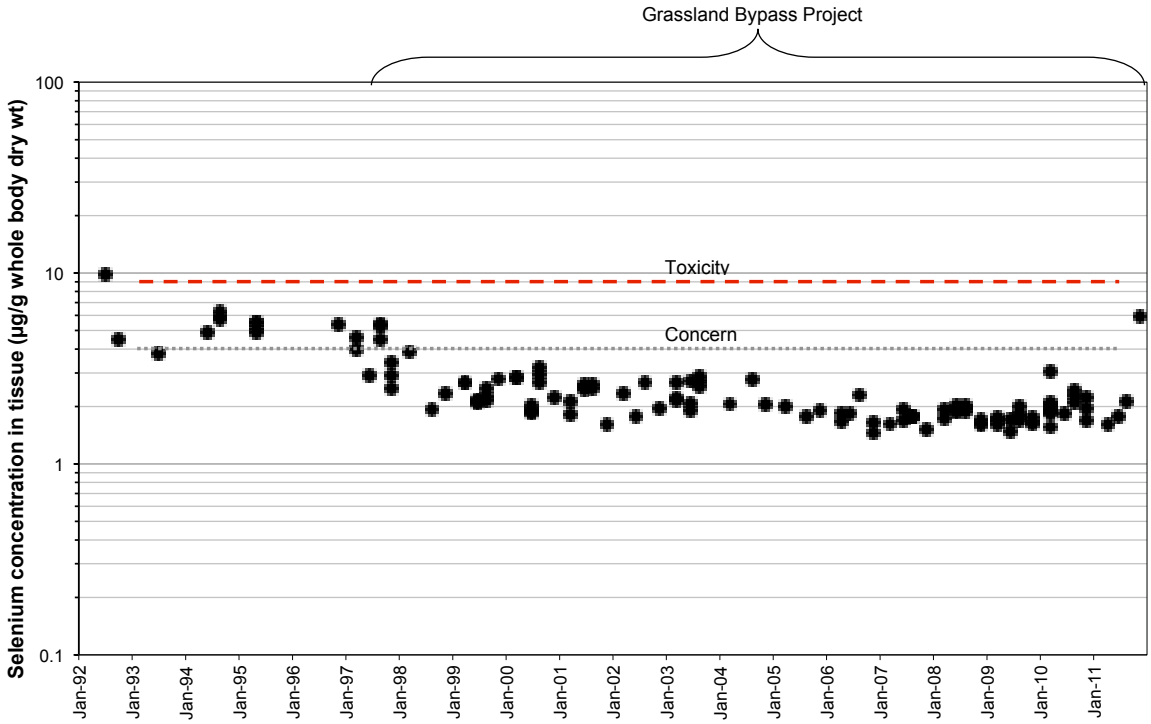


Figure 2c. Selenium in minnows in Salt Slough (Site F)

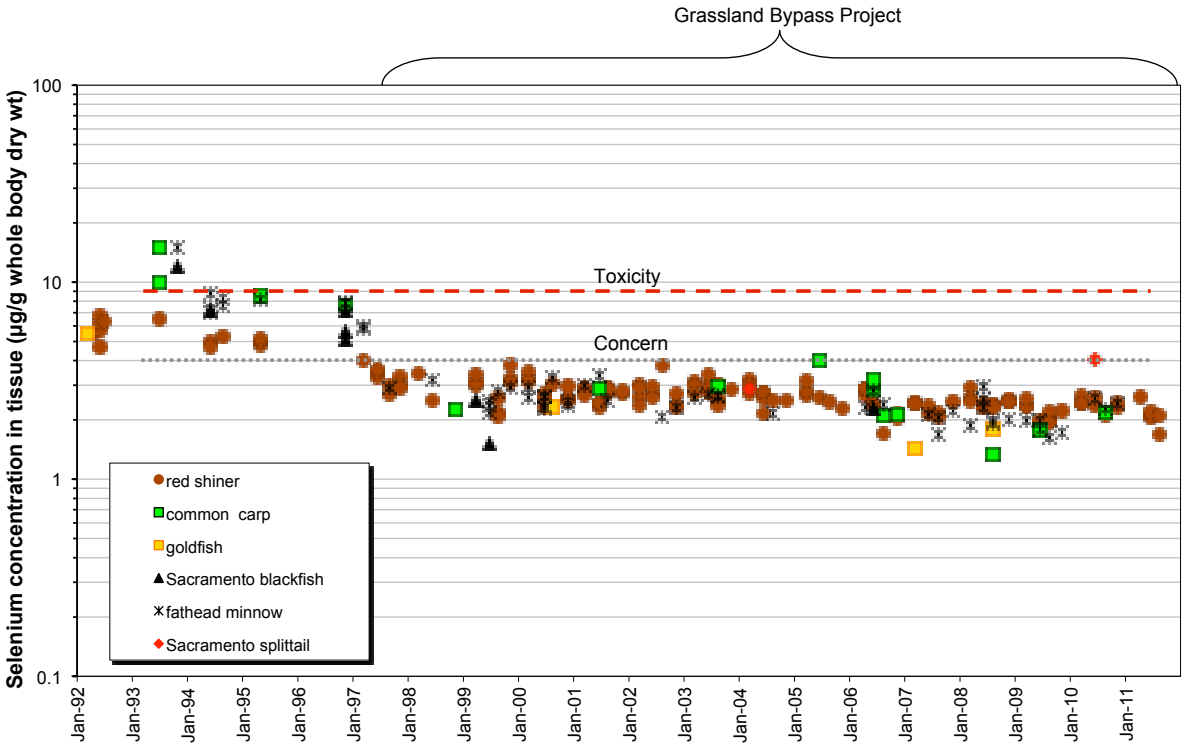


Figure 2d. Selenium in sunfish and bass in Salt Slough (Site F)

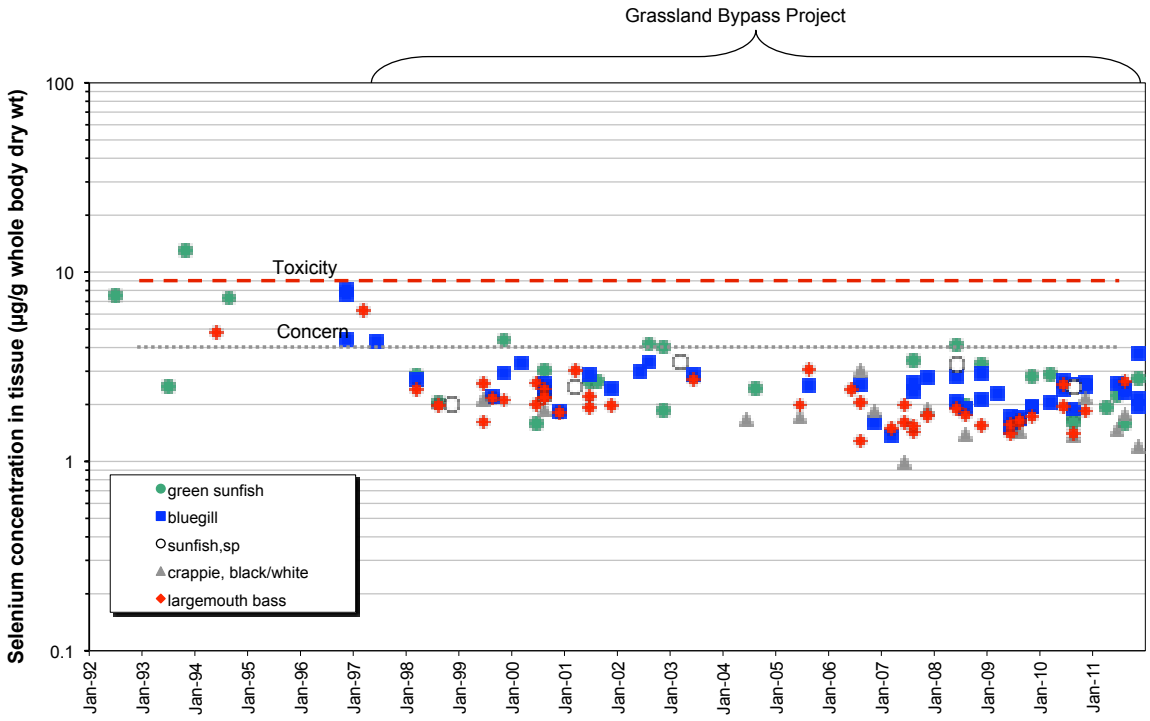


Figure 2e. Selenium in various fish in Salt Slough (Site F)

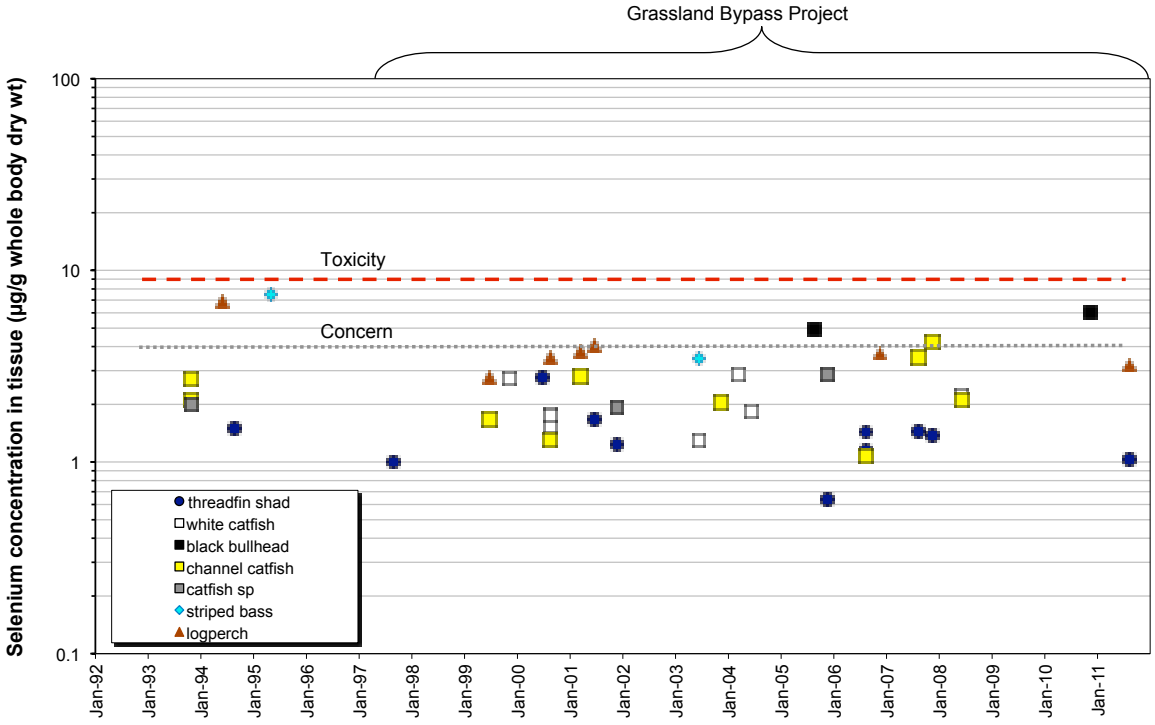


Figure 2f. Selenium in invertebrates in Salt Slough (Site F)

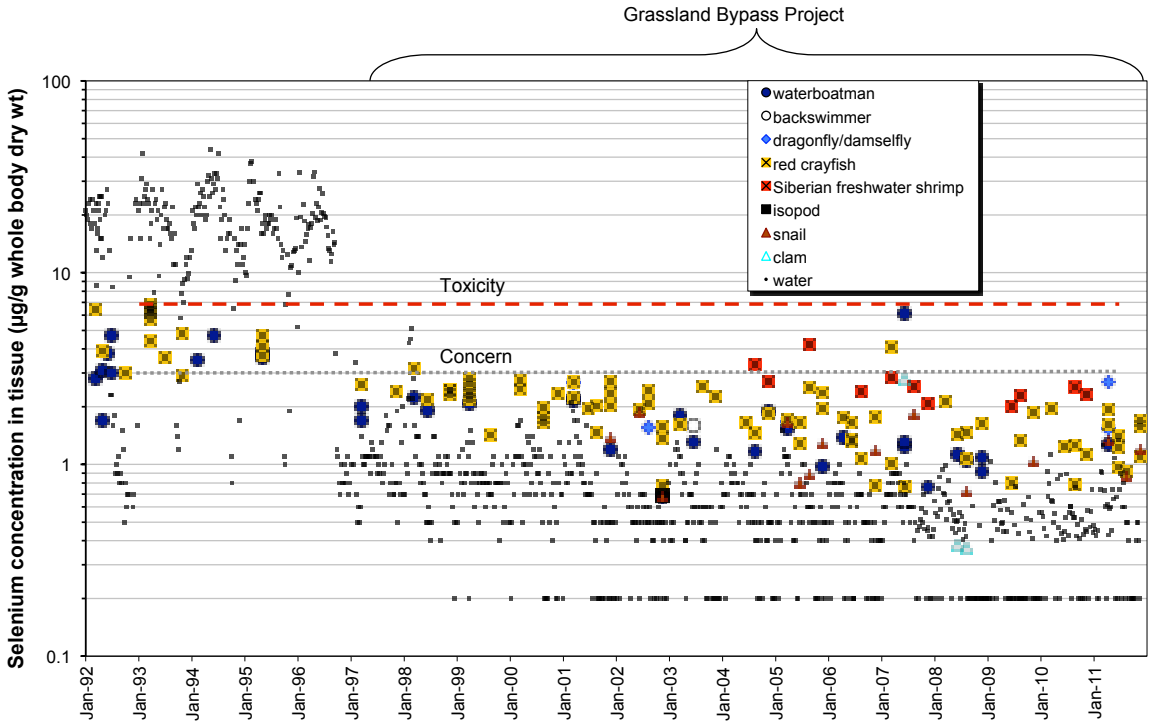


Figure 2g. Selenium in plants along Salt Slough (Site F)

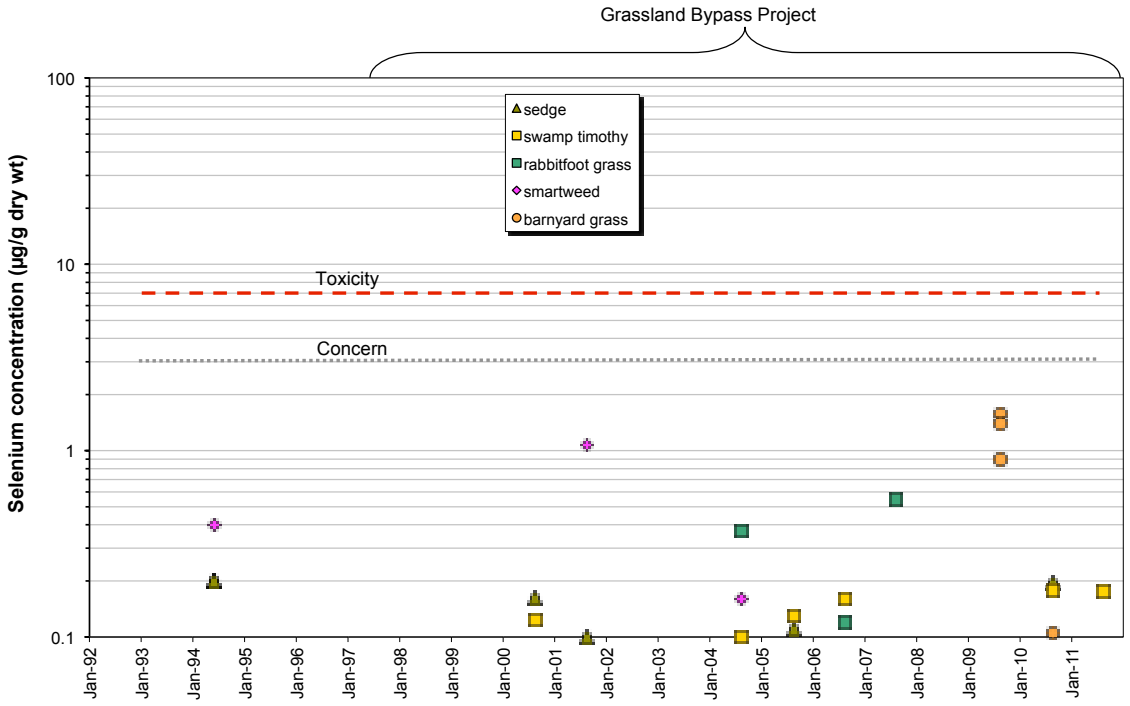


Figure 2h. Boron in plants along Salt Slough (Site F)

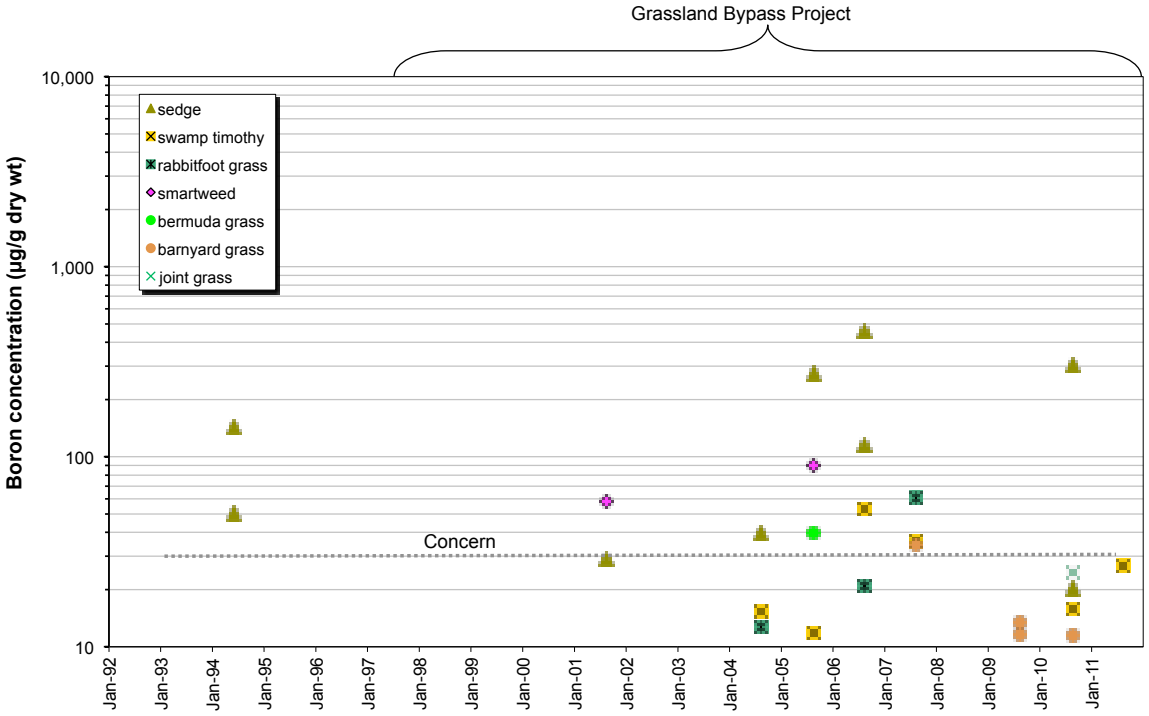


Figure 3. Selenium in all fish in Mud Slough above the San Luis Drain discharge (Site C)

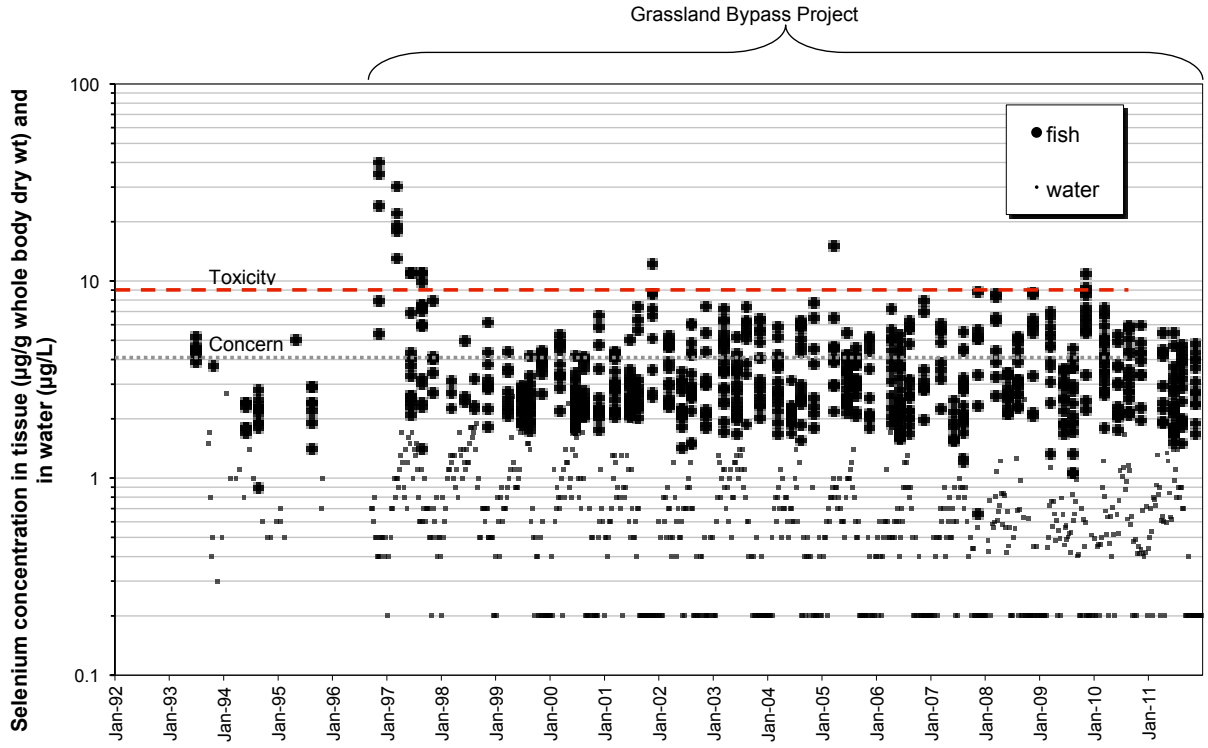


Figure 3a. Selenium in mosquitofish in Mud Slough above the San Luis Drain discharge (Site C).

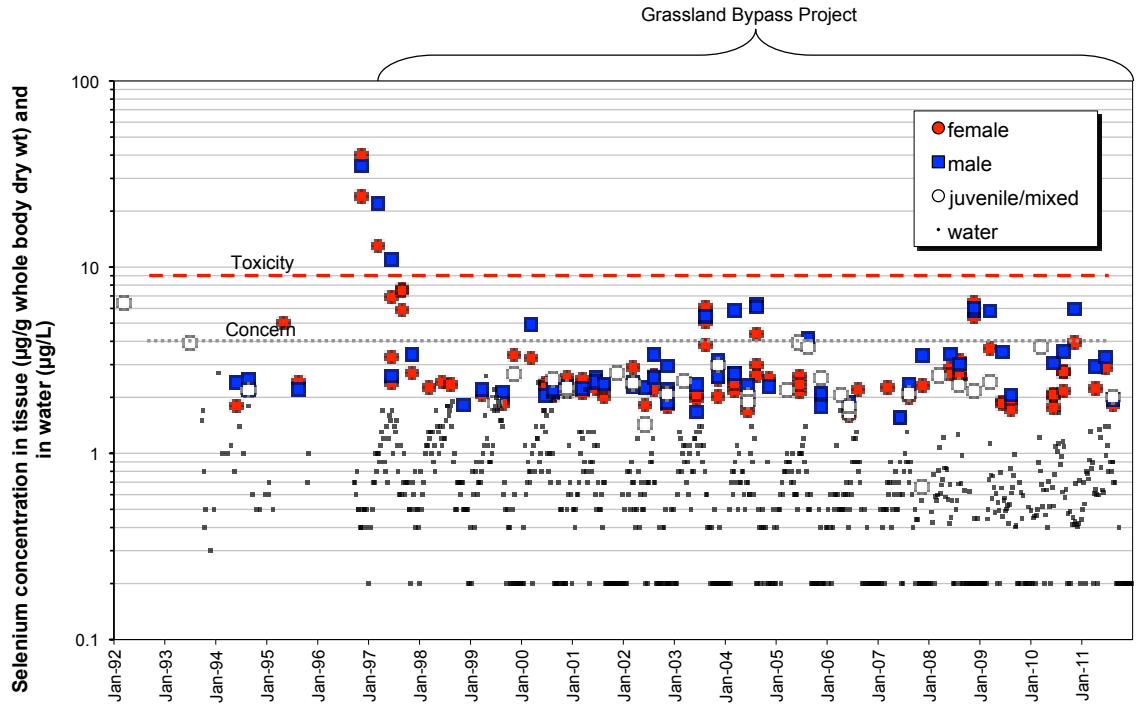


Figure 3b. Selenium in Mississippi silversides in Mud Slough above the San Luis Drain discharge (Site C)

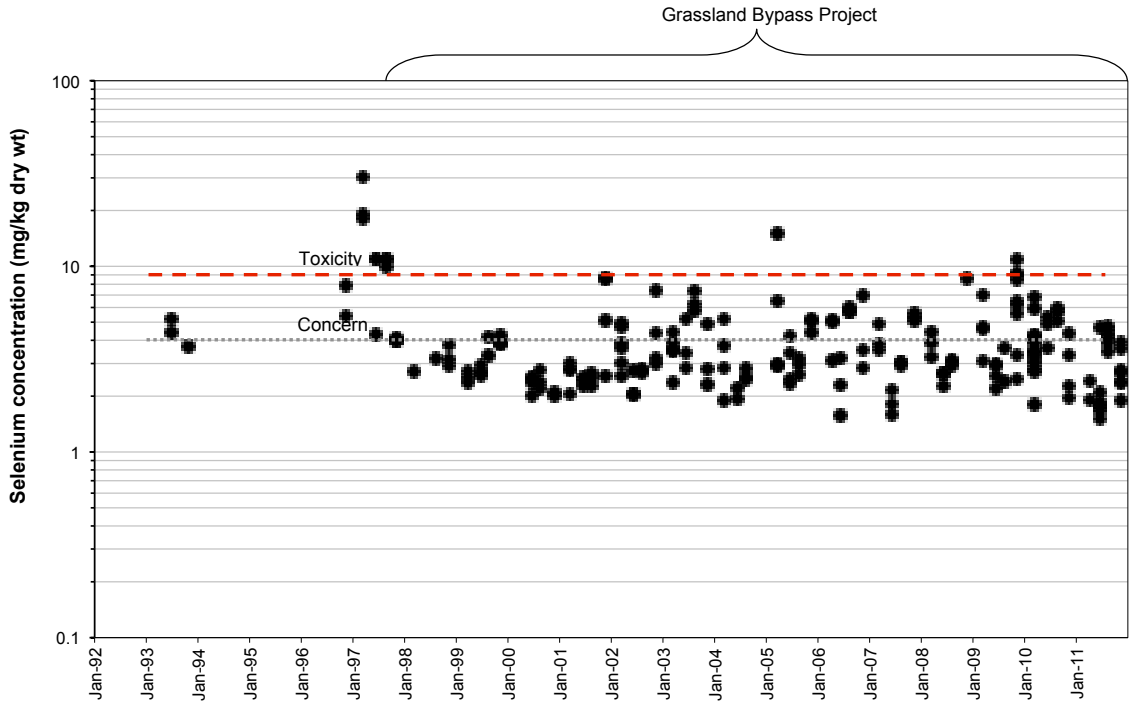


Figure 3c. Selenium in minnows in Mud Slough above the San Luis Drain discharge (Site C)

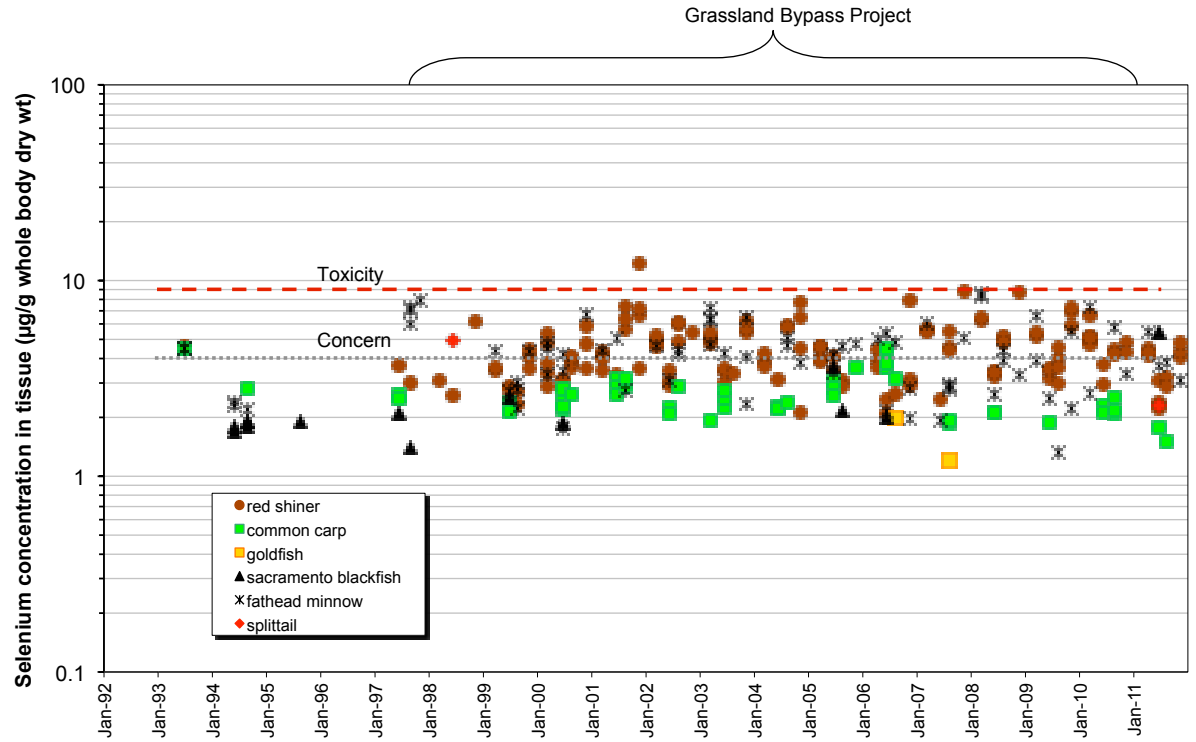


Figure 3d. Selenium in sunfish and bass in Mud Slough above the San Luis Drain discharge (Site C)

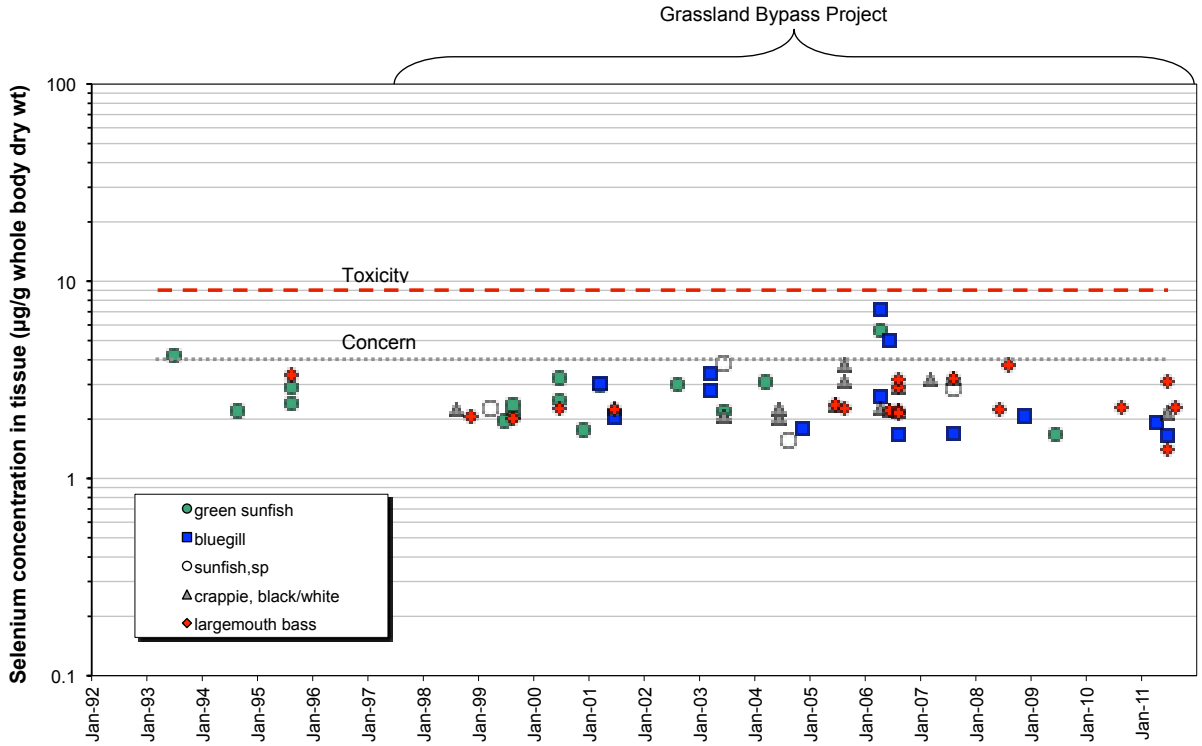


Figure 3e. Selenium in various fish in Mud Slough above the San Luis Drain discharge (Site C)

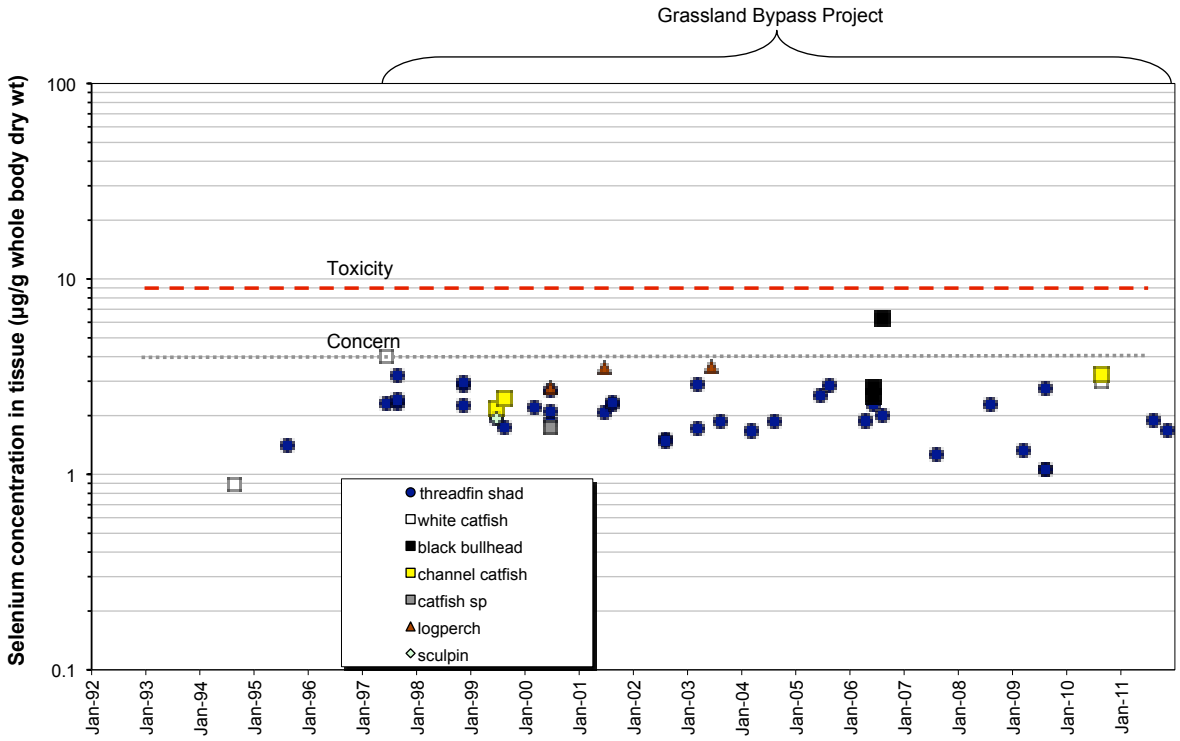


Figure 3f. Selenium in invertebrates in Mud Slough above the San Luis Drain discharge (Site C)

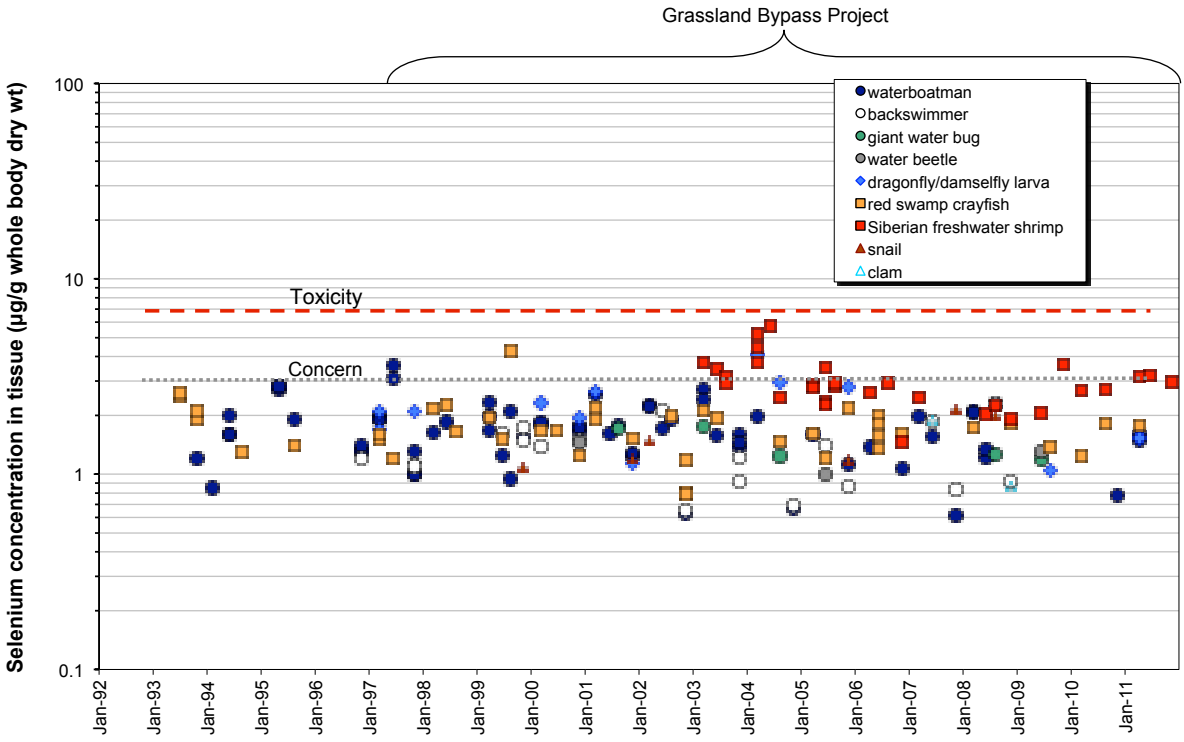


Figure 3g. Selenium in plants along Mud Slough above the San Luis Drain discharge (Site C)

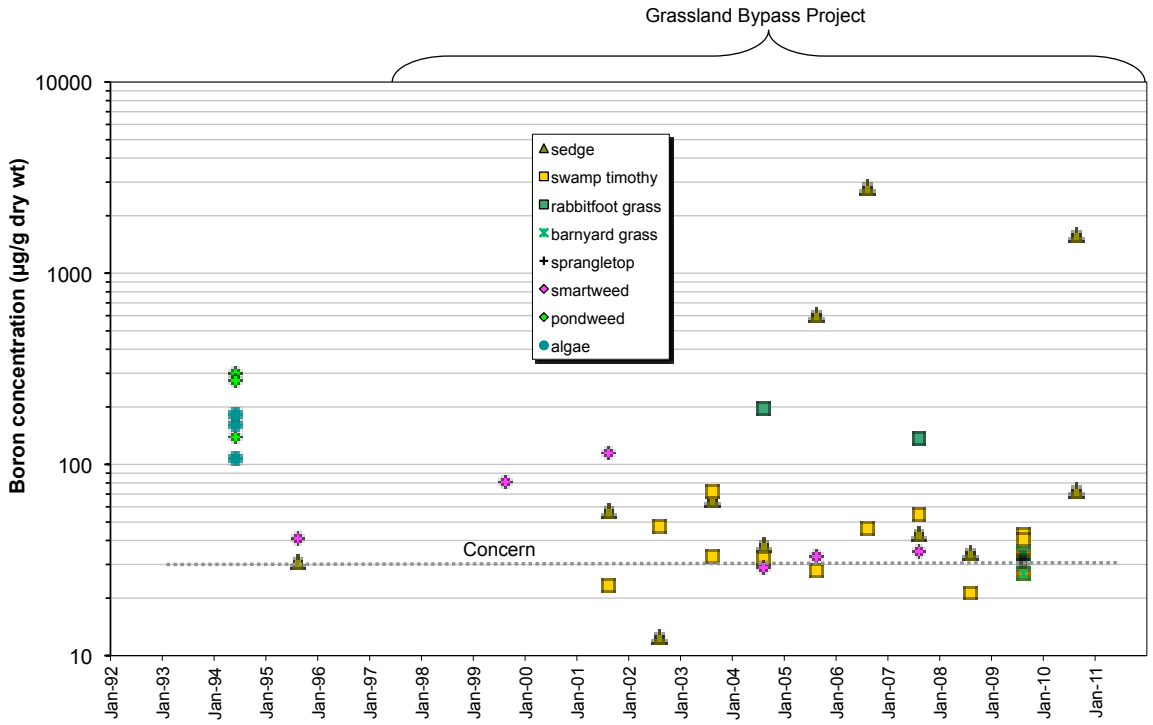


Figure 3h. Boron in plants along Mud Slough above the San Luis Drain discharge (Site C)

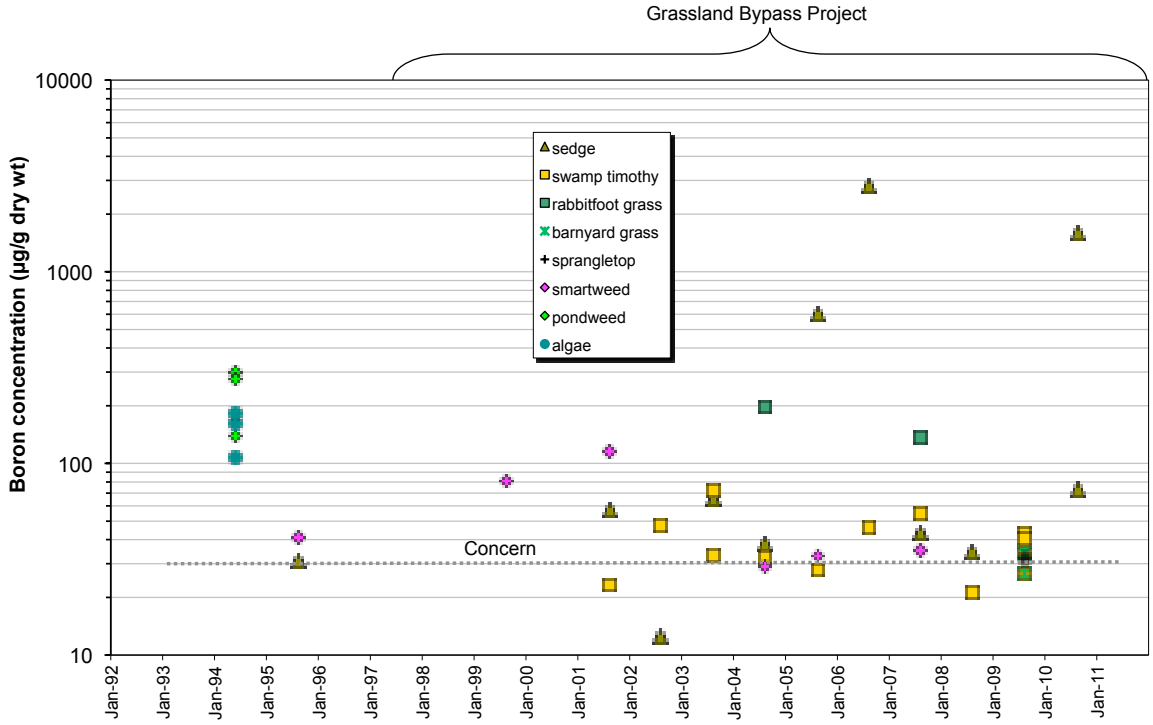


Figure 4. Selenium in all fish in Mud Slough above the San Luis Drain discharge (Site C)

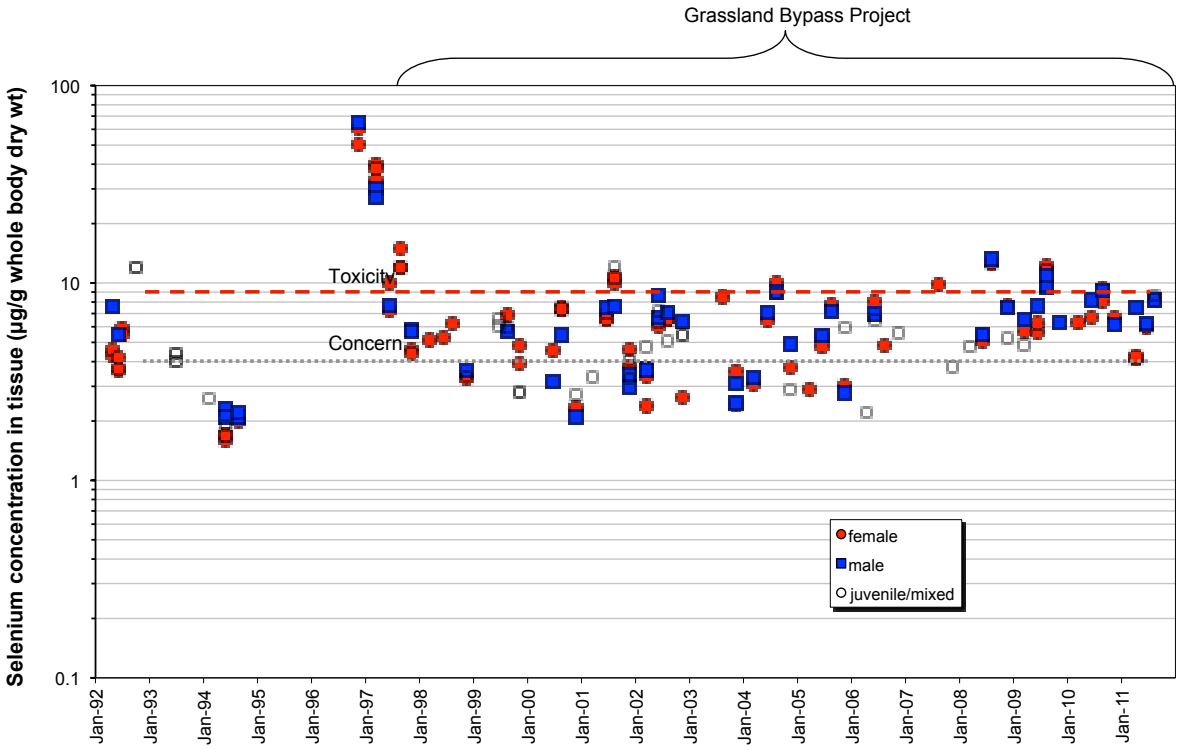


Figure 4a. Selenium in mosquitofish in Mud Slough below the San Luis Drain discharge (Site D)

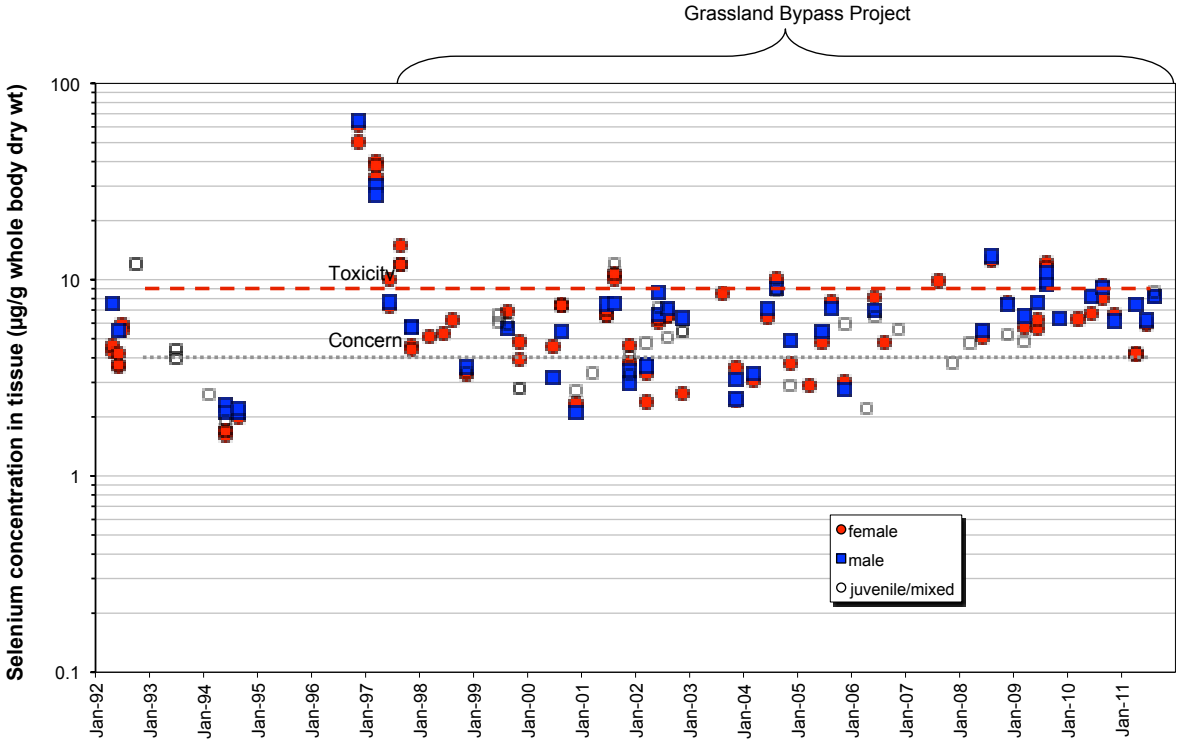


Figure 4b. Selenium in Mississippi silversides in Mud Slough below the San Luis Drain discharge (Site D)

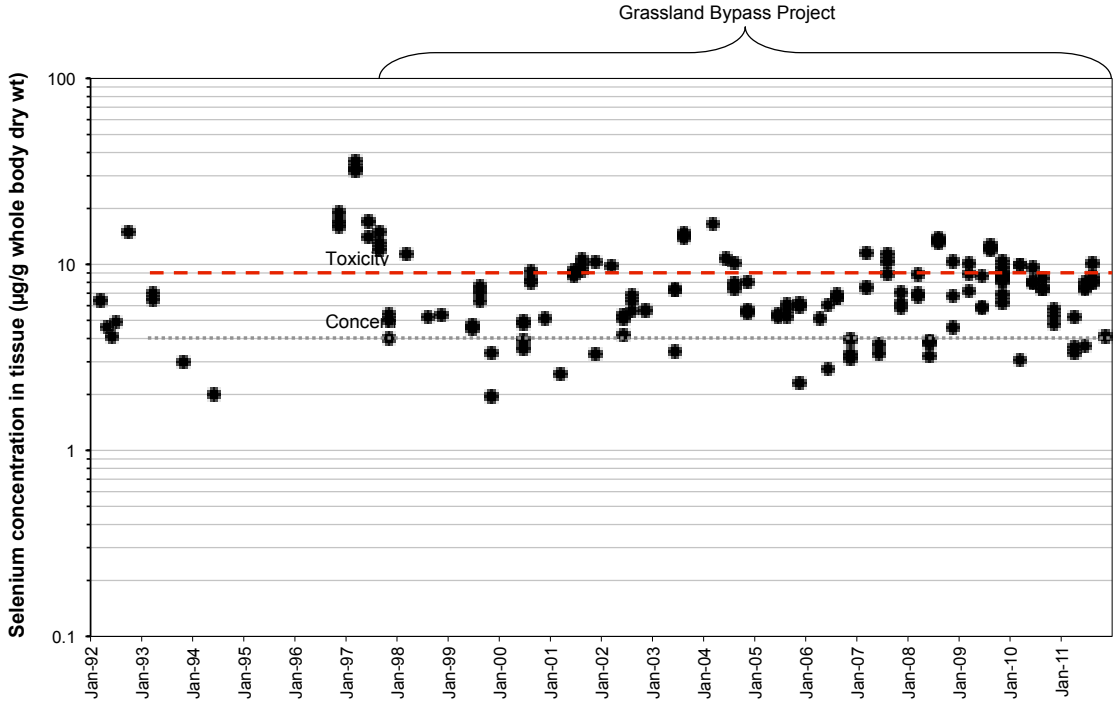


Figure 4c. Selenium in minnows in Mud Slough below the San Luis Drain discharge (Site D)

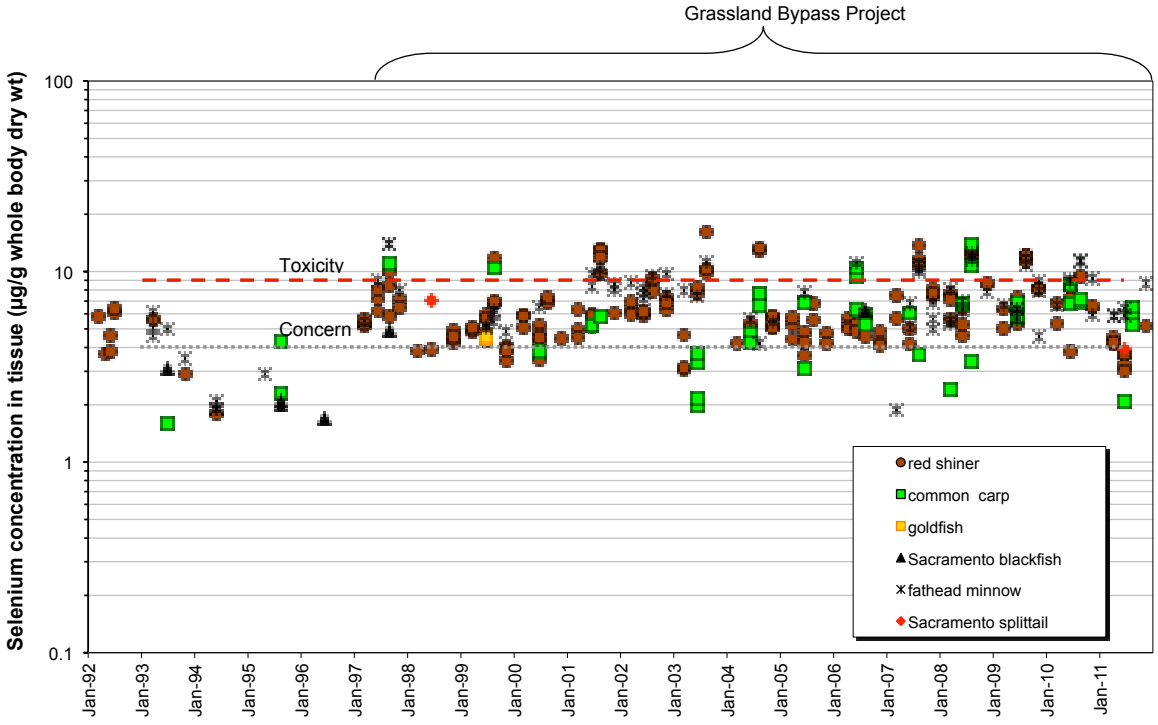


Figure 4d. Selenium in sunfish and bass in Mud Slough below the San Luis Drain discharge (Site D)

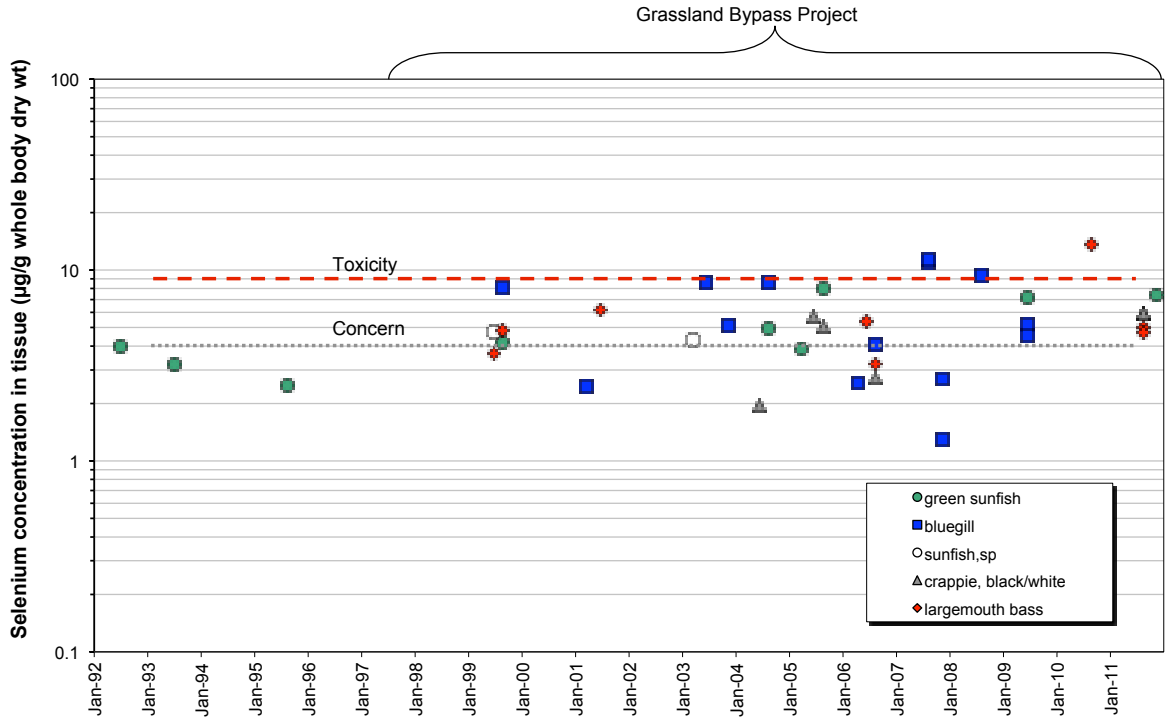


Figure 4e. Selenium in various fish in Mud Slough below the San Luis Drain discharge (Site D)

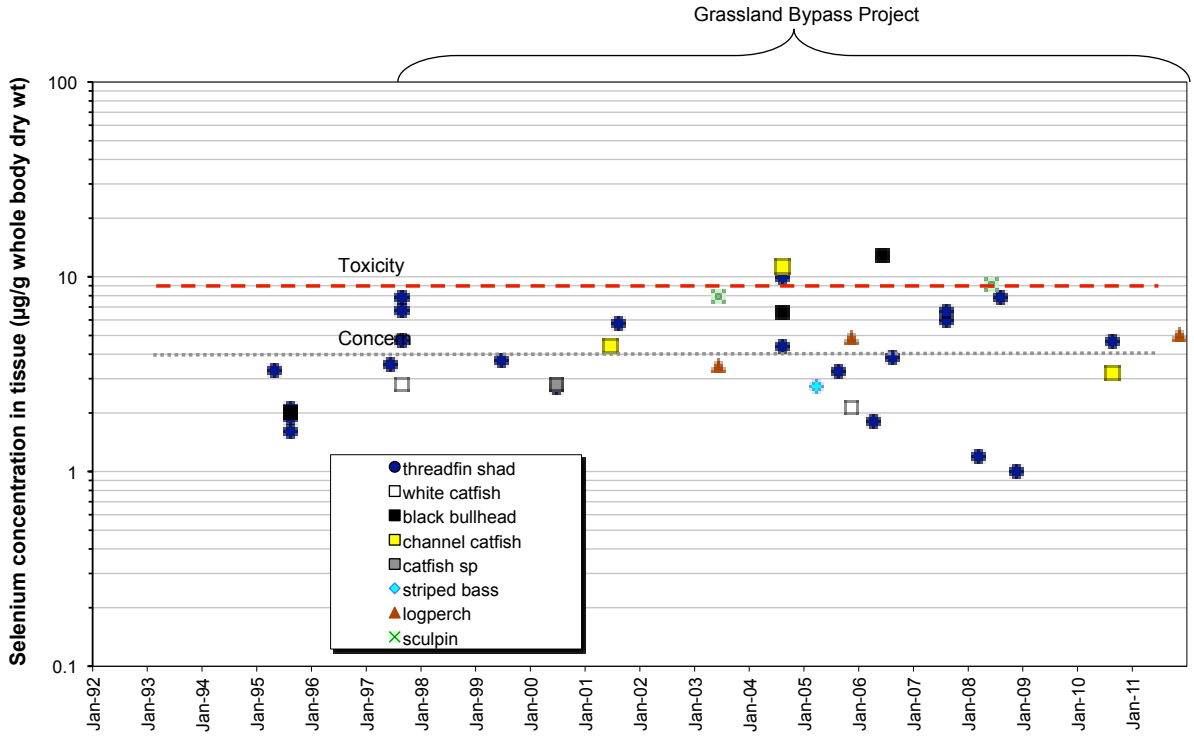


Figure 4f. Selenium in invertebrates in Mud Slough below the San Luis Drain discharge (Site D)

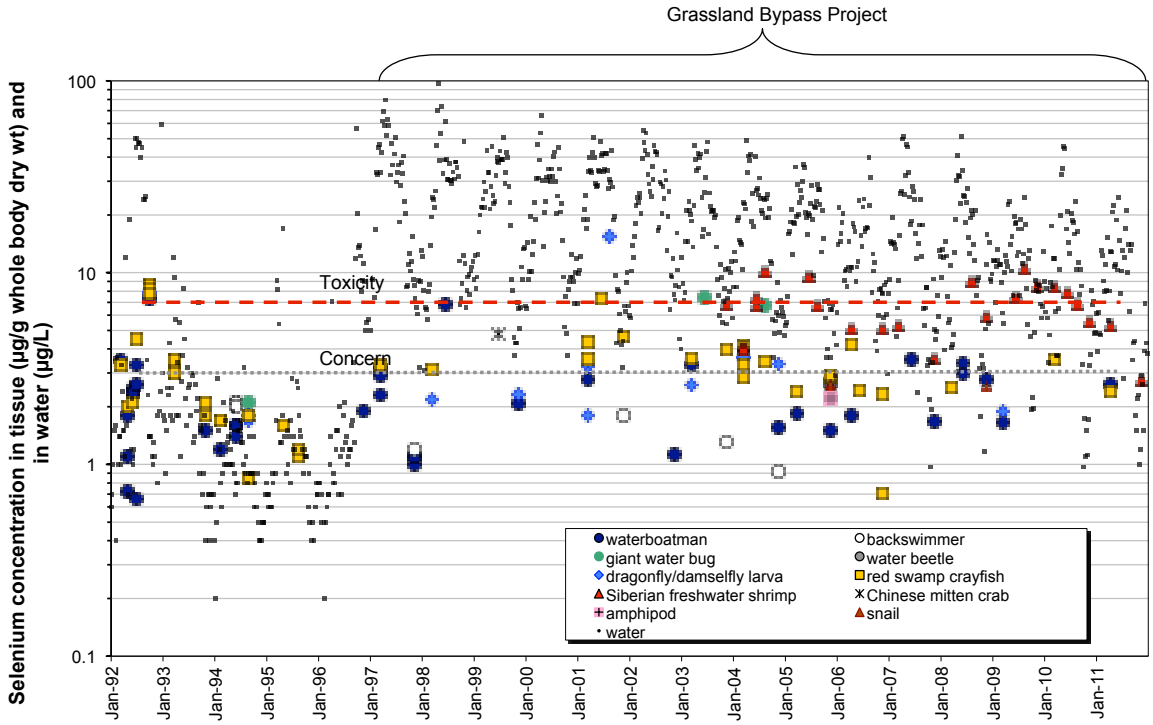


Figure 4g. Selenium in plants along Mud Slough below the San Luis Drain discharge (Site D)

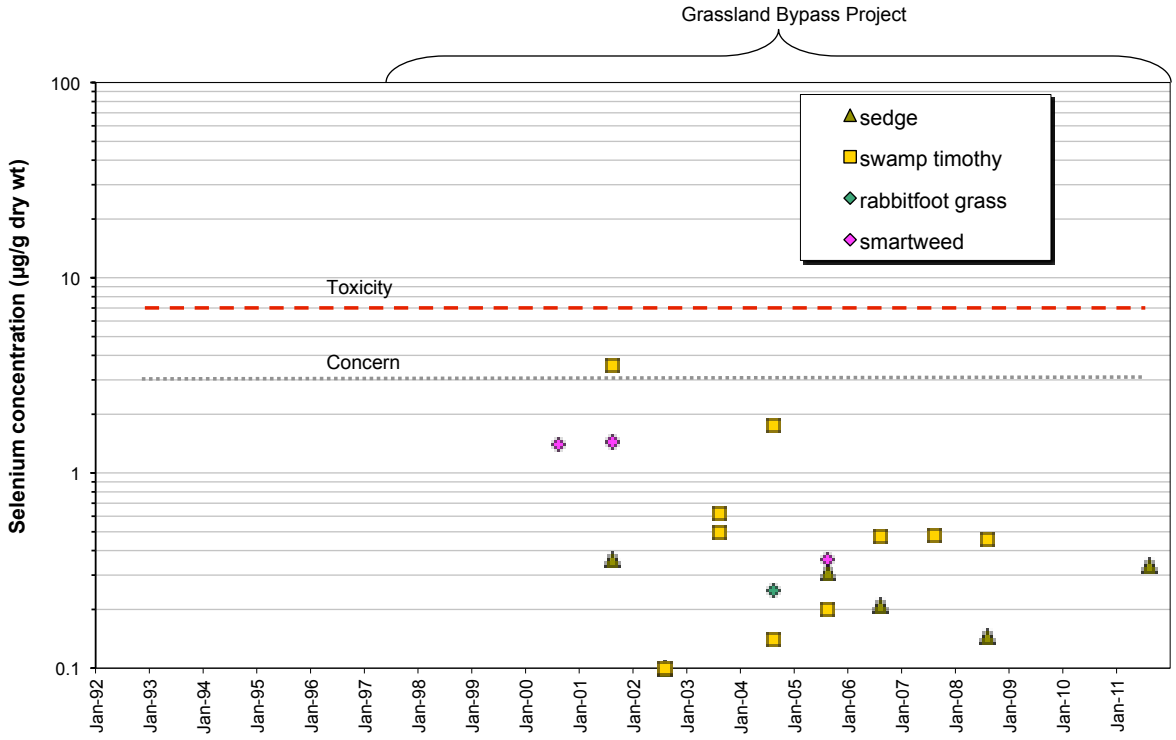


Figure 4h. Boron in plants along Mud Slough below the San Luis Drain discharge (Site D)

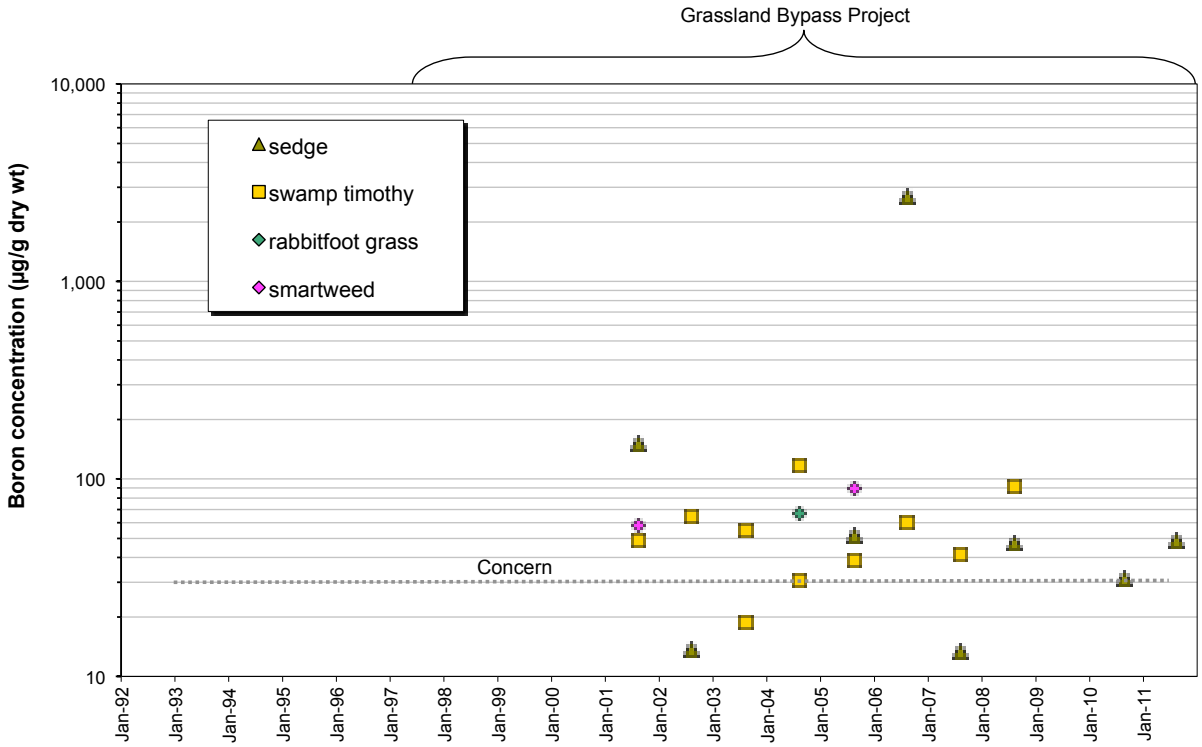


Figure 5. Selenium in all fish in a Mud Slough backwater below the Drain discharge (Site I and I2)

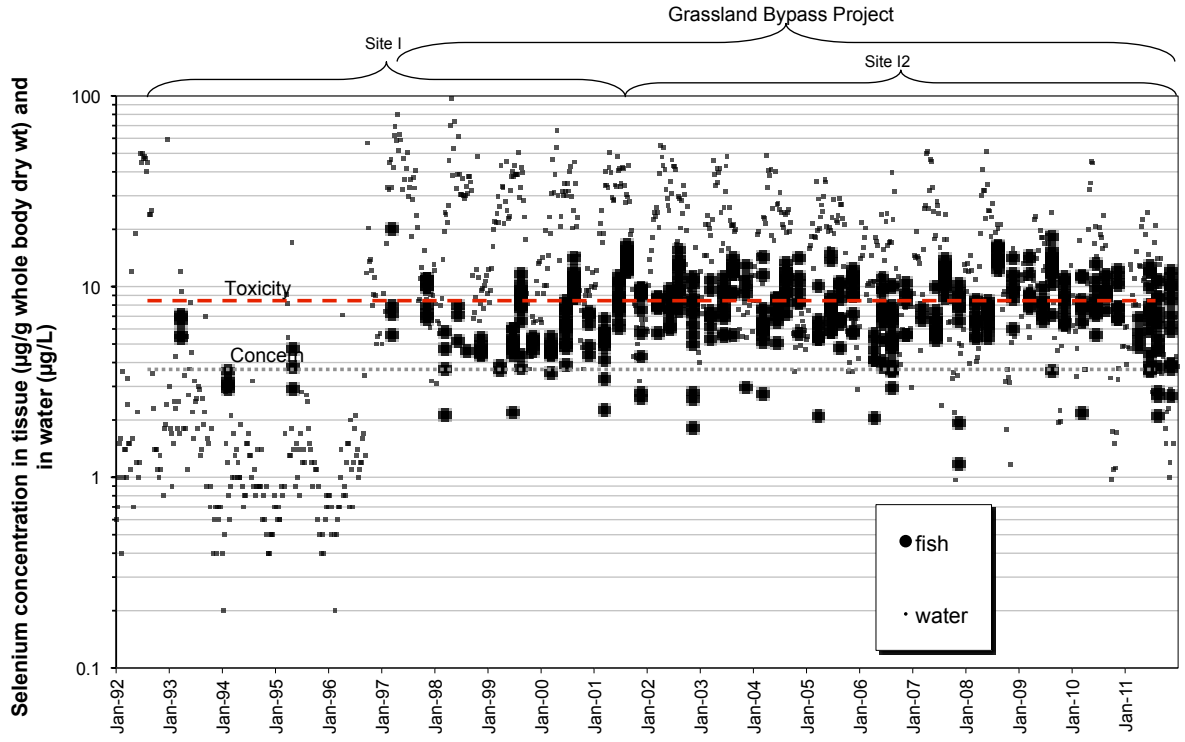


Figure 5a. Selenium in mosquitofish in a Mud Slough backwater below the Drain discharge (Sites I and I2)

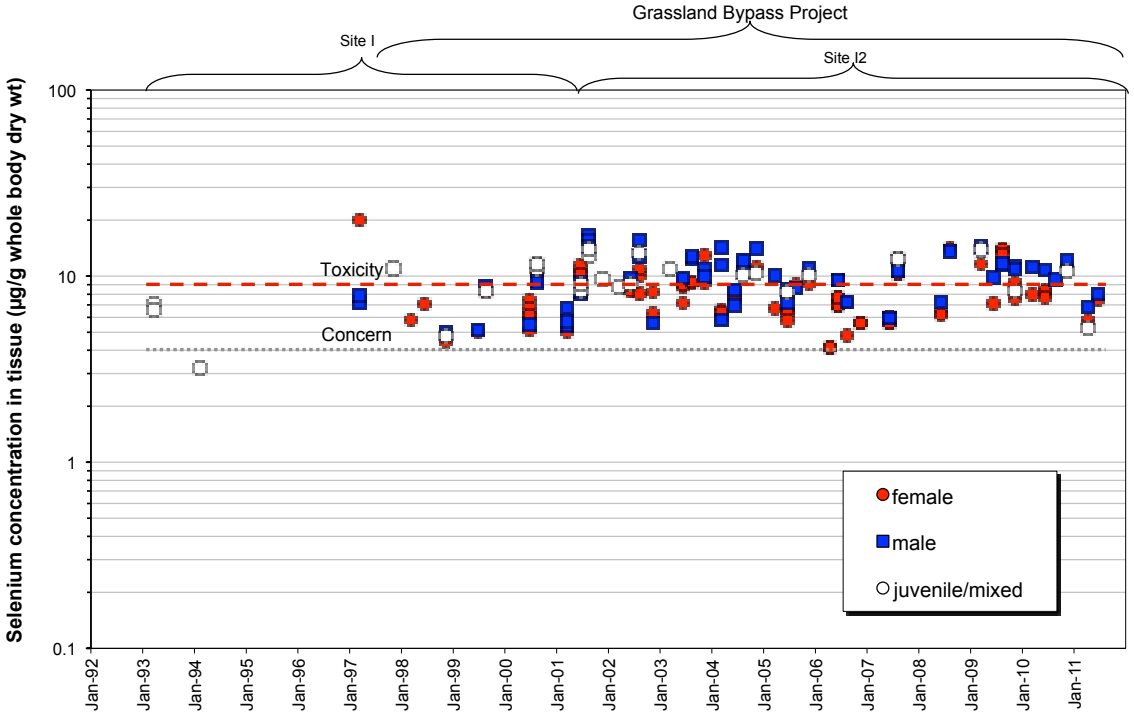


Figure 5b. Selenium in Mississippi silversides in a Mud Slough backwater below the Drain discharge (Sites I and I2)

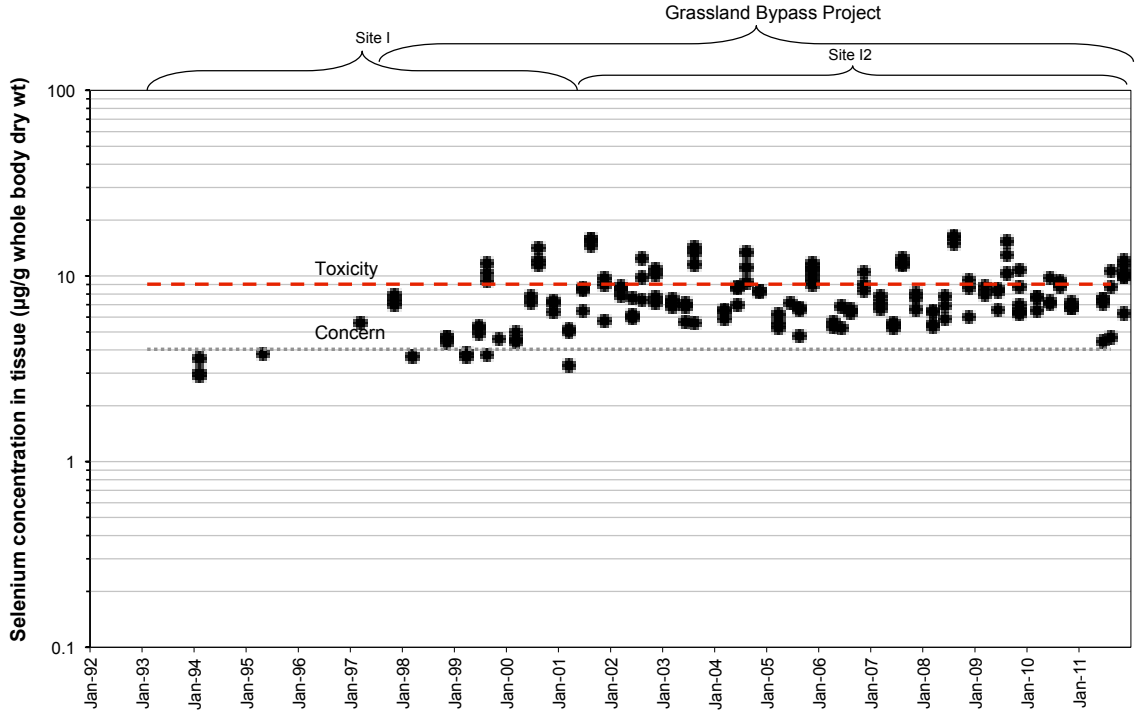


Figure 5c. Selenium in minnows in a Mud Slough backwater below the Drain discharge (Sites I and I2)

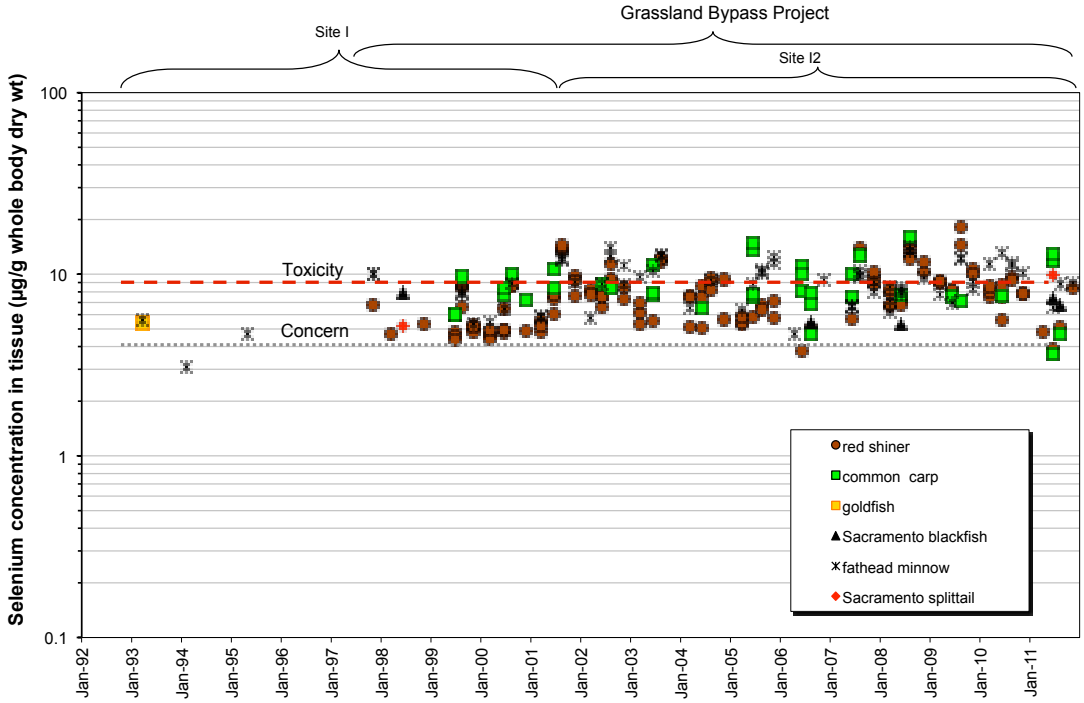


Figure 5d. Selenium in sunfish and bass in a Mud Slough backwater below the Drain discharge (Sites I and I2)

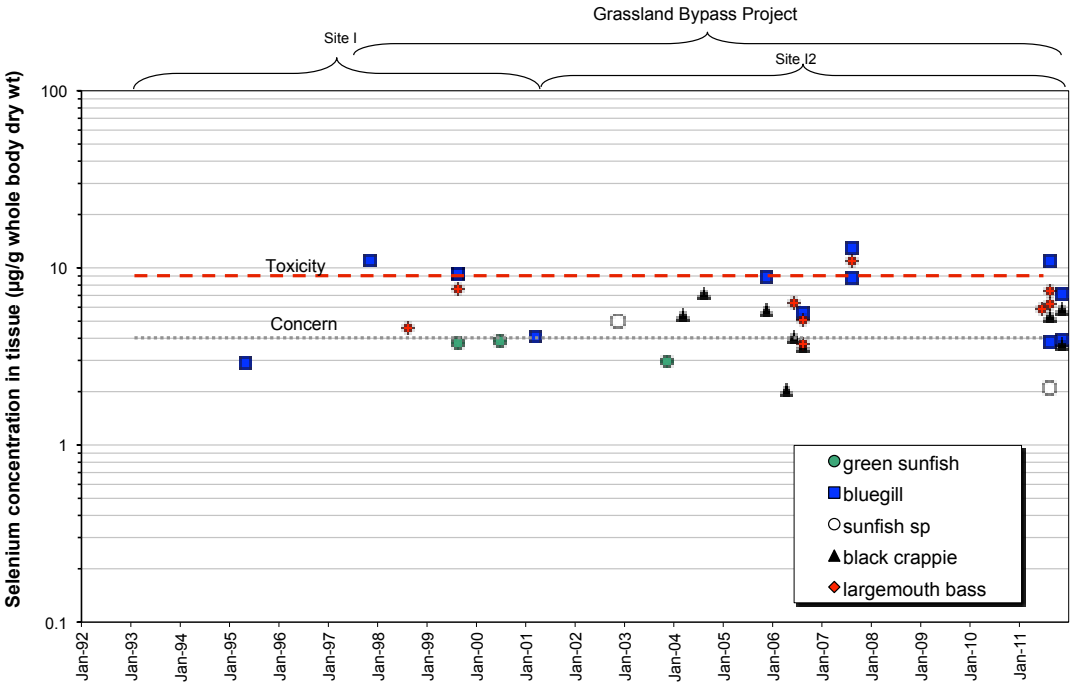


Figure 5e. Selenium in various fish in a Mud Slough backwater below the Drain discharge (Sites I and I2)

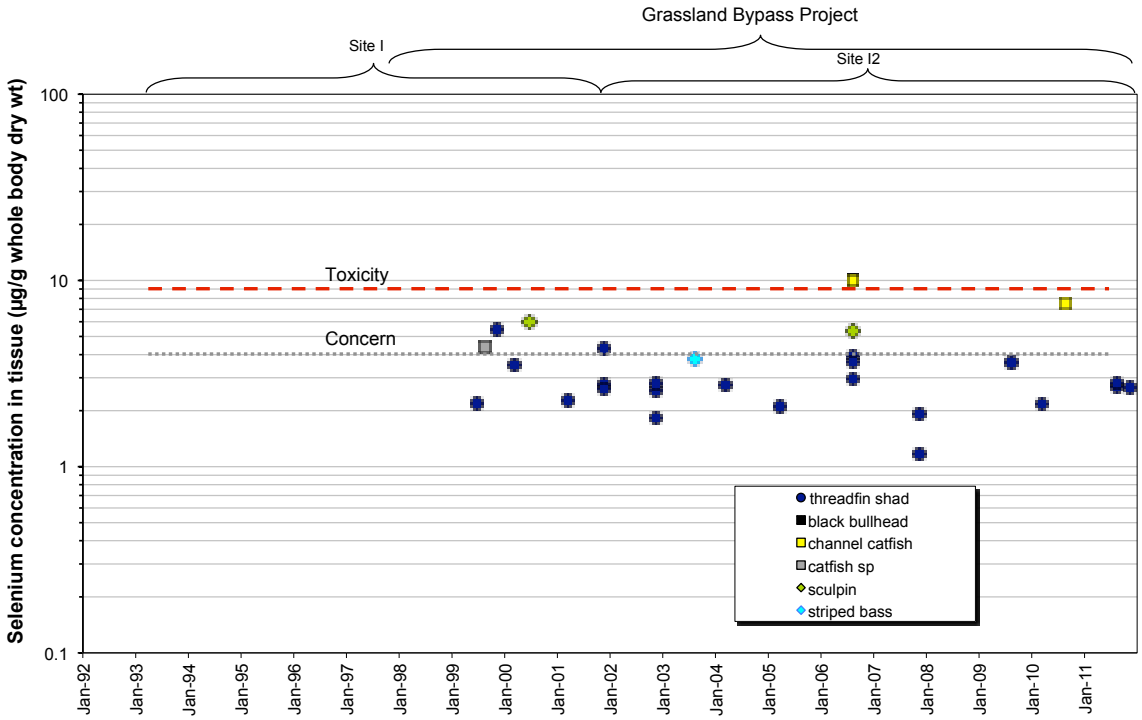


Figure 5f. Selenium in invertebrates in a Mud Slough backwater below the Drain discharge (Sites I and I2)

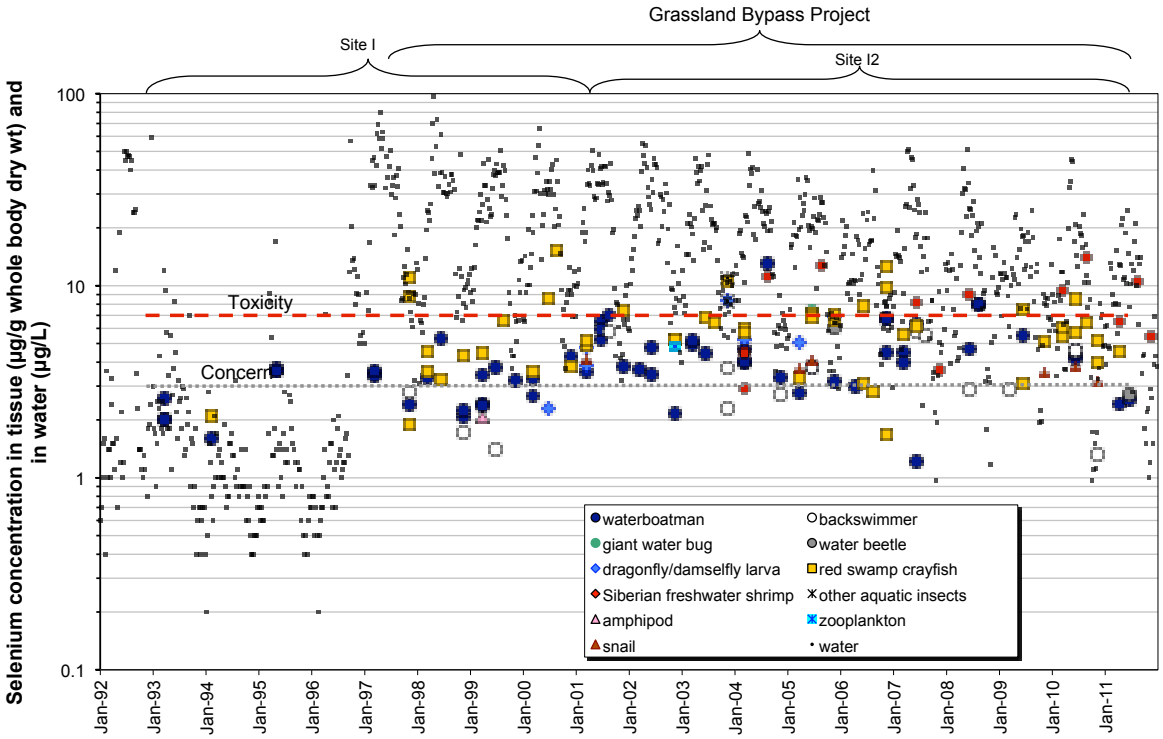


Figure 5g. Selenium in plants along a Mud Slough backwater below the Drain discharge (Sites I and I2)

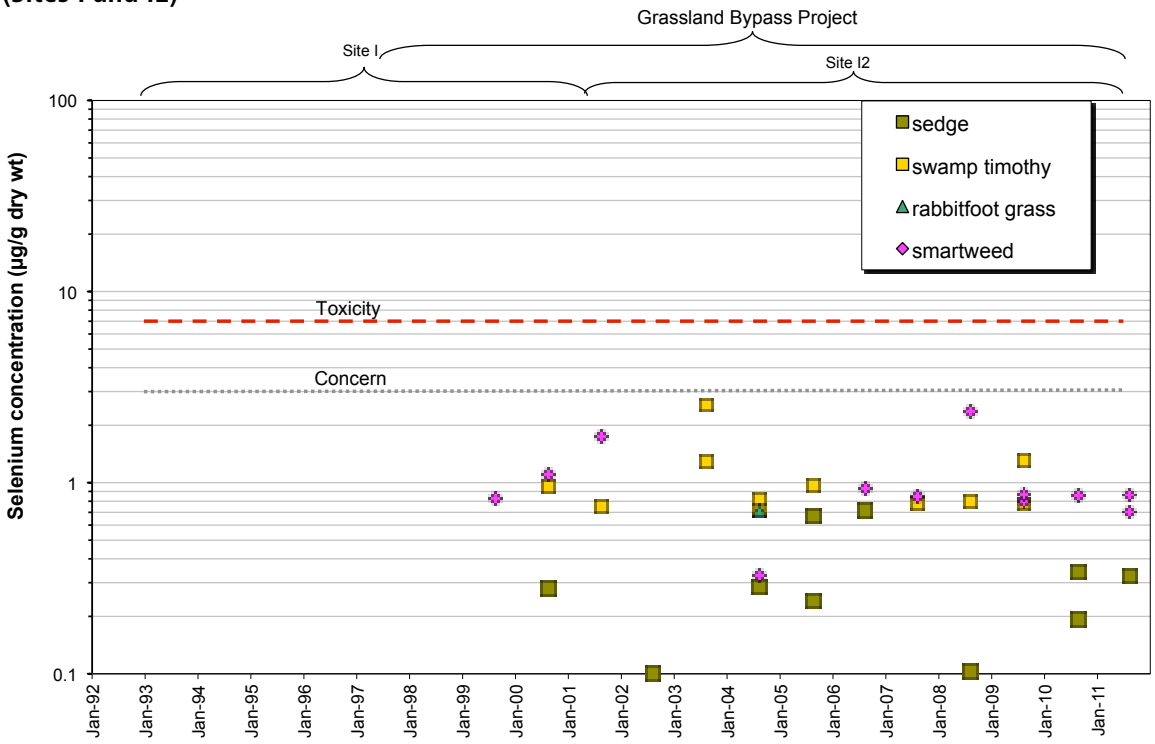


Figure 5h. Boron in plants along a Mud Slough backwater below the Drain discharge (Sites I and I2)

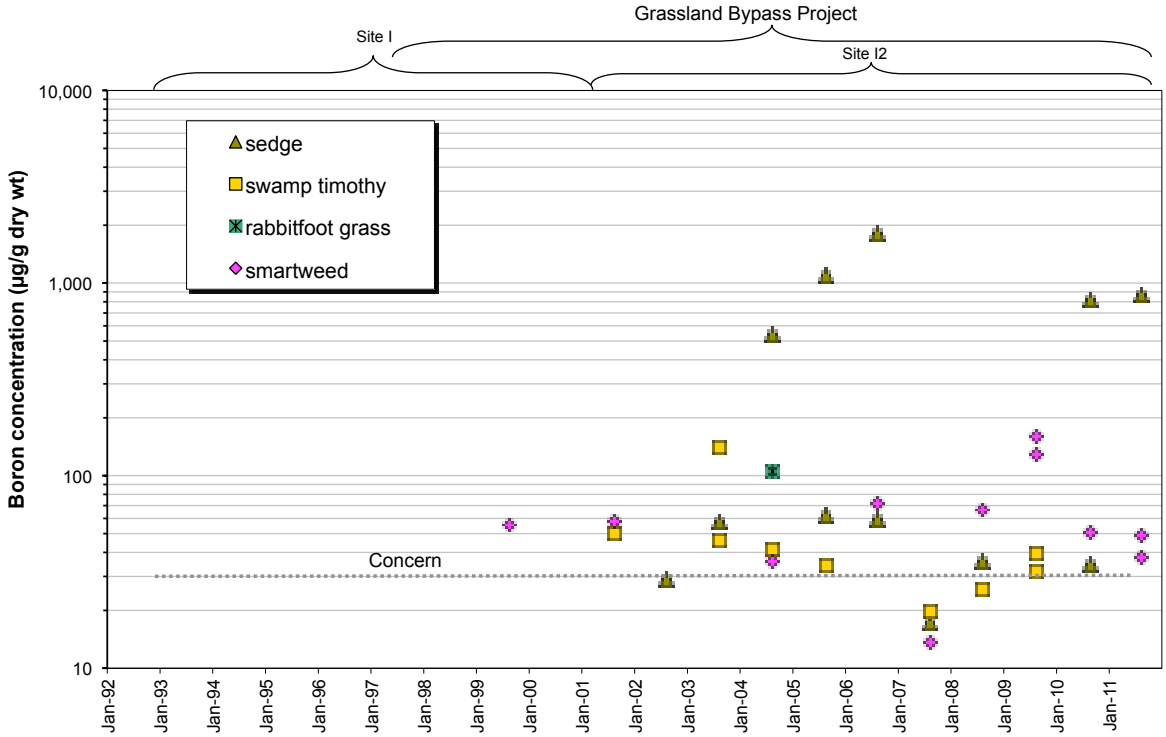


Figure 6. Selenium in frog tadpoles at all sites

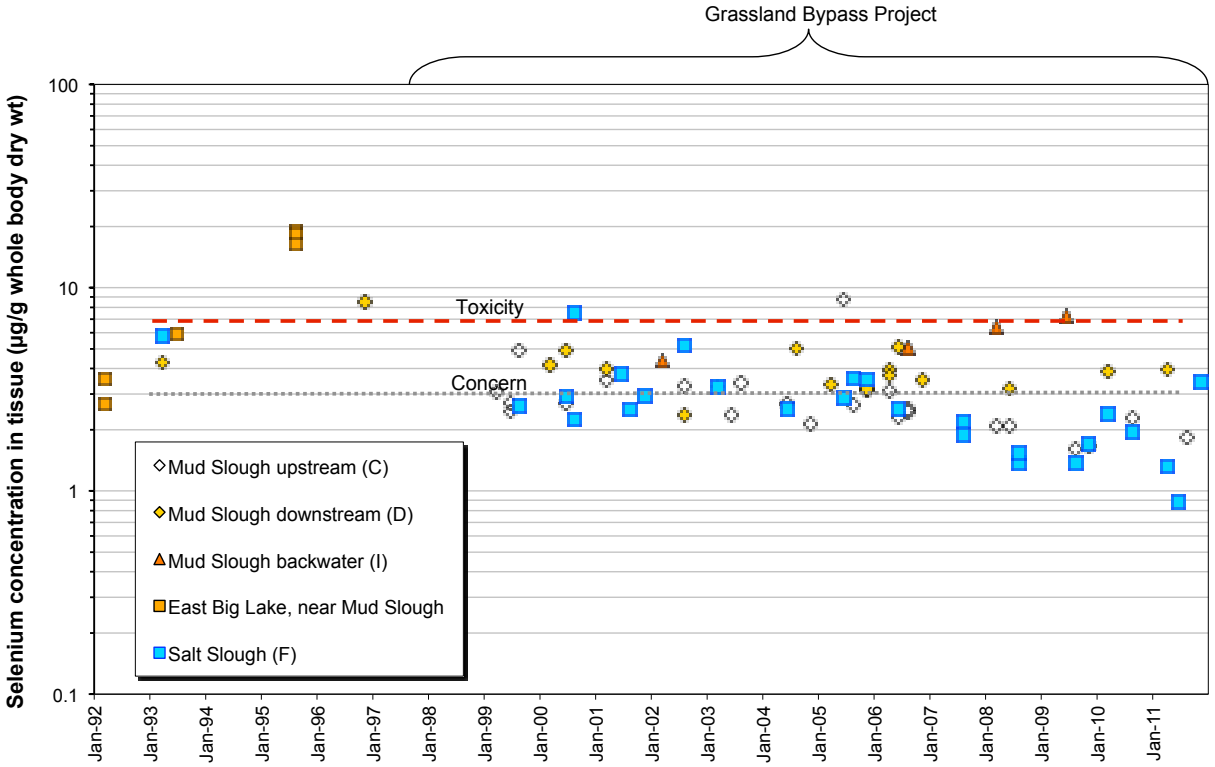


Figure 7. Selenium in bird eggs at all sites

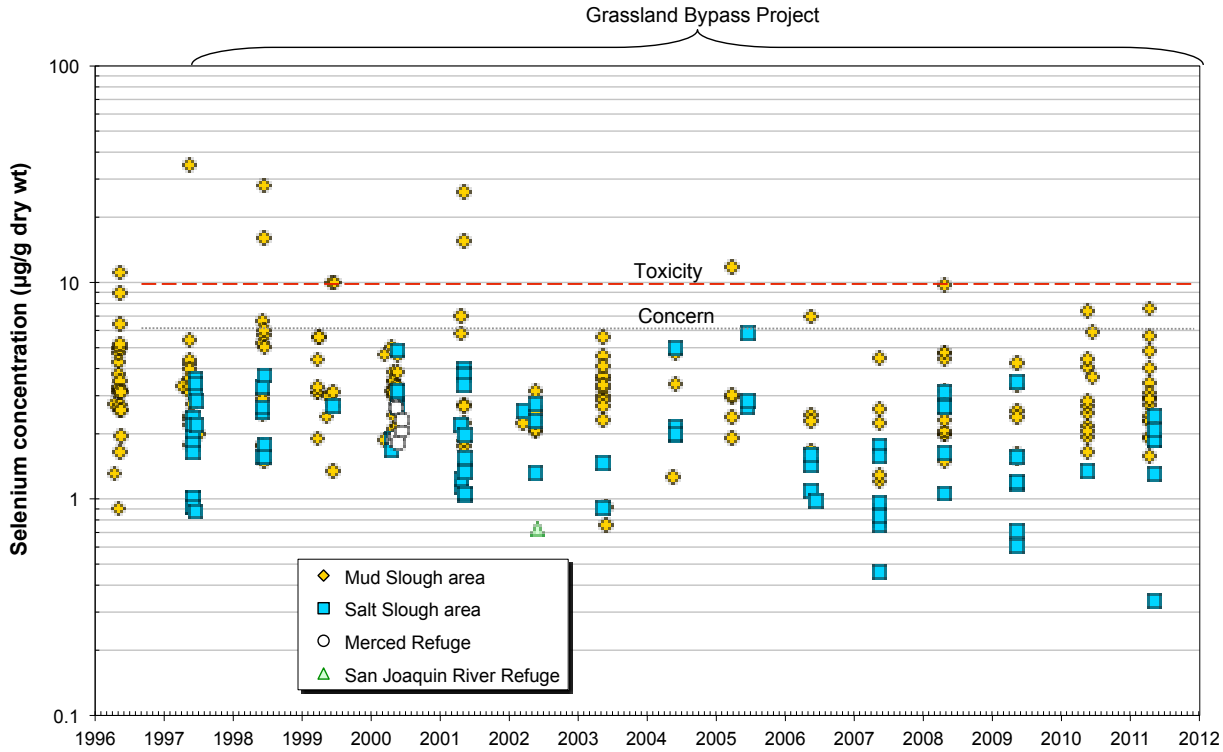


Figure 8a. Selenium in mosquitofish in Mud Slough at Hwy 140 (Site E)

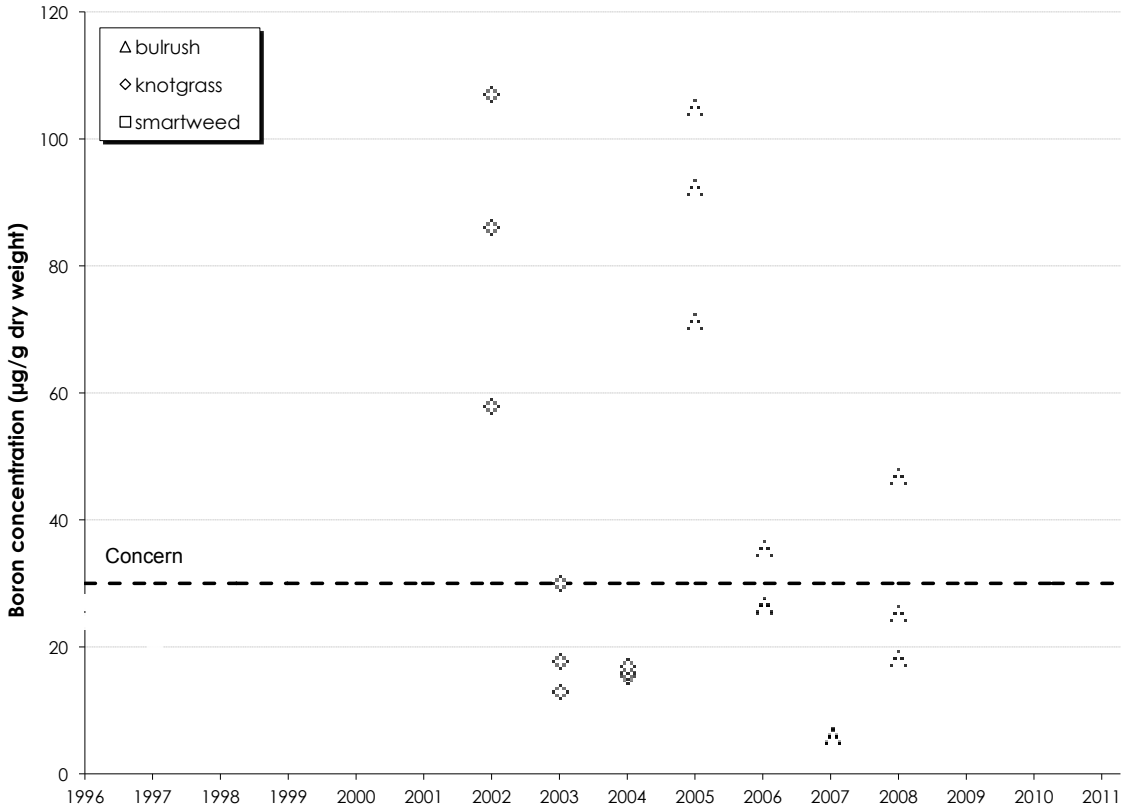


Figure 8b. Selenium in minnows in Mud Slough at Hwy 140 (Site E)

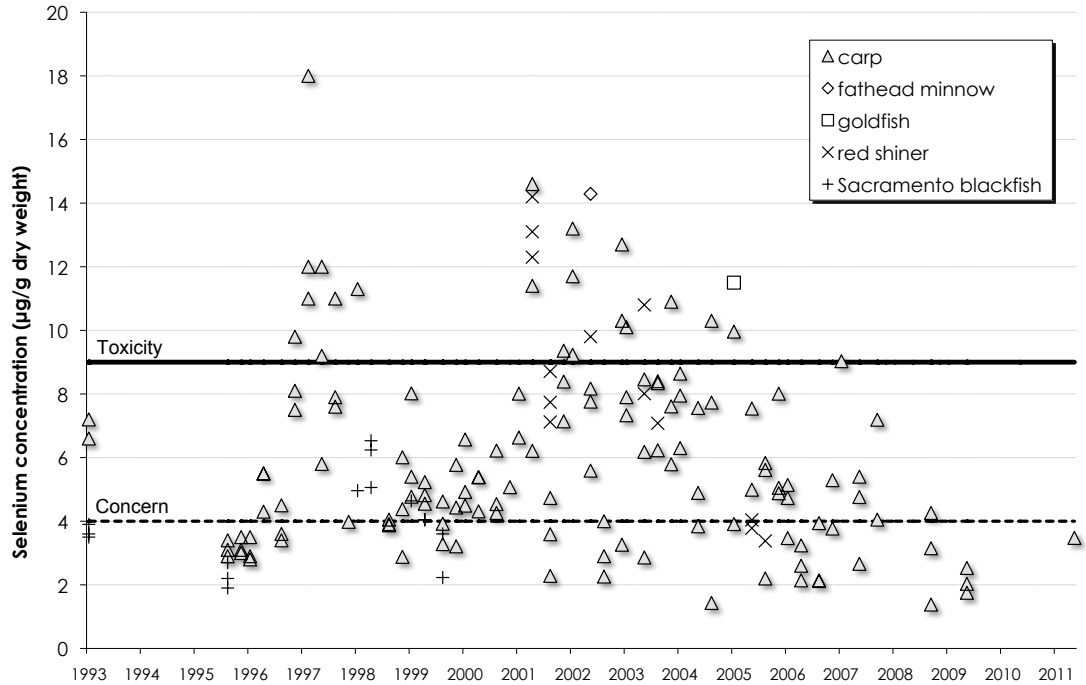


Figure 8c. Selenium in sunfish and bass in Mud Slough at Hwy 140 (Site E)

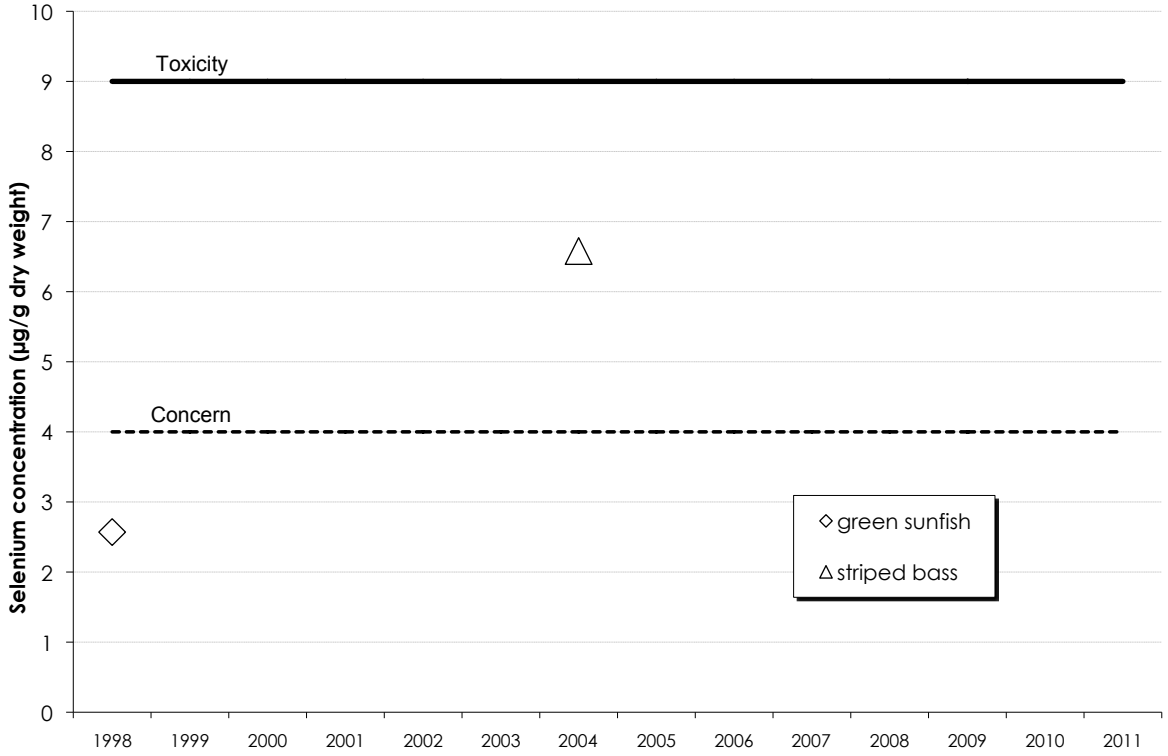


Figure 8d. Selenium in invertebrates in Mud Slough at Hwy 140 (Site E)

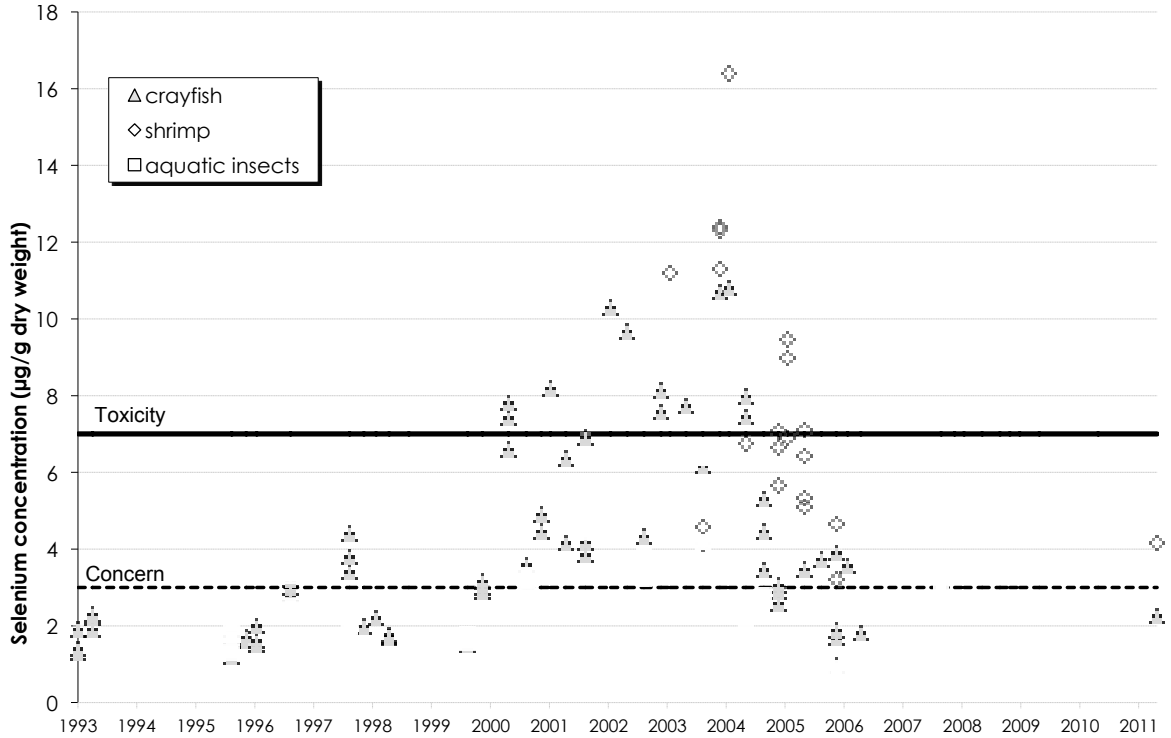


Figure 8e. Selenium in plants along Mud Slough at Hwy 140 (Site E)

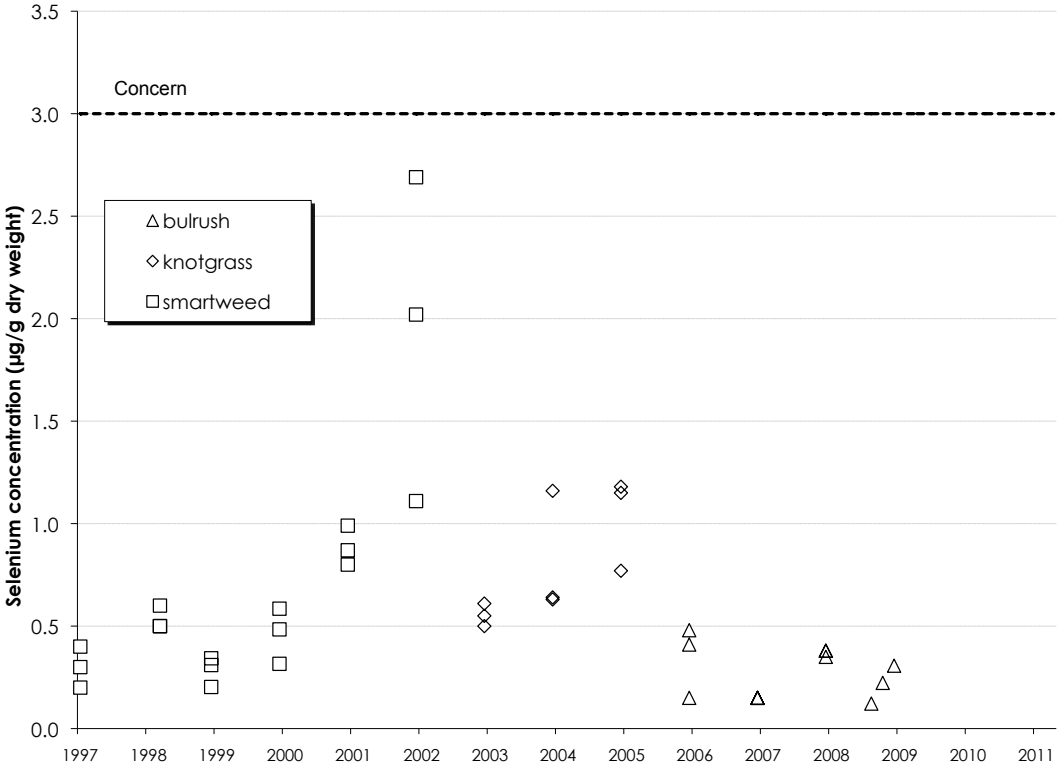


Figure 8f. Boron in plants along Mud Slough at Hwy 140 (Site E)

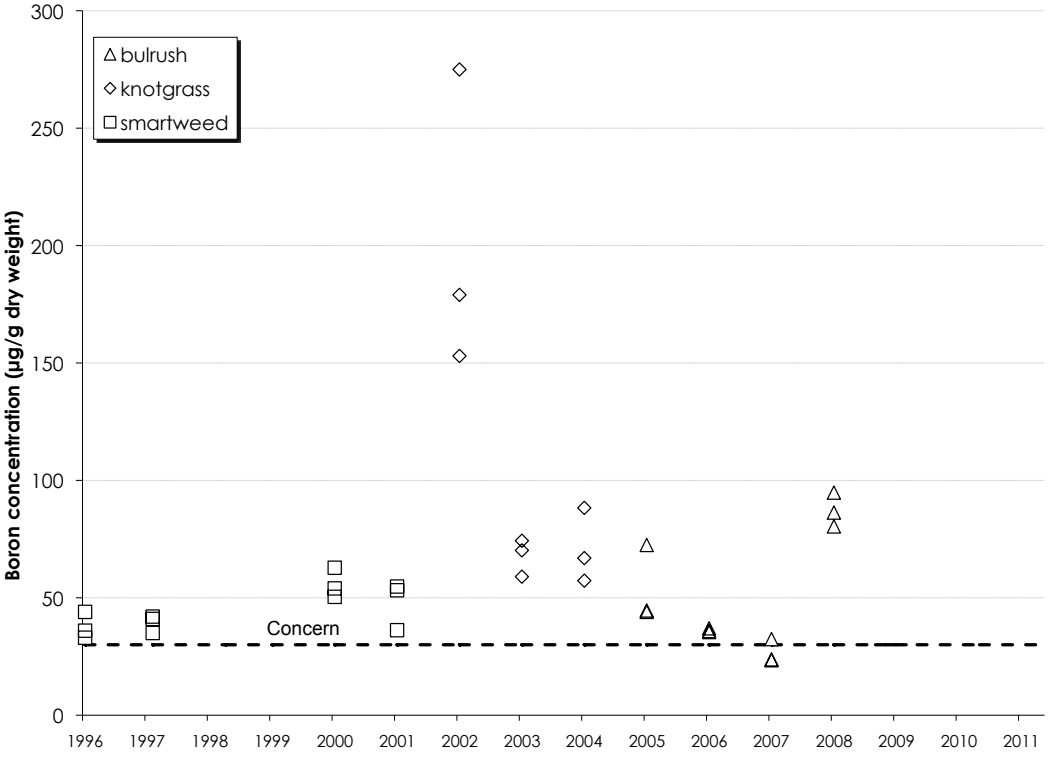


Figure 9a. Selenium in mosquitofish in the San Joaquin River near Fremont Ford

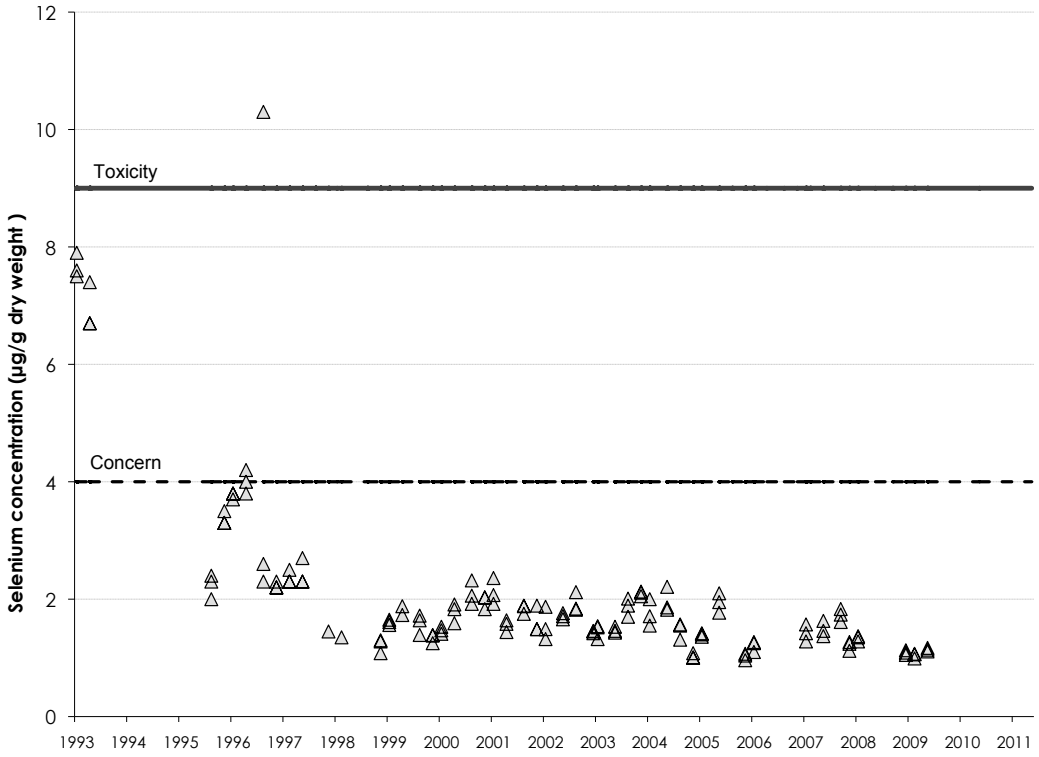


Figure 9b. Selenium in minnows in the San Joaquin River at Fremont Ford (Site G)

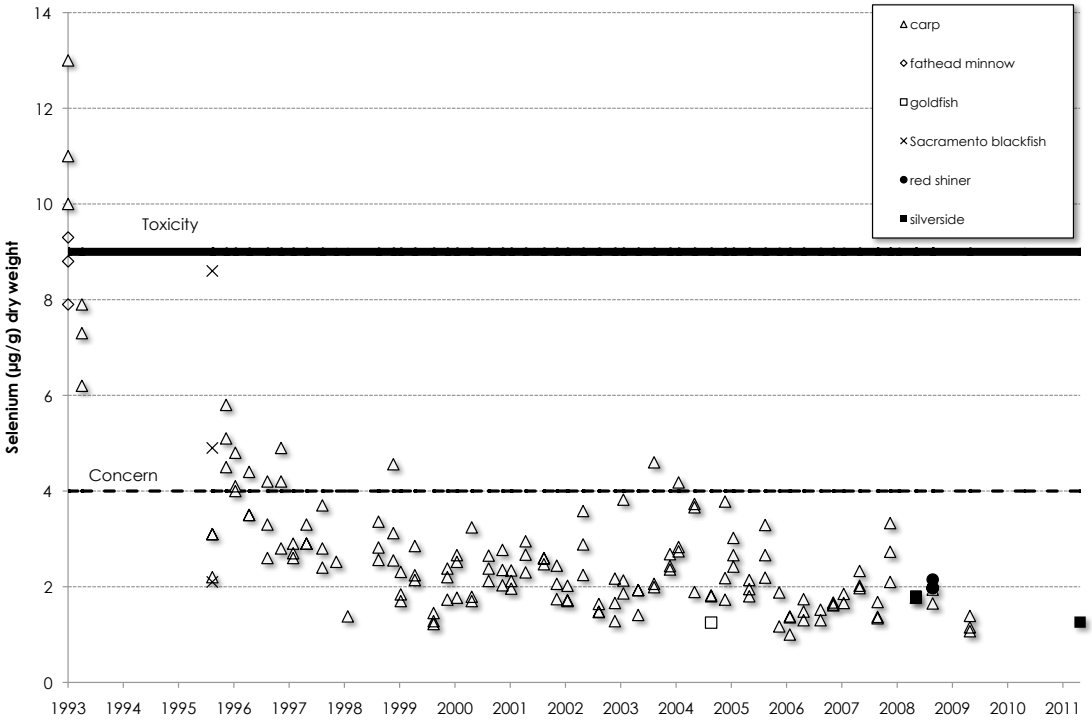


Figure 9c. Selenium in sunfish and bass in the San Joaquin River at Fremont Ford (Site G)

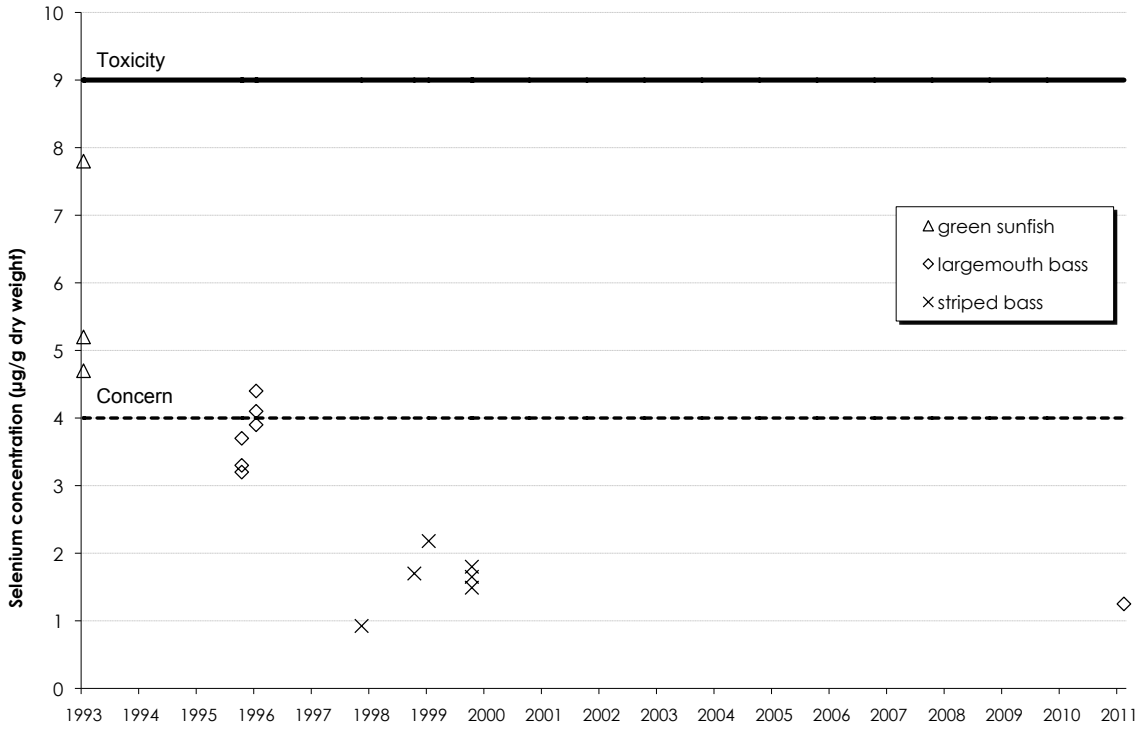


Figure 9d. Selenium in invertebrates in the San Joaquin River at fremont Ford (Site G)

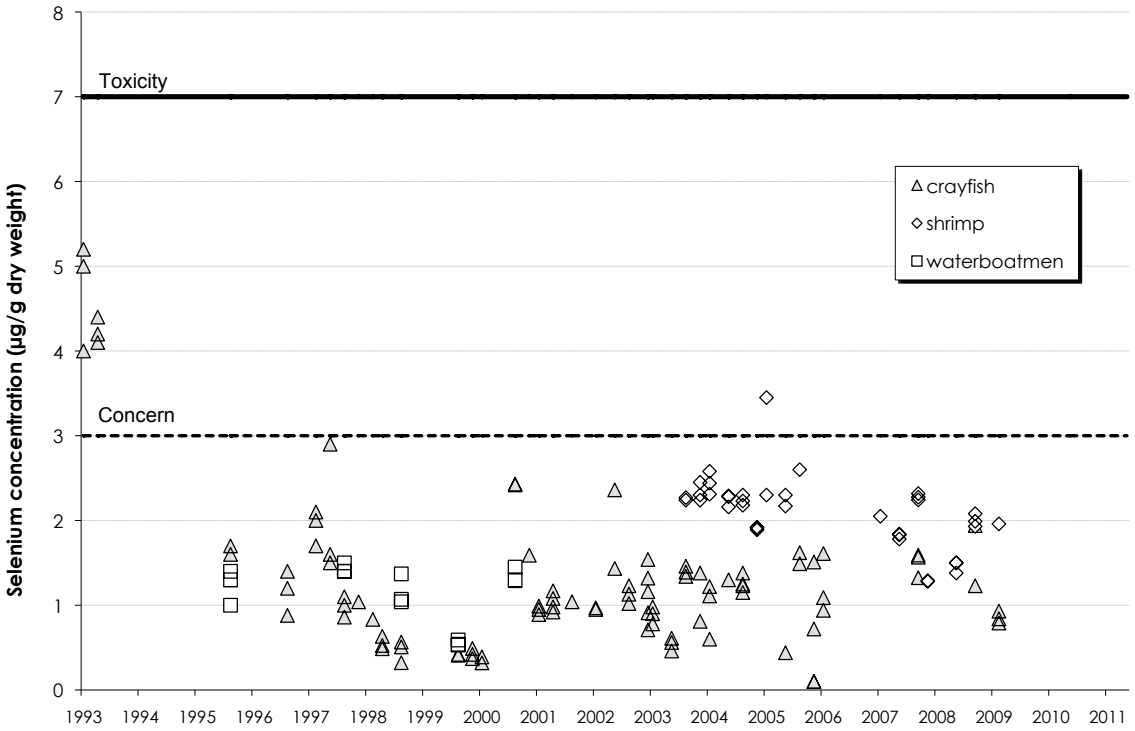


Figure 9e. Selenium in plants along the San Joaquin River at Fremont Ford (Site G)

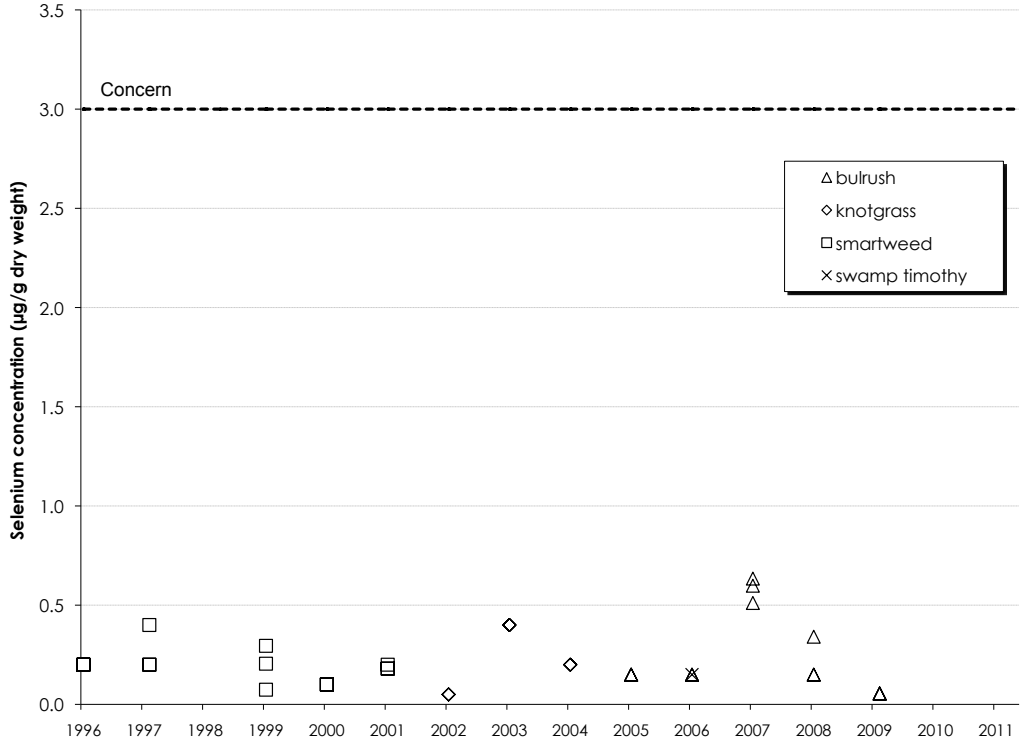


Figure 9f. Boron in plants along the San Joaquin River at Fremont Ford (Site G)

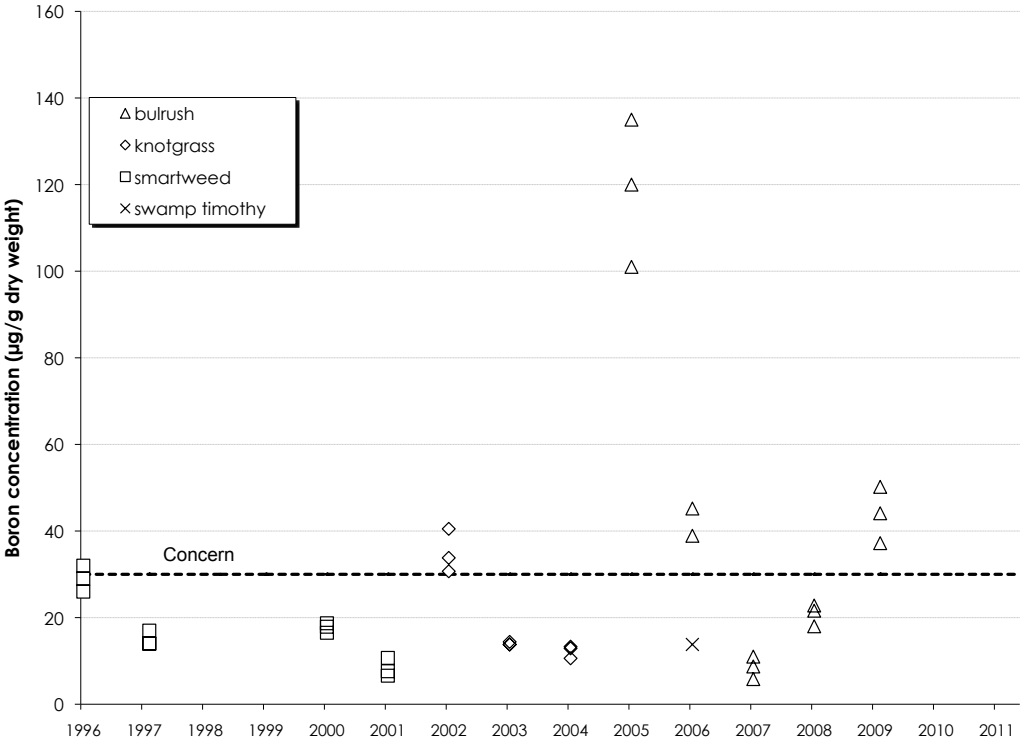


Figure 10a. Selenium in mosquitofish in the San Joaquin River near Hills Ferry (Site H)

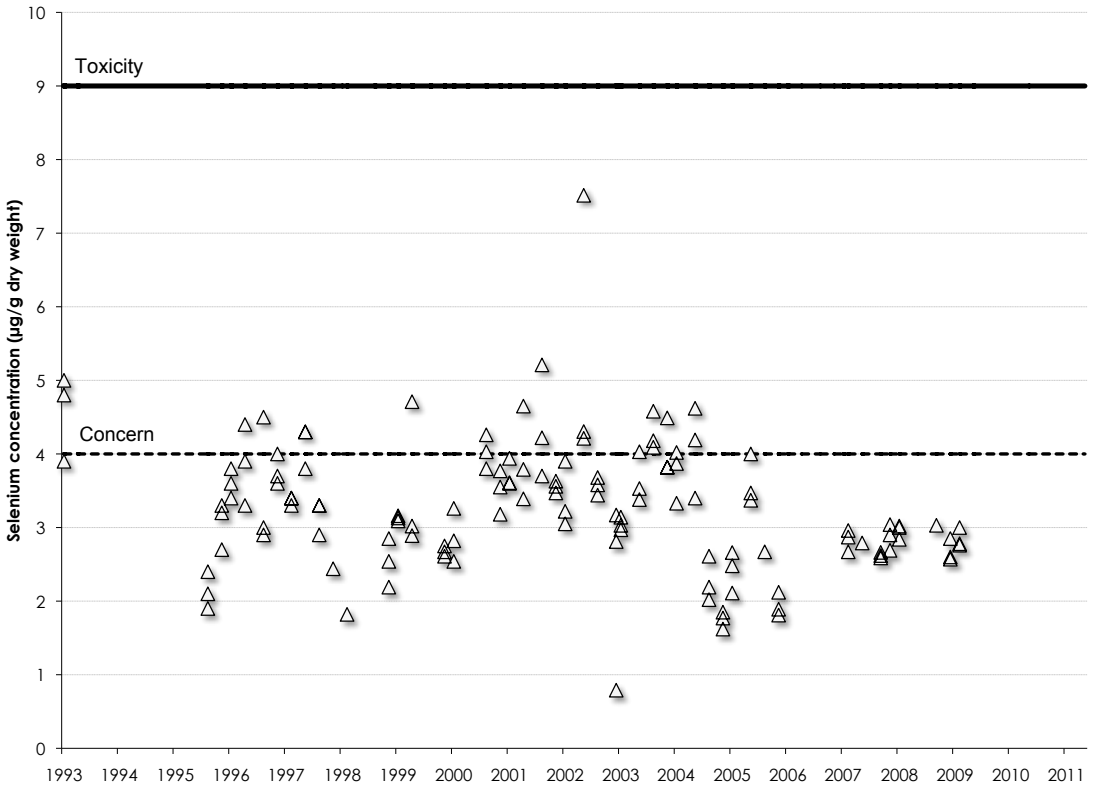


Figure 10b. Selenium in minnows in the San Joaquin River near Hills Ferry (Site H)

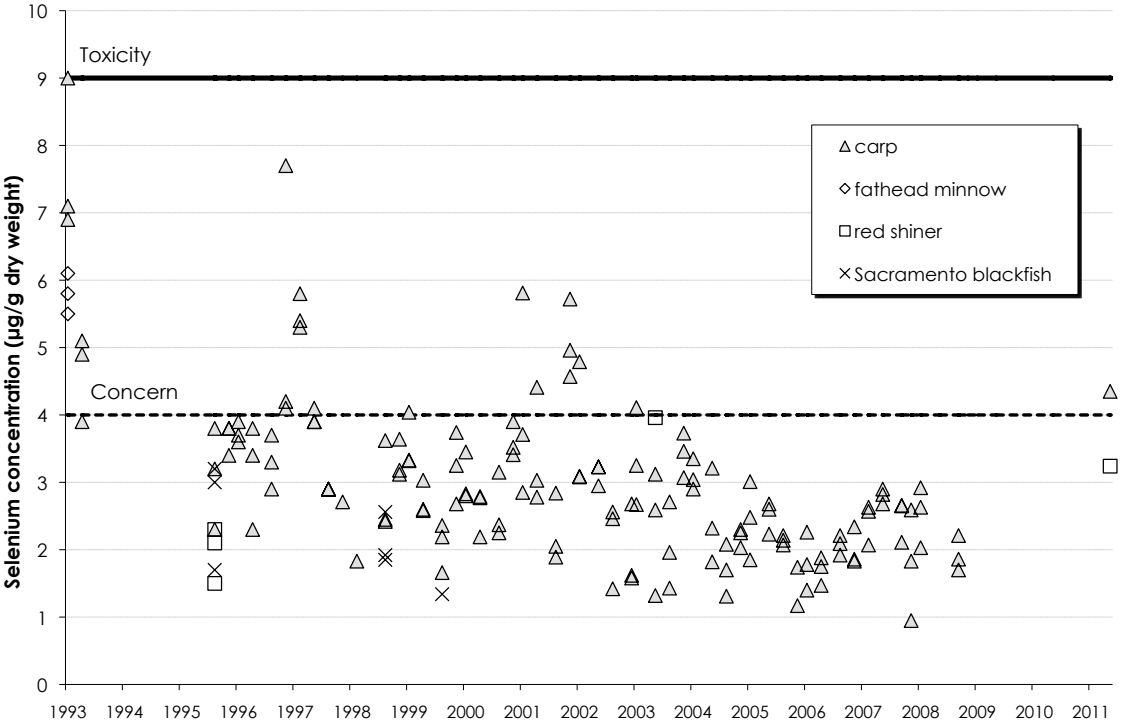


Figure 10c. Selenium in sunfish and bass in the San Joaquin River near Hills Ferry (Site H)

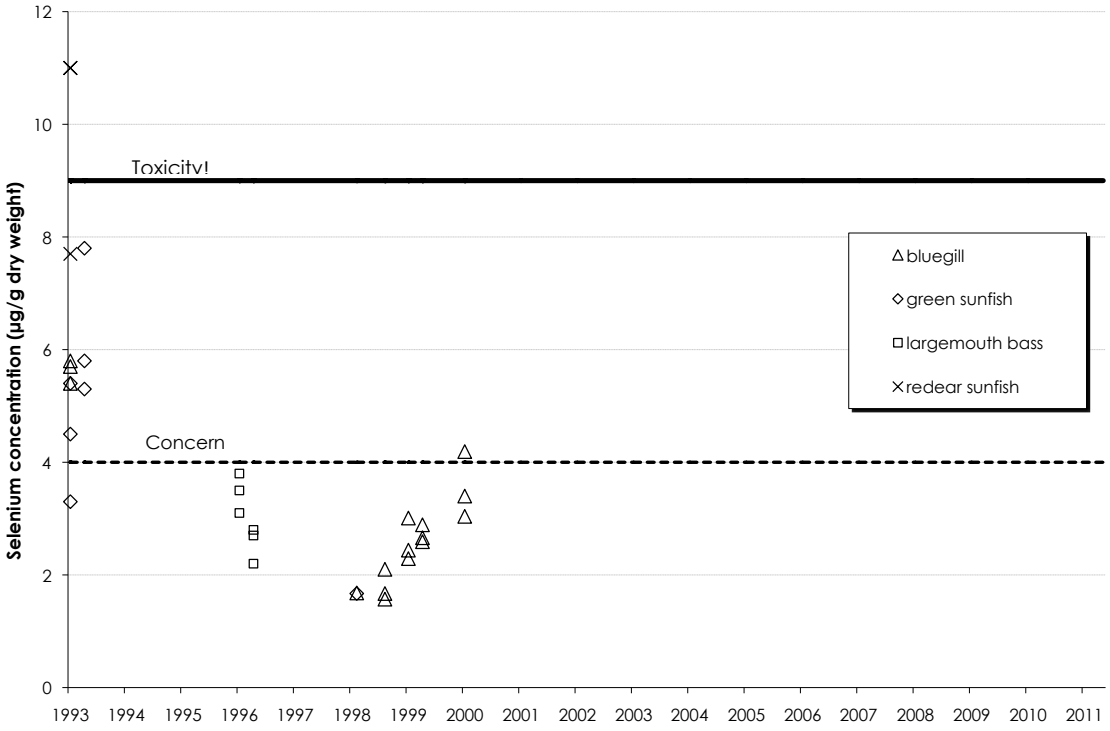


Figure 10d. Selenium in invertebrates in the San Joaquin River near Hills Ferry (Site H)

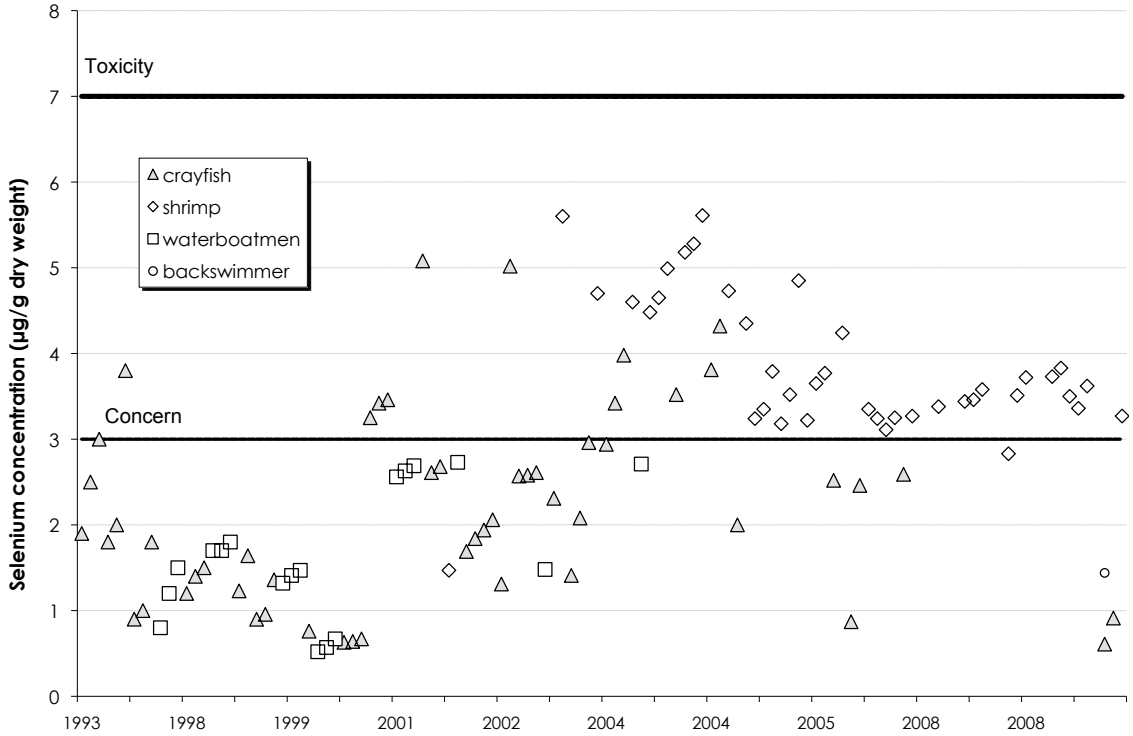


Figure 10e. Selenium in plants along the San Joaquin River near Hills Ferry (Site H)

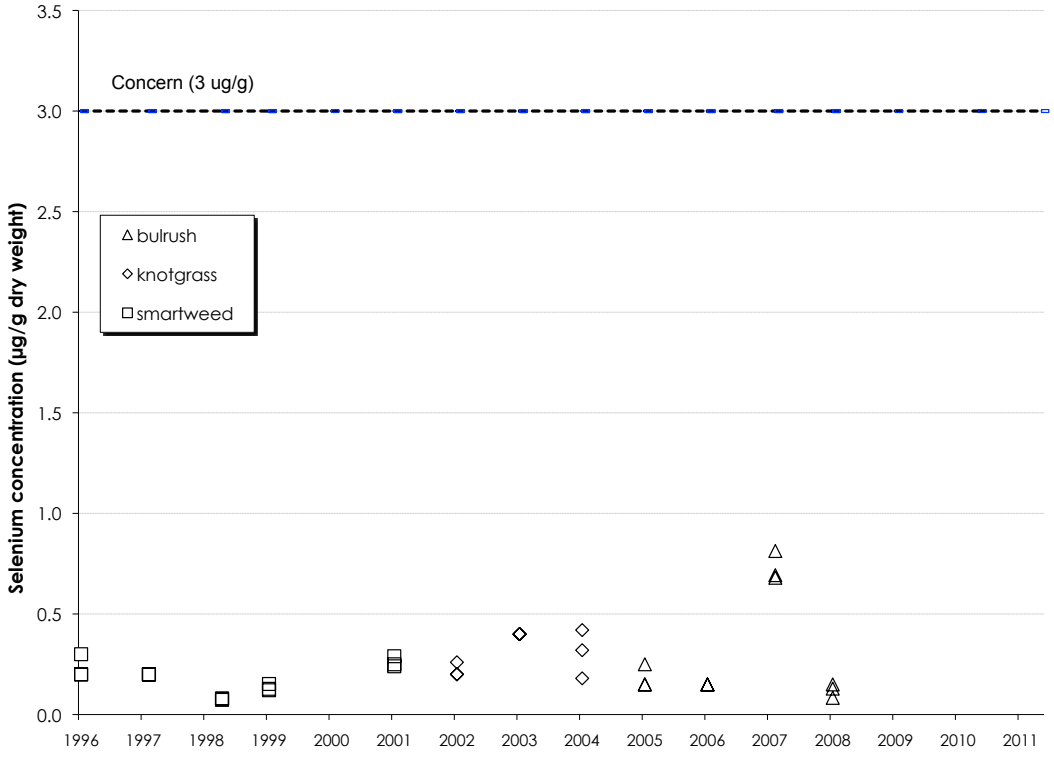


Figure 10f. Boron in plants along the San Joaquin River near Hills Ferry (Site H)

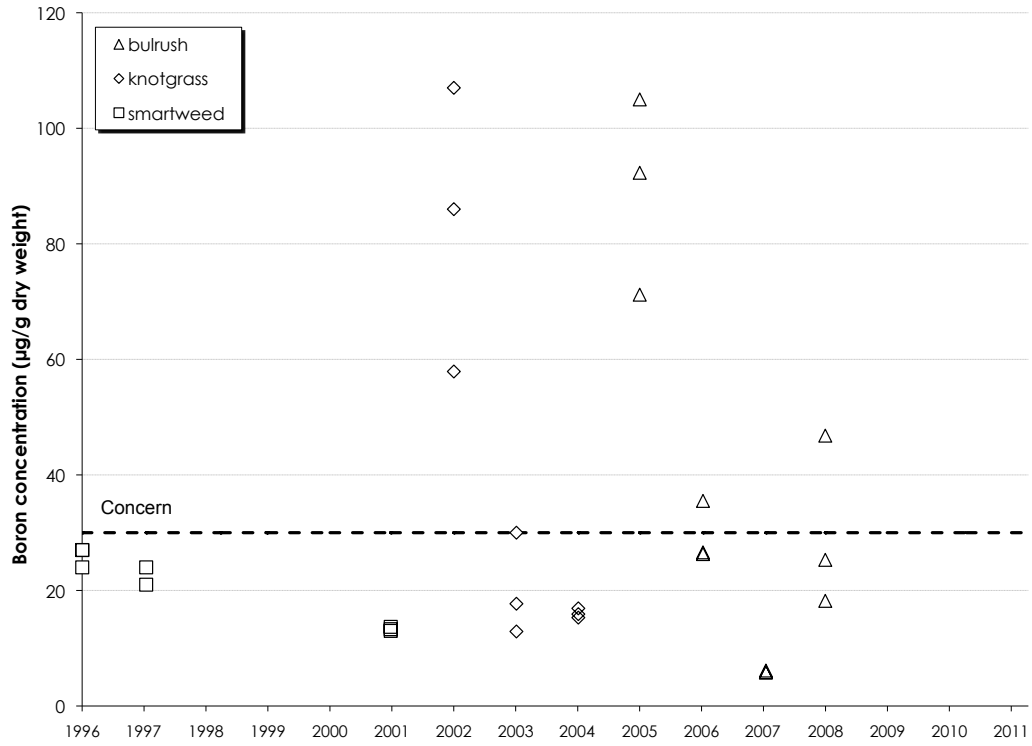


Figure 11. Percent abundance of trophic classifications in Mud Slough at Hwy 140 (Site E)

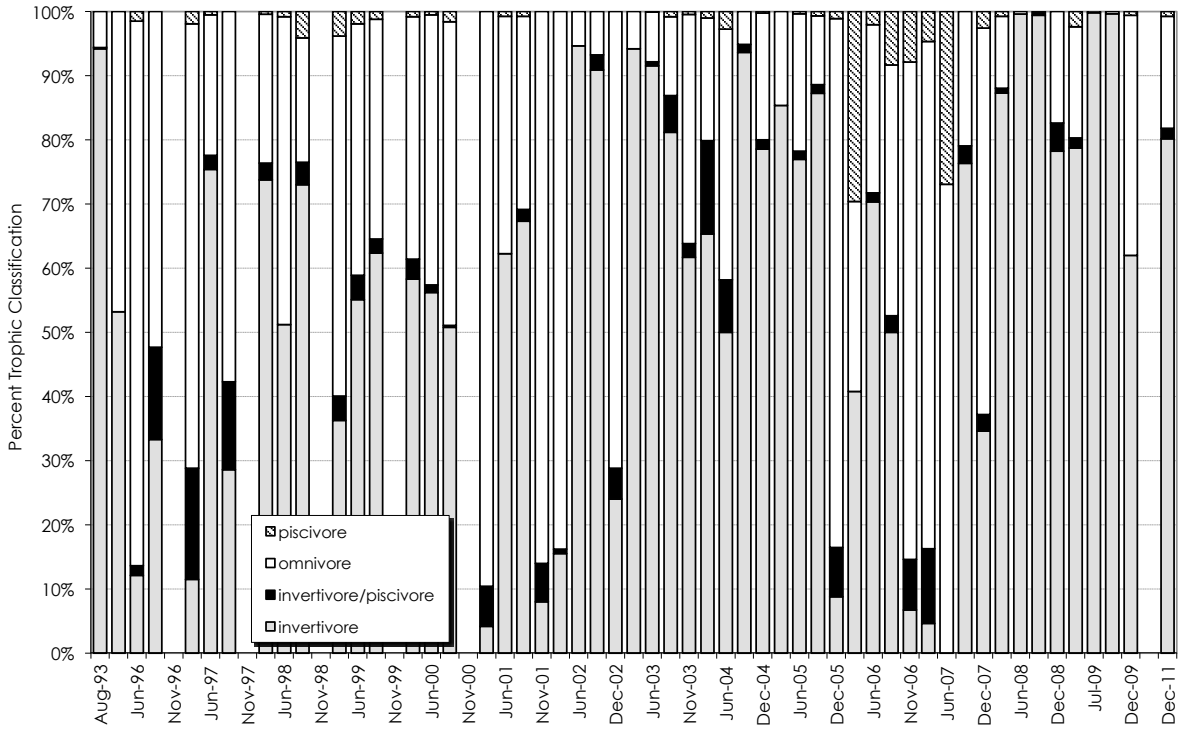


Figure 12. Percent abundance of trophic classifications in the San Joaquin River at Fremont Ford (Site G)

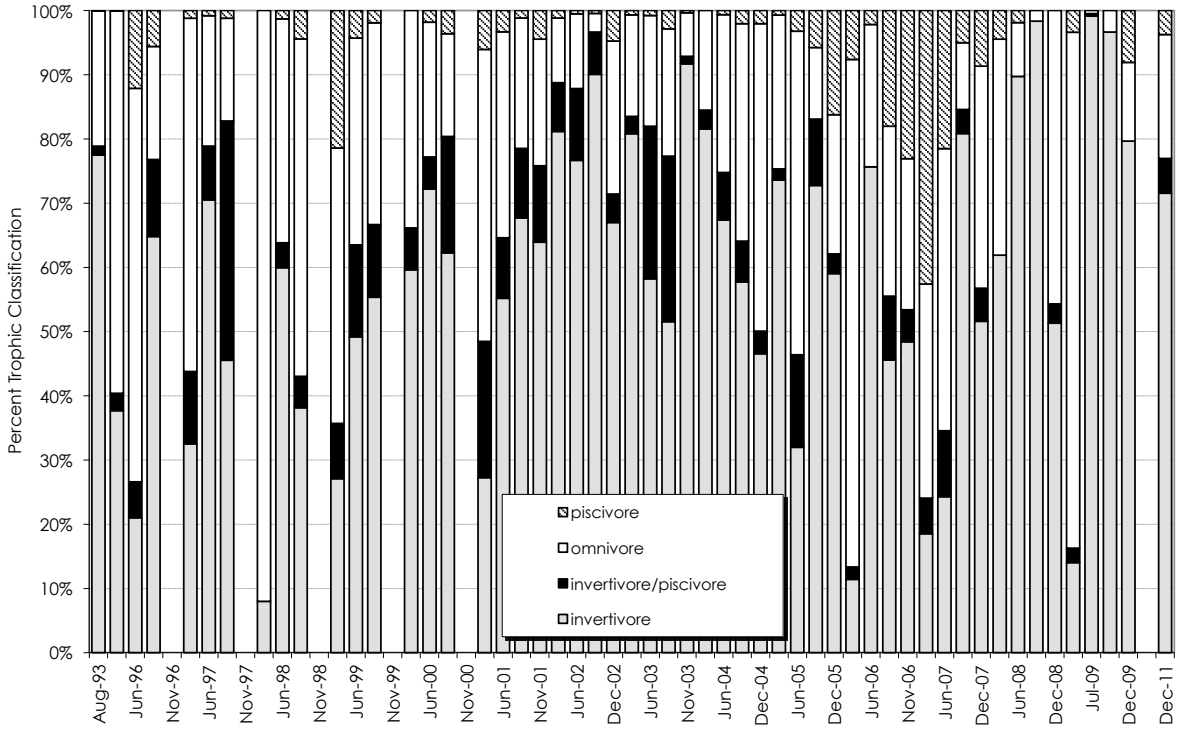


Figure 13. Percent abundance of trophic classifications in the San Joaquin River at Hills Ferry (Site H)

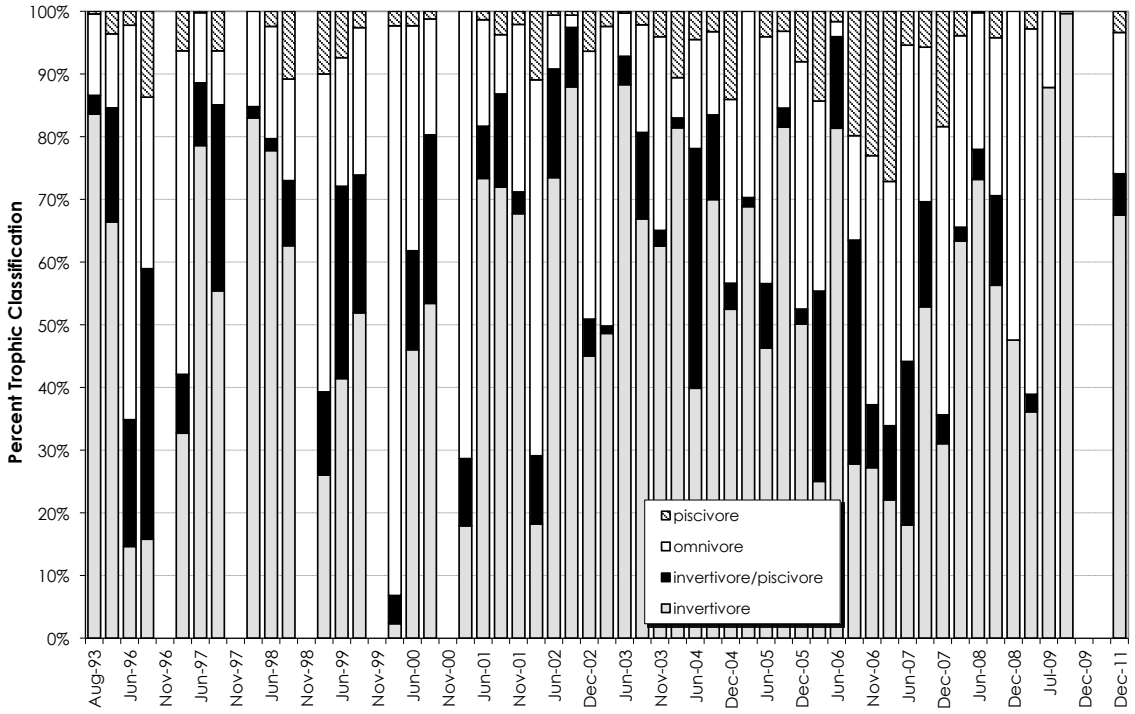
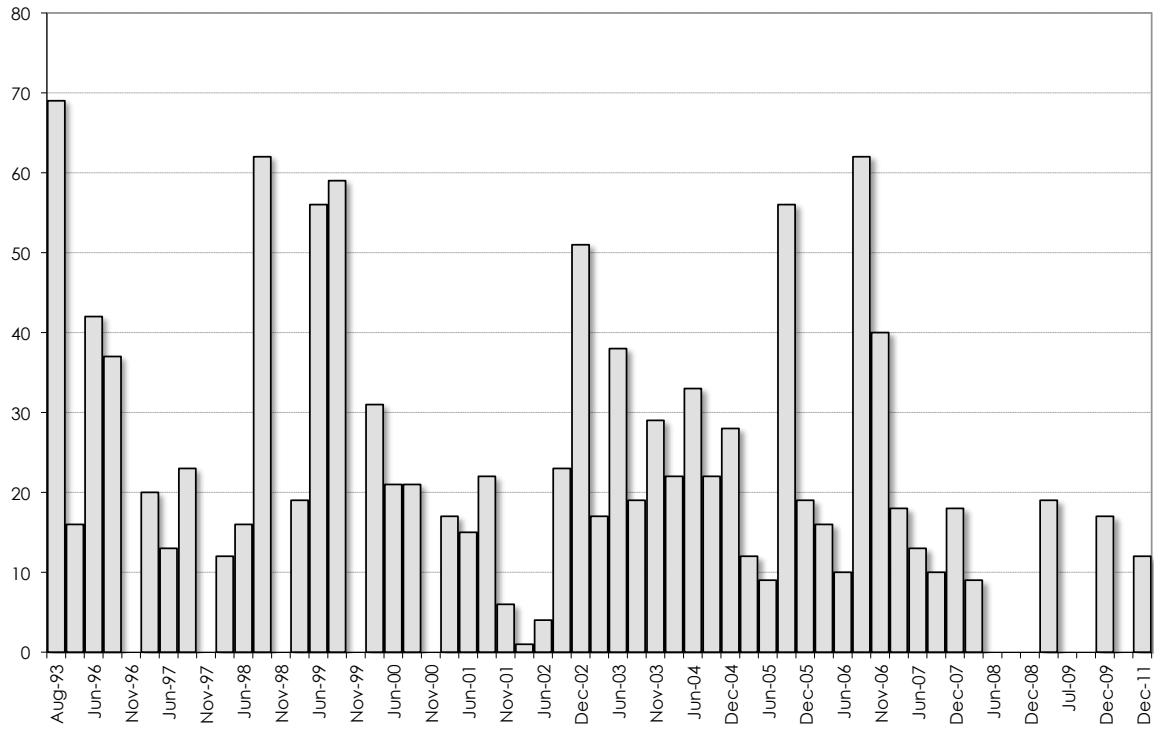
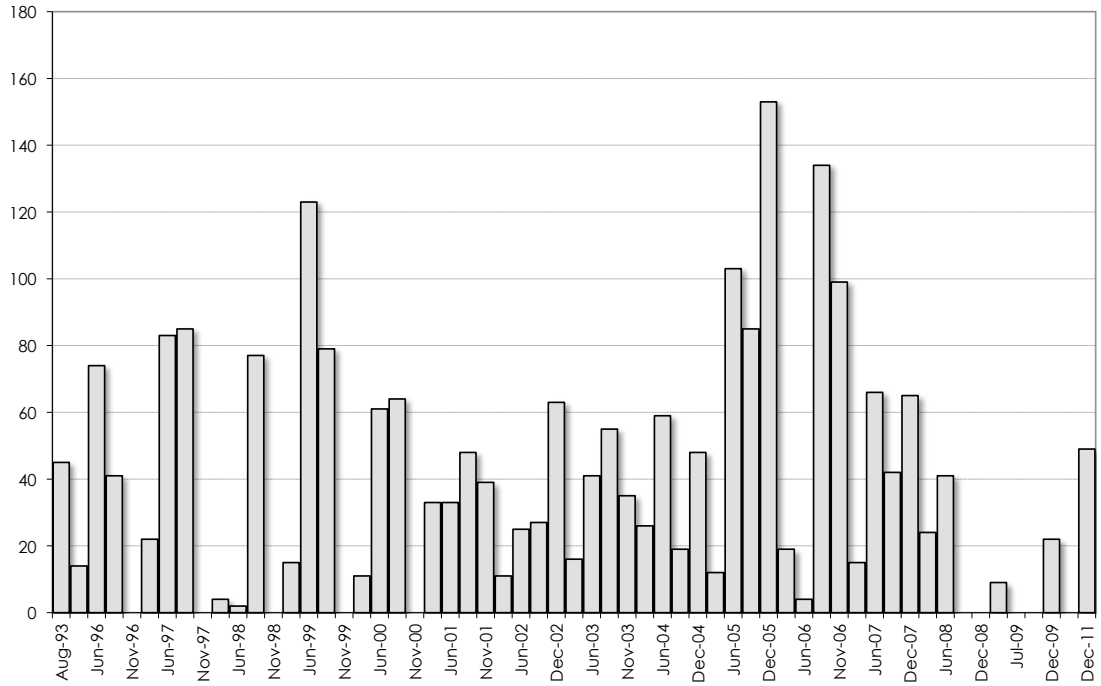


Figure 14. Observed Anomalies* in all Fish Species Caught in Mud Slough at Highway 140 (Site E)**



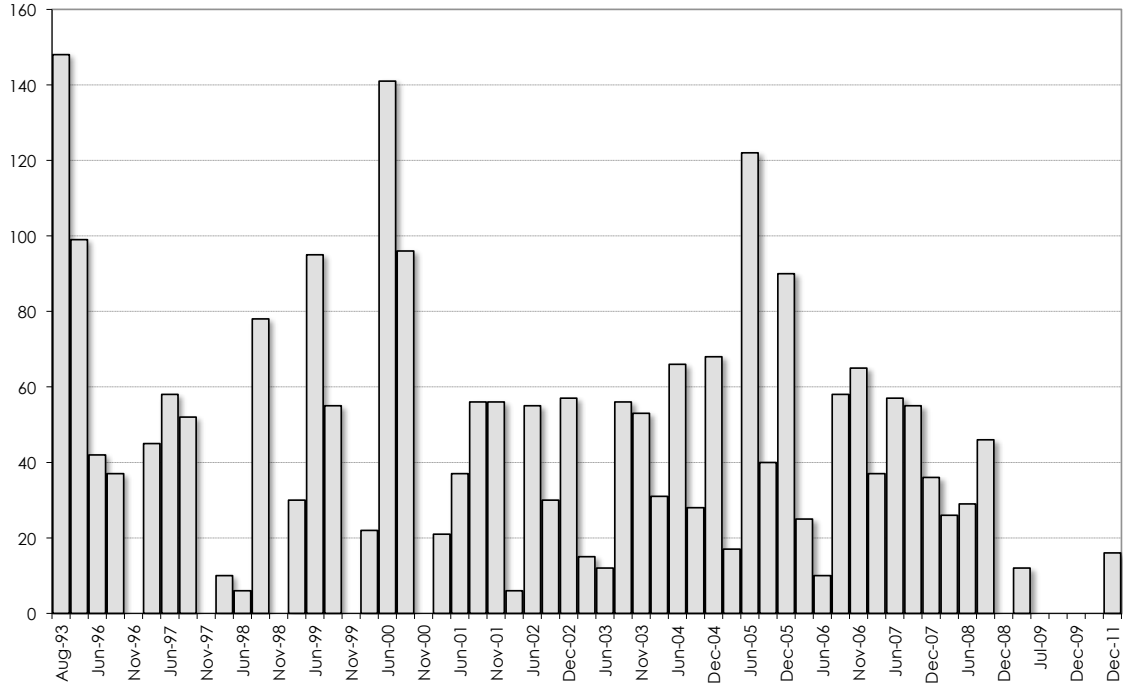
*** Discoloration, deformities, eroded fins, excessive mucus, excessive external parasites, fungus, poor condition, reddening, tumors, and ulcers, as observed by California Department of Fish & Wildlife

Figure 15. Observed Anomalies* in all Fish Species Caught in the San Joaquin River at Fremont Ford (Site G)**



*** Discoloration, deformities, eroded fins, excessive mucus, excessive external parasites, fungus, poor condition, reddening, tumors, and ulcers, as observed by California Department of Fish & Wildlife

Figure 16. Observed Anomalies* in all Fish Species Caught in the San Joaquin River at Hills Ferry (Site H)**



*** Discoloration, deformities, eroded fins, excessive mucus, excessive external parasites, fungus, poor condition, reddening, tumors, and ulcers, as observed by California Department of Fish & Wildlife

CHAPTER 8

Toxicity Testing for the Grassland Bypass Project

January 1, 2010 – December 31, 2011

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Introduction

The objective of the laboratory toxicity testing is to evaluate the potential toxicity of water-borne contaminants within the Grassland Bypass Project (GBP) area using standardized bioassay protocols conducted under controlled environmental conditions. The laboratory toxicity tests evaluate one species within each of three trophic levels using short-term chronic testing procedures (7 or 4 days) and lethal (survival) and non-lethal (growth or reproduction) endpoints (USEPA 1987; 1994). The test species are *Selenastrum capricornutum* (alga), *Daphnia magna* (water flea), and *Pimephales promelas* (fathead minnow).

The testing is not specific for any single chemical exposure, but rather demonstrates the net effect of only waterborne contaminant exposures in the site waters on the selected test species. During toxicity testing, test species are fed a controlled diet that is unrelated to field sources of food. For this reason, toxicity testing is not expected to detect selenium toxicity in invertebrates and fish because the main route of exposure in these groups of organisms is through the food they eat. However, selenium toxicity in algae is through direct exposure from water and thus toxicity testing may detect selenium toxicity in algae.

Tests are conducted at the screening level, comparing the ambient water to 100% test water. If significant toxicity is observed, definitive tests (dilution series) may be conducted. Water samples are collected from Stations B, C, D, and F for each monthly testing period. The Delta-Mendota Canal (DMC) station is the control site. Additionally, selenium concentrations were determined from water samples collected for each toxicity testing event by the U.S. Bureau of Reclamation (USBR) contract laboratories. However, in-situ chronic toxicity testing using caged fathead minnows has been eliminated during the course of the program, as well as measurement of selenium bioaccumulation in algae.

The toxicity program is conducted by Block Environmental Service's (BES) Bioassay Laboratory Division under the guidance of the San Luis and Delta-Mendota Water Authority. Technical assistance, quality assurance/quality control (QA/QC), and program oversight is provided by the U.S. Environmental Protection Agency (USEPA) and USBR. The toxicity program is currently performed on a monthly basis.

From October 1996 to September 2001 (Phase I), the monthly collected data was used to evaluate potential adverse effects to test organisms exposed to agricultural drain water from the San Luis Drain (SLD; Site B) and Mud Slough (Site D). An evaluation was also made for Mud Slough (Site C) above the influence of the SLD and for Salt Slough (Station F), which represents the water in the Grassland wetland water supply channels.

The current phase of the Grassland Bypass Project (GBP), Phase II, was initiated in October 2001 and continues through December 31, 2011. Changes implemented for Phase II included the following: 1) No in-situ water chemistries will be taken for each testing period, and 2) No sulfate analysis will be done on any of the site samples.

In Phase II (as with Phase I), each toxicity test was performed using three separate grab samples collected on Day 0, Day 2, and Day 4 of the 7-day testing period. Site results were then compared with responses to ambient control water samples collected from the DMC. The data were then used to assess contaminant exposures both temporally and spatially within the GBP area and to identify trends.

The monthly data for the current study period, which began in January 2010 and ended in December 2011, are presented in this chapter and are compared with the previous study period [2] as well as with Phase I data.

Materials and Methods

Toxicity tests were conducted monthly on three species from three different trophic levels using USEPA short-term chronic testing procedures designed to assess acute and sub lethal endpoints (USEPA, 1987; 1994).

These tests are:

Daphnid invertebrate (*Daphnia magna*) Short-term Acute Survival

Fathead Minnow (*Pimephales promelas*) 7-Day Acute Larval Survival

Daphnid invertebrate (*Daphnia magna*) Short-term Chronic Reproduction

Fathead Minnow (*Pimephales promelas*) 7-Day Chronic Larval Growth

Freshwater algae (*Selenastrum capricornutum*) 96-Hour Growth Test

The tests were conducted for five different sampling sites (Sites B, C, D, F and the DMC), totaling 25 tests each month. Each test was performed using 100% sample with results statistically compared to the DMC ambient control. For Site B, the *Selenastrum capricornutum* growth tests also included definitive tests (e.g., dilution series), with a concentration series of 0%, 12.5%, 25%, 50%, 75% and 100% Site water; DMC control water was used as the dilution water.

Grab samples were collected from Sites B, C, D, F, and the DMC three times for each monthly testing period, in accordance with the test methods. The *D. magna* and *P. promelas* toxicity tests were conducted using a static-renewal test design requiring three fresh site water samples collected on Day 0, Day 2 and Day 4 of the 7-day testing period. The *S. capricornutum* toxicity tests required were conducted as static non-renewal tests requiring only a single sampling event; algal bioassays were initiated with site waters collected from the second sampling event.

All toxicity test results were analyzed using the software program ToxCalc, (Version 5.0; Tidepool Scientific, USA). ToxCalc was used to determine if there was a statistically significant reduction ($p<0.05$) in the site test response versus the ambient control response during each monthly testing period (USEPA, 1994).

In order to independently assess the health of the test organisms and laboratory performance, a concurrent reference toxicant test was conducted for each of the test species during the monthly testing periods. The reference toxicant test was conducted using a dilution series of the toxicant in laboratory control water. The toxicity endpoints from the reference toxicant tests of each test method were plotted on a running control chart of the last 20 tests. The mean and upper and lower control limits (± 2 standard deviations) were recalculated with each successive test result. The outliers, values falling outside the upper and lower control limits, and trends of increasing or decreasing sensitivity, were

2 January 1, 2008 – December 31, 2009

identified. At the p= 0.05 probability level, one in 20 tests (5%) would be expected to fall outside of the control limits by chance alone.

Sub-samples of the three grab samples for each site water were analyzed for selenium by the USBR contract laboratories. Other laboratory analyses, which were performed by BES, included conductivity, total suspended solids, dissolved oxygen (DO), pH, salinity, alkalinity, hardness, temperature, ammonia, and total chlorine.

Except as noted above, specific sampling and testing protocols for each procedure may be found in the Monitoring Program for Use and Operation of the Grassland Bypass Project, Phase II (USBR et al., June 2002) and the Quality Assurance Project Plan (USBR et. al., August 2002).

Results

Data for Phase I of the toxicity-monitoring program may be found in the 2000- 2001 Annual Report (USBR et. al., 2003). The results from the first fifteen months of the Second Phase of the toxicity-monitoring program may be found in the 2001- 2002 Annual Report (USBR et. al., 2004). The toxicity monitoring results from the period beginning in January 2010 and ending in December 2010 are presented in **Tables 1** through **21**. **Figures 1** through **21b** present the data graphically.

There were twenty four monthly laboratory toxicity studies conducted between January 2010 and December 2011. These results are listed in **Tables 1** through **6**. **Tables 7** through **10** contain summaries of occurrences of statistically significant results over the course of the project.

Laboratory measured water chemistry data comparing each of the stations are found in **Tables 11** through **21**.

Laboratory Toxicity Testing

Daphnid invertebrate (*Daphnia magna*) Short-term Acute Survival

The *Daphnia magna* short-term acute survival results are presented in **Table 1** and in **Figures 1**, **6**, **11**, and **16**. There were no statistically significant ($p<0.05$) reductions in survival during the twenty four month testing period.

The Laboratory control and DMC ambient control met the test acceptability criteria for all but three of the 24 test periods The ambient control water failed in April 2010 and May 2011 and the Laboratory control failed in August 2010. For the concurrent *Daphnia magna* reference toxicant tests, the survival endpoint was within the Laboratory control chart limits for all 24 tests.

Fathead Minnow (*Pimephales promelas*) 7-Day Acute Larval Survival

The fathead minnow 7-day acute larval survival results are presented in **Table 2** and in **Figures 2**, **7**, **12**, and **17**. There were two statistically significant ($p<0.05$) reductions in survival during the 24 testing months. Both events was for the Site B water during July 2011 and September 2011.

The Laboratory and DMC ambient control met the 80% minimum survival acceptability criteria for all but two of the 24 test periods. The ambient control water failed in April 2011 and August 2011. Twenty of the twenty-four concurrent fathead minnow reference toxicant survival endpoint was within the control chart limits. Tests performed in July 2010, September 2010, January 2011 and February 2011 exceeded the control chart limits.

Daphnid invertebrate (*Daphnia magna*) Short-Term Chronic Reproduction

The *Daphnia magna* short-term chronic reproduction results are presented in **Table 3** and in **Figures 3**, **8**, **13**, and **18**. There were three statistically significant ($p<0.05$) reductions in reproduction for the 24 testing months: Site F (June 2011 and July 2011) and Site C (October 2011).

The DMC ambient control data met the 10-neonates/surviving female minimum reproduction acceptability criterion for all tests. Twenty-three of the twenty-four concurrent fathead minnow reference toxicant survival endpoint was within the control chart limits. The test performed in August 2010 exceeded the control chart limits. All of the reproduction endpoints were within the control chart limitations.

Fathead Minnow (*Pimephales promelas*) 7-Day Chronic Larval Growth

The fathead minnow 7-day chronic larval growth results are presented in **Table 4** and in **Figures 4**, **9**, **14**, and **19**. A statistically significant ($p<0.05$) reduced rate of growth was observed in four tests when compared to the DMC ambient control: Site B (July 2010 and July 2011) and Site C (February 2011 and October 2011).

Twenty-two of the twenty-four concurrent fathead minnow reference toxicant survival endpoint was within the control chart limits. The test performed in for July 2010 and February 2011 exceeded the control chart limits. All data for the laboratory control and DMC control met the 0.25mg/surviving adult minimum growth acceptability criterion except for one; the ambient control water failed in April 2011.

Freshwater Alga (*Selenastrum capricornutum*) 96-Hour Growth Test

The freshwater algal 96-hour growth test results are presented in **Table 5** and in **Figures 5**, **10**, **15**, and **20**. Twelve tests produced statistically significant ($p<0.05$) reductions in algal growth. The reduced growth was observed during the January 2010 (Site B), February 2010 (Sites B), April (Site B), November (Site B), December (Site B), February 2011 (Site B), March 2011 (Site B, D and F), September 2011 (Site B and D), and November 2011 (Site B) tests.

The Laboratory control and DMC control met the minimum growth criterion for twenty-two of twenty-four tests. The tests performed in September 2011 and December 2011 exceeded the control chart limits. These results are summarized in **Table 5**.

The concurrent green algae reference toxicant growth (IC 25) endpoint was within control chart limits for twenty-one of twenty-four tests. The tests performed in February 2011, September 2011, and December 2011 exceeded the control chart limits.

Definitive Bioassay Testing

Definitive bioassay tests were conducted on Site B water samples during all 24 months of the study period (**Table 6**). The definitive bioassay used a dilution series of the site water at 12.5, 25, 50, 75, and 100 percent of the site water diluted with water from the DMC (ambient water). The results were compared to the DMC water. Laboratory control water was used as a second control for possible toxicity in the DMC water.

The definitive bioassay method allowed for the determination of the No Observed Effect Concentration (NOEC). The NOEC is a statistically derived calculation of the amount of the test water dilution needed to eliminate those adverse effects that are measured by these tests. For example, in February 2006, the NOEC was 25% (**Table 6**). This sample result indicates that in order for a test endpoint not to differ statistically from the control, sample water must be diluted to 25 percent with ambient water.

Results from the 24 monthly tests for the study period (**Table 6**) showed that 13 samples did not exhibit toxicity (NOEC of 100%) at full-strength test water. November 2010, February 2011 and November 2011 had an NOEC of 75%. Four samples had NOECs of 50% (January, February, April and December 2010) and four samples had an NOEC less than 50%.

These data also can be expressed in toxicity units, where:

Toxicity Unit (TU) = 100/NOEC

In general, toxicity units are used to standardize the results of toxicity tests regardless of the statistical endpoint used. In the example given above for February 2006, the NOEC was 25, which is calculates to 4 TU. A compilation of data for 90 months in which there was definitive testing of algae is listed in **Table 6**. Two months' results showed toxicity units of greater than sixteen (December 1999, September 2000). During these months, the Site B water would have had to be diluted more than sixteen times to eliminate adverse growth.

Toxicity units were greater than or equal to eight in samples collected June 2000, February 2002, March 2002, January 2003, February 2003, July 2003, August 2003, December 2003, February 2004, May 2004, January 2005, July 2005, August 2005, January 2006, February 2007, June 2008, August 2008, January 2009, February 2009, April 2009 and March 2011; equal to 4 for 12 months and equal to 2 for 15 months. Toxicity units were between 1 and 2 for 17 months (November 2001, September 2002, March 2003, May 2003, January 2004, March 2004, July 2004, August 2004, September 2004, April 2007, November 2007, April 2008, November 2008, November 2009, November 2010, March 2011 and November 2011). On the other hand, 71 of the 138 tests resulted in toxicity units equal to one.

Water Chemistry

Selenium

The selenium data are presented in **Table 11** and **Figures 21a** and **21b.** Sub samples were submitted for each sampling event in 2011 but only results for January and March were received. Site B had the highest selenium concentrations for the 24-month study period, with the months of January through May having the highest concentrations (ranging from 20-63 μg/L). The September, October and November 2010 sampling events had the lowest selenium concentrations at Site B, ranging from 5.7 to 21.20 μg/L. Site D showed a similar seasonal trend when compared to Site B, with the highest concentrations observed in the months of May, June and July. The lowest values at Site D were observed during the sampling periods of October, November and December. Site D had comparative selenium concentrations to Site B for January 2011. The 24-month period showed selenium concentrations at Sites C (ranging from < 0.40- 1.10 μg/L) and F (ranging from < 0.40-0.9 μg/L) comparable to the levels measured in the Delta Mendota Canal (ranging from <0.40-0.70 μg/L).

Other Water Chemistry

The laboratory water chemistry data are presented in **Tables 12** through **21**. All analyses were performed at the BES Laboratory, except for selenium.

The Site B conductivity was higher than all other Site waters for each monthly sampling event except for April when site D had comparable or higher conductivity values. May 2010 produced the highest conductivity values for the Site C water. Site D water showed a different trend when compared to Site C, with increased levels of conductivity occurring during, May, July and August 2010. Site F waters possessed the lowest conductivity when compared to the other Sites except for single sampling events in September, October, November and December 2010. January 2010 and December 2011 showed the highest conductivity for Site F for the 24 months. In general the DO at sites C, D, and F was lower than the DO at Site B (**Table 14**), while the pH of all Site waters were similar (**Table 15**). The Site B water is about two to three times greater in hardness than the other sites, exceeding 1000 mg/L (as CaCO3) for all 12 months except April, September, October and December 2010 as well as June and September 2011 (**Table 18**). Total suspended solids were generally lower in the Delta Mendota Canal relative to water collected from Sites B, C, D, and F water. The highest alkalinity data was observed in January 2011 for Site B, May 2010 for Site C, September 2010 for Site D, December 2011 for Site F and March 2010 for the Delta Mendota Canal (**Table 17**). The highest ammonia nitrogen concentration was observed at Site B in October (0.54 mg/L) (**Table 20**), while the total chlorine concentration ranged from non-detectable to 0.27 mg/L. On average, Site B exhibited the highest chlorine concentrations of all the sites (58 of the 72 sampling events) (**Table 21**).

Conclusions

A total of 288 laboratory toxicity tests (three species, four sites, 24 months), comparing the Site waters (B, C, D, and F) with the ambient control (Delta Mendota Canal), were conducted between January 2010 and December 2011 using short-term chronic bioassays. Each set of tests included five toxicity endpoints (fish survival and growth, water flea survival and reproduction, and algae growth). Of these tests, 21 endpoints (Site B = 13, Site C = 3, Site D = 2 and Site F = 3) out of the 480 total endpoints (4.38 %) exhibited a statistically significant result ($p<0.05$) compared to the ambient control.

The survival endpoint for *Daphnia magna* was the least sensitive of the five endpoints tested with no significant responses for those endpoints. The *Pimephales promelas* survival endpoint had two significant responses.

The freshwater alga was the most sensitive species tested. The algae exposed to Site B water exhibited reduced growth when compared to DMC ambient control water 12 out of the 24 months. Definitive testing was initiated in November 1999 for Site B to evaluate the No Observed Effect Concentration (NOEC) when compared to the ambient water. Of the 24 tests conducted during the current study period, 13 samples had NOECs of 100%, 3 samples had an NOEC of 75%, 4 samples had an NOEC of 50%, and 4 samples had an NOEC less than 50% as shown in **Table 6**.

All statistically significant events are summarized in the **Tables 7** through **10**.

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Table 1. Daphnid invertebrate (Daphnia magna) Short-term Acute Survival

Units	Site B Percent	Site C Percent	Site D Percent	Site F Percent	Ambient (DMC) Percent	Laboratory Control Percent
Jan-10	100	90	90	100	90	100
Feb-10	90	90	90	100	100	90
Mar-10	90	100	90	80	90	90
Apr-10	70	90	90	80	40	80
May-10	80	70	100	100	90	80
Jun-10	100	100	100	90	90	100
Jul-10	90	100	90	90	100	100
Aug-10	100	100	100	100	90	50
Sep-10	100	100	90	100	90	90
Oct-10	80	100	90	100	100	100
Nov-10	90	90	100	80	100	80
Dec-10	90	80	70	80	90	80
Jan-11	100	90	90	100	90	90
Feb-11	90	90	100	90	100	90
Mar-11	90	80	90	80	80	90
Apr-11	100	100	80	100	100	100
May-11	70	80	70	60	10	80
Jun-11	100	100	100	80	90	90
Jul-11	90	80	100	90	100	100
Aug-11	90	90	90	100	90	90
Sep-11	100	90	70	100	90	90
Oct-11	90	60	100	90	100	100
Nov-11	100	100	100	100	100	100
Dec-11	90	80	80	70	80	90
Figure:	1	6	11	16		

Notes:

No statistics were computed between sampling dates.

* Statistically significant event (P<0.05). Statistics were computed between all site means and the DMC ambient water sample.

** DMC/Control water failed to meet the survival (≥80%) acceptability criteria.

Table 2. Fathead Minnow (*Pimephales promelas*) 7-Day Acute Larval Survival

Units:	Site B (Percent ± Standard Deviation)	Site C (Percent ± Standard Deviation)	Site D (Percent ± Standard Deviation)	Site F (Percent ± Standard Deviation)	Ambient (DMC) (Percent ± Standard Deviation)	Laboratory Control (Percent ± Standard Deviation)
Jan-10	98 + 5.00	95 + 5.77	95 + 5.77	100 + 0	98 + 5.00	100 + 0
Feb-10	98 + 5.00	100 + 0	95 + 5.77	95 + 10.00	100 + 0	90 + 14.14
Mar-10	98 + 5.00	95 + 5.77	95 + 5.77	100 + 0	98 + 5.00	100 + 0
Apr-10	95 + 5.77	98 + 5.00	100 + 0	100 + 0	100 + 0	98 + 5.00
May-10	95 + 5.77	93 + 9.57	98 + 5.00	85 + 23.80	90 + 14.14	95 + 5.77
Jun-10	100 + 0	100 + 0	100 + 0	98 + 5.00	95 + 5.77	98 + 5.00
Jul-10	95 + 5.77	98 + 5.00	100 + 0	100 + 0	100 + 0	93 + 9.57
Aug-10	98 + 5.00	98 + 5.00	98 + 5.00	98 + 5.00	93 + 9.57	95 + 5.77
Sep-10	95 + 5.77	93 + 9.57	100 + 0	100 + 0	100 + 0	98 + 5.77
Oct-10	95 + 5.77	100 + 0	100 + 0	100 + 0	100 + 0	100 + 0
Nov-10	95 + 5.77	100 + 0	83 + 17.08	98 + 5.00	100 + 0	100 + 0
Dec-10	98 + 5.00	95 + 5.77	95 + 5.77	100 + 0	98 + 5.00	100 + 0
Jan-11	88 + 5.00	95 + 5.77	100 + 0	98 + 5.00	90 + 8.16	100 + 0
Feb-11	93 + 5.00	95 + 10.00	100 + 0	100 + 0	93 + 15.00	100 + 0
Mar-11	100 + 0	100 + 0	98 + 5.00	88 + 18.93	98 + 5.00	100 + 0
Apr-11	93 + 5.00	95 + 5.77	88 + 5.00	60 + 29.43	**63 + 9.57**	93 + 9.57
May-11	95 + 5.77	83 + 17.08	95 + 5.77	78 + 22.17	80 + 28.28	95 + 5.77
Jun-11	95 + 5.77	98 + 5.00	98 + 5.00	93 + 9.57	93 + 9.57	95 + 5.77
Jul-11	**33 + 28.72**	100 + 0	95 + 5.77	100 + 0	98 + 5.00	90 + 8.16
Aug-11	90 + 14.14	88 + 5.00	95 + 10.00	93 + 5.00	**70 + 16.33**	90 + 8.16
Sep-11	**75 + 12.91**	88 + 15.00	90 + 8.16	95 + 5.77	95 + 10.00	95 + 5.77
Oct-11	90 + 14.14	98 + 5.00	98 + 5.00	100 + 0	98 + 5.00	100 + 0
Nov-11	100 + 0	93 + 5.00	98 + 5.00	93 + 15.00	100 + 0	100 + 0
Dec-11	100 + 0	98 + 5.00	98 + 5.00	95 + 5.77	95 + 5.77	98 + 5.00
Figure:	2	7	12	17		

Notes:

No statistics were computed between sampling dates.

Statistically significant event (P<0.05). Statistics were computed between all site means and the DMC ambient water sample.

DMC/Control water failed to meet the survival (≥80%) acceptability criteria.

Table 3. Daphnid invertebrate (*Daphnia magna*) Short-term Chronic Reproduction

Units:	Site B Number of Neonates per Female ± Standard Deviation	Site C Number of Neonates per Female ± Standard Deviation	Site D Number of Neonates per Female ± Standard Deviation	Site F Number of Neonates per Female ± Standard Deviation	Ambient (DMC) Number of Neonates per Female ± Standard Deviation	Laboratory Control Number of Neonates per Female ± Standard Deviation
Jan-10	31.50 + 15.11	30.50 + 19.47	26.20 + 21.56	33.60 + 14.31	25.60 + 14.73	34.20 + 21.39
Feb-10	22.90 + 14.74	22.10 + 12.40	26.20 + 13.10	25.70 + 8.18	23.10 + 11.50	25.40 + 8.57
Mar-10	23.60 + 13.47	28.40 + 13.13	23.30 + 14.80	19.50 + 15.84	25.00 + 12.15	16.60 + 7.60
Apr-10	34.80 + 27.20	41.40 + 22.99	39.20 + 26.20	24.10 + 20.38	20.10 + 26.29	28.50 + 22.29
May-10	30.60 + 23.38	45.40 + 22.24	39.30 + 22.73	42.90 + 12.36	33.80 + 22.41	19.40 + 18.03
Jun-10	0.23 + 8.56	27.20 + 4.76	29.50 + 7.69	24.20 + 9.69	23.10 + 10.14	21.40 + 5.36
Jul-10	43.60 + 18.13	48.80 + 14.09	46.30 + 16.43	46.60 + 12.17	38.70 + 7.27	38.60 + 6.52
Aug-10	27.70 + 10.20	31.80 + 4.29	28.40 + 13.65	25.80 + 4.42	26.10 + 10.12	**13.60 ± 15.35**
Sep-10	35.50 + 11.12	29.80 + 10.56	30.00 + 16.98	28.10 + 10.61	24.33 + 15.00	20.00 + 9.49
Oct-10	28.10 + 12.05	23.70 + 12.68	30.00 + 14.24	29.20 + 6.34	29.90 + 11.04	25.20 + 6.39
Nov-10	40.70 + 17.07	27.20 + 10.32	36.30 + 10.40	30.10 + 17.64	31.60 + 10.60	28.80 + 11.05
Dec-10	31.5 + 15.11	30.50 + 19.47	26.20 + 21.56	33.60 + 14.31	25.60 + 14.73	34.20 + 21.39
Jan-11	40.80 + 4.69	35.90 + 13.56	37.40 + 7.04	42.70 + 5.10	31.60 + 12.00	38.50 + 4.38
Feb-11	25.70 + 12.70	26.40 + 13.78	24.40 + 9.49	26.80 + 12.03	25.50 + 8.10	22.10 + 10.45
Mar-11	53.10 + 22.54	39.10 + 21.33	59.10 + 25.49	41.30 + 22.06	29.80 + 20.27	49.90 + 23.43
Apr-11	28.60 + 10.34	23.10 + 4.89	25.40 + 11.33	29.90 + 10.24	28.60 + 12.18	29.20 + 6.99
May-11	44.80 + 19.02	36.60 + 14.97	45.70 + 16.44	24.80 + 16.44	22.90 + 11.45	37.90 + 7.80
Jun-11	66.00 + 21.79	58.00 + 6.88	62.80 + 18.06	**38.90 + 18.47**	50.30 + 20.09	42.20 + 12.59
Jul-11	31.70 + 16.63	43.80 + 21.40	40.90 + 10.52	**21.70 + 9.55**	30.50 + 9.54	25.30 + 10.90
Aug-11	38.10 + 22.52	32.80 + 18.90	40.40 + 17.28	31.40 + 11.97	31.00 + 7.53	34.30 + 17.76
Sep-11	41.30 + 16.04	33.10 + 19.21	37.20 + 28.67	35.00 + 13.93	29.60 + 15.11	28.40 + 12.30
Oct-11	26.90 + 18.17	**13.20 + 12.08**	29.90 + 7.62	20.80 + 10.18	24.20 + 8.05	27.10 + 8.75
Nov-11	51.90 + 13.62	46.80 + 12.39	48.10 + 12.97	39.30 + 16.70	44.60 + 10.19	27.00 + 7.57
Dec-11	24.30 + 17.64	32.10 + 19.73	36.70 + 19.87	24.00 + 22.48	28.00 + 20.70	34.10 + 14.41
Figure	3	8	13	18		

Notes:

No statistics were computed between sampling dates.

Statistically significant event (P<0.05). Statistics were computed between all site means and the DMC ambient water sample.

DMC/Control water failed to meet the reproduction (≥10) acceptability criteria.

Table 4. Fathead Minnow (*Pimephales promelas*) 7 Day Chronic Larval Growth

Units:	Site B (In Milligrams ± Standard Deviation)	Site C (In Milligrams ± Standard Deviation)	Site D (In Milligrams ± Standard Deviation)	Site F (In Milligrams ± Standard Deviation)	Ambient (DMC) (In Milligrams ± Standard Deviation)	Laboratory Control (In Milligrams ± Standard Deviation)
Jan-10	0.39 + 0.03	0.40 + 0.03	0.46 + 0.03	0.44 + 0.05	0.39 + 0.05	0.39 + 0.06
Feb-10	0.47 + 0.06	0.53 + 0.05	0.49 + 0.04	0.52 +0.10	0.49 + 0.06	0.51 + 0.08
Mar-10	0.41 + 0.02	0.48 + 0.09	0.48 + 0.04	0.46 + 0.05	0.40 + 0.03	0.45 + 0.04
Apr-10	0.53 + 0.08	0.48 + 0.07	0.53 + 0.07	0.50 + 0.09	0.43 + 0.11	0.48 + 0.02
May-10	0.35 + 0.04	0.34 + 0.03	0.36 + 0.05	0.39 + 0.05	0.37 + 0.05	0.37 + 0.03
Jun-10	0.37 + 0.01	0.34 + 0.04	0.35 + 0.05	0.35 + 0.03	0.37 + 0.04	0.38 + 0.05
Jul-10	**0.35 + 0.01**	0.37 + 0.08	0.39 + 0.02	0.37 + 0.07	0.41 + 0.05	0.41 + 0.03
Aug-10	0.32 + 0.06	0.28 + 0.05	0.33 + 0.05	0.33 + 0.04	0.26 + 0.06	0.35 + 0.04
Sep-10	0.41 + 0.03	0.43 + 0.06	0.39 + 0.05	0.41 + 0.05	0.41 + 0.03	0.38 + 0.05
Oct-10	0.38 + 0.03	0.43 + 0.01	0.42 + 0.05	0.39 + 0.03	0.37 + 0.03	0.33 + 0.02
Nov-10	0.46 + 0.05	0.47 + 0.04	0.43 + 0.02	0.47 + 0.06	0.42 + 0.03	0.35 + 0.03
Dec-10	0.39 + 0.03	0.40 + 0.03	0.46 + 0.03	0.44 + 0.05	0.39 + 0.05	0.39 + 0.06
Jan-11	0.37 + 0.03	0.38 + 0.02	0.41 + 0.03	0.38 + 0.03	0.35 + 0.03	0.38 + 0.04
Feb-11	0.46 + 0.03	**0.34 + 10.00**	0.44 + 0.03	0.42 + 0.03	0.40 + 0.05	0.32 + 0.04
Mar-11	0.36 + 0.04	0.40 + 0.03	0.37 + 0.07	0.38 + 0.04	0.37 + 0.03	0.35 + 0.05
Apr-11	0.37 + 0.03	0.40 + 0.04	0.40 + 0.05	0.33 + 0.06	**0.22 + 0.03**	0.29 + 0.04
May-11	0.48 + 0.03	0.48 + 0.03	0.50 + 0.07	0.40 + 0.07	0.38 + 0.13	0.43 + 0.04
Jun-11	0.36 + 0.06	0.34 + 0.02	0.36 + 0.05	0.36 + 0.06	0.33 + 0.02	0.33 + 0.02
Jul-11	**0.06 + 0.05**	0.26 + 0.03	0.25 + 0.03	0.28 + 0.02	0.27 + 0.03	0.26 + 0.01
Aug-11	0.26 + 0.03	0.25 + 0.04	0.26 + 0.04	0.28 + 0.02	0.25 + 0.04	0.29 + 0.02
Sep-11	0.28 + 0.02	0.30 + 0.02	0.33 + 0.02	0.34 + 0.01	0.32 + 0.04	0.32 + 0.04
Oct-11	0.45 + 0.02	**0.34 + 0.02**	0.41 + 5.00	0.42 + 0.02	0.37 + 0.02	0.38 + 0.04
Nov-11	0.50 + 0.06	0.47 + 0.04	0.47 + 0.01	0.46 + 0.08	0.48 + 0.05	0.44 + 0.08
Dec-11	0.42 + 0.06	0.38 + 0.04	0.44 + 0.05	0.39 + 0.05	0.37 + 0.01	0.36 + 0.05
Figure	4	9	14	19		

Notes:

No statistics were computed between sampling dates.

Statistically significant event (P<0.05). Statistics were computed between all site means and the DMC ambient water sample.

DMC/Control water failed to meet the growth (≥ 0.25mg dry wgt./surviving organism) acceptability criteria.

Table 5. Freshwater algae (*Selenastrum capricornutum*) 96-Hour Growth Test

	Site B		Site C		Site D		Site F		Ambient (DMC)		Lab Control	
	Cells cells/mL	Variance %	Cells cells/mL	Variance %	Cells cells/mL	Variance %	Cells cells/mL	Variance %	Cells cells/mL	Variance %	Cells cells/mL	Variance %
Jan-10	**12.40**	13.75	28.49	5.17	29.82	9.31	24.78	5.05	19.73	14.64	20.26	9.32
Feb-10	**19.13**	9.36	36.04	6.80	31.71	9.99	29.86	9.07	28.73	15.55	23.06	11.00
Mar-10	**17.64**	14.66	28.41	7.44	27.84	6.17	27.44	13.18	19.45	13.82	15.52	61.18
Apr-10	**5.15**	42.51	22.16	13.09	25.14	25.57	33.19	8.01	26.27	24.47	24.71	13.43
May-10	**12.77**	10.52	23.51	25.50	23.22	5.09	26.44	7.27	15.00	14.76	11.27	13.12
Jun-10	**17.74**	6.81	29.55	3.83	24.82	6.89	33.04	16.48	22.71	19.44	21.98	15.75
Jul-10	**17.58**	8.03	25.29	13.70	18.75	19.58	19.73	14.30	17.58	14.02	16.11	11.00
Aug-10	**19.64**	6.54	24.96	5.34	21.80	5.56	28.76	10.67	21.43	5.08	22.27	11.42
Sep-10	**22.62**	3.95	28.89	3.89	26.26	5.72	29.05	9.12	25.12	11.16	25.21	7.27
Oct-10	**27.63**	11.26	34.35	4.52	38.03	5.64	28.95	4.01	25.57	12.32	21.17	13.30
Nov-10	**18.17**	2.51	29.02	5.12	33.39	3.25	28.26	8.86	26.49	22.60	26.69	14.57
Dec-10	**12.40**	18.84	28.49	5.17	29.82	9.31	24.78	5.05	19.73	14.64	20.26	9.32
Jan-11	23.45	3.29	30.16	4.28	32.97	7.23	30.85	3.69	24.47	5.45	28.72	15.06
Feb-11	**20.93**	6.14	31.31	4.28	30.34	7.33	25.40	9.45	26.86	11.24	27.64	9.56
Mar-11	**2.89**	11.33	17.97	4.99	**9.82**	11.04	**10.31**	6.28	21.51	6.31	19.56	6.18
Apr-11	22.30	6.07	33.57	3.59	33.20	8.76	30.42	6.96	20.52	4.54	21.24	8.43
May-11	23.73	9.52	27.65	17.79	22.86	20.68	24.49	9.49	10.02	12.59	23.56	8.26
Jun-11	20.40	6.17	31.17	11.53	29.11	3.83	32.38	21.61	23.84	19.96	19.93	4.54
Jul-11	20.84	11.35	25.97	16.65	18.21	14.09	20.28	4.94	22.77	22.90	19.05	16.97
Aug-11	**20.39**	19.27	23.54	11.58	23.18	15.68	24.30	9.16	27.40	17.41	18.96	8.59
Sep-11	**7.09**	8.76	24.94	38.88	3.26*	23.50	29.18	10.50	17.78	6.28	2.01	24.01
Oct-11	20.14	13.33	26.60	20.17	33.29	6.82	25.90	3.37	22.89	12.73	18.78	4.85
Nov-11	**14.73**	6.41	32.50	3.93	30.69	4.31	26.74	13.86	22.22	7.94	26.28	4.81
Dec-11	**17.40**	24.21	36.60	10.48	36.00	3.35	35.60	8.23	25.10	12.57	2.90	28.67
Figure	5	10	15	20								

Notes:

Cell count values expressed as the exponent 10^5.

Statistically significant event ($p<0.05$). Statistics were computed between all site means and the DMC ambient water sample.

DMC/Control water failed to meet the growth ($\geq 1 \times 10^6$) acceptability criteria.

Table 6. Statistical analysis of growth endpoints for algae at Site B

Test Month	IC 50	IC 25	NOEC	LOEC	Toxic Units
Jan-10	>100	83.58	50	75	2
Feb-10	>100	84.08	50	75	2
Mar-10	>100	>100	100	>100	1
Apr-10	84.26	63.31	50	75	2
May-10	>100	>100	100	>100	1
Jun-10	>100	>100	100	>100	1
Jul-10	>100	>100	100	>100	1
Aug-10	>100	>100	100	>100	1
Sep-10	>100	>100	100	>100	1
Oct-10	>100	>100	100	>100	1
Nov-10	>100	94.26	75	100	1.33
Dec-10	>100	83.58	50	75	2
Jan-11	>100	>100	100	>100	1
Feb-11	>100	>100	75	100	1.33
Mar-11	34.96	12.34	<12.5	12.5	>8
Apr-11	>100	>100	100	>100	1
May-11	>100	>100	100	>100	1
Jun-11	>100	>100	100	>100	1
Jul-11	>100	>100	100	>100	1
Aug-11	>100	30.38	25	50	4
Sep-11	88.43	57.32	25	50	4
Oct-11	>100	>100	100	>100	1
Nov-11	>100	90.82	75	100	1.33
Dec-11	>100	83.63	100	>100	1

Data Source: Block Environmental Services

Notes:
NA - Not available
IC - Inhibition concentration. The toxicant concentration that would cause a given percent (i.e., 50% or 25%) reduction in a biological measurement (in this case, algal growth).
NOEC - No observed effect concentration. The highest concentration of a toxicant to which organisms are exposed that causes no observable adverse effects.
LOEC - Lowest observed effect concentration. The lowest concentration of toxicant to which organisms are exposed which causes adverse effects.
Toxic Units: 100 / NOEC. Toxicity units are used to standardize the results of toxicity tests regardless of the statistical endpoint used.

Table 7. Summary of statistically significant results – Site B

Table 7a. *Daphnia magna* Short-term Acute Survival

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997												
1998												
1999												
2000												
2001					*	*		*				
2002												
2003									*	*		
2004												
2005										*		
2006												
2007												
2008												
2009												
2010												
2011												

Table 7b. Fathead Minnow 7-day Acute Larval Survival

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997												
1998												
1999												
2000												
2001												
2002												
2003												
2004												
2005												
2006												
2007												
2008												
2009												
2010												
2011							*		*			

Table 7c. *Daphnia magna* Short-term Chronic Reproduction

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997												
1998	*									*		
1999												
2000												
2001					*	*		*				
2002		*									*	
2003												
2004												
2005										*		
2006												
2007						*			*			
2008												
2009												
2010												
2011												

Table 7d. Fathead Minnow 7-day Chronic Larval Growth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997		*								*	*	
1998												
1999												
2000												
2001		*				*						
2002						*		*				
2003					*		*					
2004												
2005												
2006						*						
2007											*	
2008											*	
2009												
2010												
2011							*					

Table 7e. Freshwater Algae (*Selenastrum capricornutum*) 96-hour Growth Test

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												*
1997		*	*	*		*			*	*		
1998	*	*	*		*	*			*	*	*	*
1999	*	*						*			*	*
2000	*	*										*
2001		*			*	*		*	*		*	*
2002	*	*	*	*		*					*	
2003	*		*	*	*	*	*	*	*			*
2004		*		*		*			*	*	*	*
2005	*						*	*		*		
2006	*	*							*			
2007		*		*							*	
2008				*		*		*			*	
2009	*	*	*	*					*		*	*
2010												
2011		*	*					*	*		*	

* Statistically significant event ($p<0.05$). Statistics were computed between all site means and the DMC ambient water sample.

No Analysis or Results Not Available

Table 8. Summary of statistically significant results – Site C

Table 8a. *Daphnia magna* Short-term Acute Survival

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997												
1998												
1999												
2000												
2001	*					*						
2002												
2003												
2004												
2005												
2006												
2007			*									
2008												
2009						*						
2010												
2011												

Table 8b. Fathead Minnow 7-day Acute Larval Survival

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												*
1997		*									*	*
1998	*	*	*							*	*	*
1999											*	*
2000	*									*	*	*
2001												*
2002											*	
2003	*		*									*
2004									*	*		
2005												*
2006												
2007			*									
2008												
2009												
2010												
2011												

Table 8c. *Daphnia magna* Short-term Chronic Reproduction

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997												
1998												
1999												
2000												
2001						*						
2002												
2003												
2004												
2005												
2006												
2007					*							
2008								*				
2009						*						
2010												
2011										*		

Table 8d. Fathead Minnow 7-day Chronic Larval Growth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997							*			*	*	*
1998	*	*	*					*		*	*	
1999											*	*
2000	*									*	*	*
2001		*										*
2002											*	*
2003					*		*					*
2004											*	
2005												*
2006						*					*	
2007			*								*	
2008									*			
2009												
2010												
2011		*										

Table 8e. Freshwater Algae *(Selenastrum capricornutum)* 96-hour Growth Tests

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997		*		*	*							
1998												
1999			*	*								
2000												
2001						*						
2002			*					na		*		
2003						*						
2004					*							
2005												
2006					*						*	
2007												
2008			*						*			
2009												
2010												
2011												

* Statistically significant event ($p<0.05$). Statistics were computed between all site means and the DMC ambient water sample.

No Analysis or Results Not Available

Table 9. Summary of statistically significant results – Site D

Table 9a. *Daphnia magna* Short-term Acute Survival

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997												
1998												
1999												
2000										*		
2001						*	*	*				
2002												
2003												
2004												
2005												
2006												
2007												
2008												
2009						*						
2010												
2011												

Table 9b. Fathead Minnow 7-day Acute Larval Survival

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												*
1997												*
1998	*	*	*								*	
1999	*										*	*
2000	*	*									*	
2001											*	*
2002												*
2003											*	*
2004								*	*			*
2005												*
2006												
2007												
2008												
2009												
2010												
2011												

Table 9c. *Daphnia magna* Short-term Chronic Reproduction

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997												
1998	*									*		
1999												
2000												
2001						*		*				
2002												
2003												
2004							*					
2005												
2006								*				
2007												
2008												
2009						*						
2010												
2011												

Table 9d. Fathead Minnow 7-day Chronic Larval Growth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996										*		
1997										*		
1998	*	*	*								*	
1999											*	
2000										*	*	*
2001												
2002												*
2003					*						*	
2004												*
2005												
2006						*						
2007							*					
2008					*						*	
2009												
2010												
2011												

Table 9e. Freshwater Algae (*Selenastrum capricornutum*) 96-hour Growth Test

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												*
1997		*	*		*							
1998									*		*	
1999		*								*	*	
2000												
2001						*		*				
2002		*	*	*		*		na		*	*	
2003						*	*	*	*			
2004										*	*	
2005	*						*	*				
2006		*										
2007						*		*	*			
2008						*		*	*			
2009												
2010												
2011			*						*			

* Statistically significant event ($p<0.05$). Statistics were computed between all site means and the DMC ambient water sample.

No Analysis or Results Not Available

Table 10. Summary of statistically significant results – Site F

Table 10a. *Daphnia magna* Short-term Acute Survival

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997												
1998												
1999												
2000												
2001												
2002								*				
2003												
2004												
2005												
2006												
2007												
2008												
2009												
2010												
2011												

Table 10b. Fathead Minnow 7-day Acute Larval Survival

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997										*		
1998		*	*			*					*	
1999	*									*	*	*
2000		*									*	
2001												
2002											*	
2003												
2004												
2005												
2006												
2007												
2008												
2009												
2010												
2011												

Table 10c. *Daphnia magna* Short-term Chronic Reproduction

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997												
1998	*	*										
1999												
2000												
2001												
2002						*						
2003	*				*							
2004												
2005												
2006												
2007			*									
2008												*
2009												
2010												
2011						*						

Table 10d. Fathead Minnow 7-day Chronic Larval Growth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997										*	*	
1998		*	*			*					*	
1999	*							*			*	*
2000		*									*	
2001												
2002											*	
2003												
2004												
2005												
2006												
2007												
2008				*							*	
2009		*										
2010												
2011												

Table 10e. Freshwater Algae *(Selenastrum capricornutum)* 96-hour Growth Test

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
1997			*	*	*							
1998												*
1999	*	*										
2000		*										
2001		*		*		*						
2002		*				*		na		*	*	
2003	*			*		*	*		*	*		*
2004							*			*	*	
2005		*					*					
2006		*										
2007			*	*	*							
2008			*	*	*				*			
2009					*							
2010												
2011			*									

* Statistically significant event ($p<0.05$). Statistics were computed between all site means and the DMC ambient water sample.

No Analysis or Results Not Available

Table 11. Summary of Statistically Significant Results - All Sites October 1996 - December 2011

Table 11a. *Daphnia magna* Short-term Acute Survival

	Site B	Site C	Site D	Site F	# of Tests
1996	0	0	0	0	
1997	0	0	0	0	
1998	0	0	0	0	
1999	0	0	0	0	
2000	0	0	1	0	
2001	3	2	3	0	
2002	0	0	0	1	
2003	2	0	0	0	
2004	0	0	0	0	
2005	1	0	0	0	
2006	0	0	0	0	
2007	0	1	0	0	
2008	0	0	0	0	
2009	0	1	1	0	
2010	0	0	0	0	
2011	0	0	0	0	
Results	6	4	5	1	183
Percent	3%	2%	3%	1%	

Table 11b. Fathead Minnow 7-day Acute Larval Survival

	Site B	Site C	Site D	Site F	# of Tests
1996	0	1	1	0	
1997	0	3	1	1	
1998	0	6	4	4	
1999	0	2	3	4	
2000	0	4	3	2	
2001	0	1	2	0	
2002	0	1	1	1	
2003	0	3	2	0	
2004	0	2	3	0	
2005	0	1	1	0	
2006	0	0	0	0	
2007	0	1	0	0	
2008	0	0	0	0	
2009	0	0	0	0	
2010	0	0	0	0	
2011	2	0	0	0	
Results	2	25	21	12	183
Percent	1%	14%	11%	7%	

Table 11c. *Daphnia magna* Short-term Chronic Reproduction

	Site B	Site C	Site D	Site F	# of Tests
1996	0	0	0	0	
1997	0	0	0	0	
1998	2	0	2	2	
1999	0	0	0	0	
2000	0	0	0	0	
2001	3	1	2	0	
2002	2	0	0	1	
2003	0	0	0	2	
2004	0	0	1	0	
2005	1	0	0	0	
2006	0	0	1	0	
2007	2	1	0	1	
2008	0	1	0	1	
2009	0	1	1	0	
2010	0	0	0	0	
2011	0	1	0	1	
Results	10	5	7	8	183
Percent	5%	3%	4%	4%	

Table 11d. Fathead Minnow 7-day Chronic Larval Growth

	Site B	Site C	Site D	Site F	# of Tests
1996	0	0	1	0	
1997	3	4	1	2	
1998	0	6	4	4	
1999	0	2	1	4	
2000	0	4	3	2	
2001	2	2	0	0	
2002	2	2	1	1	
2003	2	3	2	0	
2004	0	1	1	0	
2005	0	1	0	0	
2006	1	2	1	0	
2007	1	2	1	0	
2008	1	1	2	2	
2009	0	0	0	1	
2010	0	0	0	0	
2011	1	1	0	0	
Results	13	31	18	16	183
Percent	7%	17%	10%	9%	

Table 11e. Freshwater Algae (*Selenastrum capricornutum*) 96-hour Growth Test

	Site B	Site C	Site D	Site F	# of Tests
1996	1	0	1	0	
1997	6	3	3	3	
1998	9	0	2	1	
1999	5	2	3	2	
2000	3	0	0	1	
2001	7	1	2	3	
2002	6	3	7	5	
2003	9	1	4	7	
2004	7	1	2	3	
2005	4	0	3	2	
2006	3	2	1	1	
2007	3	0	3	3	
2008	4	2	3	4	
2009	7	0	0	1	
2010	0	0	0	0	
2011	5	0	2	1	
Results	79	15	36	37	182
Percent	43%	8%	20%	20%	

Table 12. Conductivity of site waters as received at the BES laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		Site B	Site C	Site D	Site F	Delta-Mendota Canal
	11-Jan-10	4300	2250	2810	1948	743
Jan-10	13-Jan-10	4360	2130	2790	1890	890
	15-Jan-10	4190	2150	2070	2060	874
	22-Feb-10	4640	2070	2860	1814	565
Feb-10	24-Feb-10	4340	2380	3180	1532	853
	26-Feb-10	4600	2040	3050	1493	853
	8-Mar-10	4650	1787	2540	1629	569
Mar-10	10-Mar-10	4800	1769	2380	1667	694
	12-Mar-10	4500	2060	2640	1719	615
	5-Apr-10	2629	1660	1860	1029	657
Apr-10	7-Apr-10	3256	1525	1633	1086	458
	9-Apr-10	3870	1996	2655	1265	735
	3-May-10	4350	3880	4350	1434	437
May-10	5-May-10	4540	4060	4670	1540	448
	7-May-10	4390	4370	4940	1353	452
	14-Jun-10	5220	1762	3270	855	310
Jun-10	16-Jun-10	4930	1924	3490	966	299
	18-Jun-10	3910	1812	3150	1127	275
	12-Jul-10	5590	1925	4990	920	213
Jul-10	14-Jul-10	5570	1553	4220	1003	438
	16-Jul-10	4820	1470	3620	1068	200
	9-Aug-10	5570	1257	4230	844	336
Aug-10	11-Aug-10	5650	1299	4300	802	247
	13-Aug-10	4500	3310	4870	831	229
	20-Sep-10	4000	991	2180	1111	450
Sep-10	22-Sep-10	3860	1286	2270	1151	524
	24-Sep-10	3760	1256	2390	1201	478
	18-Oct-10	2540	1128	1332	1075	448
Oct-10	20-Oct-10	2790	1095	1386	1063	550
	22-Oct-10	3200	1184	1505	1185	448
	15-Nov-10	3900	1493	1963	1495	470
Nov-10	17-Nov-10	4000	1542	2030	1481	600
	19-Nov-10	3820	1517	1947	1499	792
	13-Dec-10	3880	1470	1840	1525	325
Dec-10	15-Dec-10	3880	1544	1966	1589	347
	17-Dec-10	3900	NA	1840	1563	422
	10-Jan-11	4400	1432	1752	1573	246
Jan-11	12-Jan-11	4330	1447	1773	1598	266
	14-Jan-11	4650	1613	1901	1533	229
	7-Feb-11	4800	2080	2980	1328	290
Feb-11	9-Feb-11	5200	1922	2890	1469	294
	14-Feb-11	4980	2060	2840	1443	396
	11-Feb-11	4630	2130	2960	1340	458
	7-Mar-11	4200	1520	2200	1138	303
Mar-11	9-Mar-11	3910	1774	2380	1148	302
	11-Mar-11	4240	1821	2470	1230	305
	4-Apr-11	4900	1679	2170	1627	230
Apr-11	6-Apr-11	5260	1880	2320	1601	213
	8-Apr-11	5590	1822	2560	1754	218
	16-May-11	5280	1709	3140	967	175
May-11	18-May-11	5440	1217	2420	983	181
	20-May-11	5010	1118	2740	864	185
	23-May-11	5050	1466	3070	864	217
	13-Jun-11	4600	1574	2370	1068	223

Table 12. Conductivity of site waters as received at the BES laboratory (cont.)

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
Jun-11	15-Jun-11	4480	1627	2330	1198	227
	17-Jun-11	4630	1593	2460	948	234
	11-Jul-11	5400	1167	1765	678	154
Jul-11	13-Jul-11	5730	1026	1344	646	152
	15-Jul-11	5930	1015	1992	642	162
	8-Aug-11	5600	980	2530	770	218
	10-Aug-11	5700	882	3010	766	242
Aug-11	12-Aug-11	5210	985	2730	812	288
	15-Aug-11	5300	1020	3010	774	289
	17-Aug-11	5330	958	3150	889	235
	19-Sep-11	4370	846	2180	823	186
Sep-11	21-Sep-11	4790	764	2060	275	214
	23-Sep-11	5230	814	2140	942	237
	17-Oct-11	3910	823	1300	1002	198
Oct-11	19-Oct-11	4490	807	1311	934	202
	21-Oct-11	4470	923	1542	883	192
	14-Nov-11	4100	1020	1383	897	181
Nov-11	16-Nov-11	4310	1040	1350	897	280
	18-Nov-11	4020	1054	1346	894	304
	12-Dec-11	4610	1565	2390	2100	250
Dec-11	14-Dec-11	4740	1441	2290	1982	423
	16-Dec-11	5370	1541	2180	2020	515

Table 13. Total suspended solids of site water as received at the BES laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		Site B	Site C	Site D	Site F	Delta-Mendota Canal
	11-Jan-10	31	11	21	15	3
Jan-10	13-Jan-10	26	45	48	50	4
	15-Jan-10	33	22	38	27	3
	22-Feb-10	104	58	75	34	17
Feb-10	24-Feb-10	80	30	58	40	14
	26-Feb-10	93	63	90	33	15
	8-Mar-10	66	82	86	9	18
Mar-10	10-Mar-10	59	137	128	57	17
	12-Mar-10	67	194	168	15	21
	5-Apr-10	39	64	83	20	8
Apr-10	7-Apr-10	77	82	60	20	10
	9-Apr-10	105	155	119	25	21
	3-May-10	50	59	77	50	16
May-10	5-May-10	47	37	87	65	13
	7-May-10	52	24	60	48	9
	14-Jun-10	39	44	49	43	24
Jun-10	16-Jun-10	79	62	100	48	27
	18-Jun-10	93	52	90	126	35
	12-Jul-10	44	81	64	78	26
Jul-10	14-Jul-10	52	71	74	95	12
	16-Jul-10	68	108	88	147	29
	9-Aug-10	51	29	44	102	17
Aug-10	11-Aug-10	96	31	72	75	26
	13-Aug-10	102	35	115	106	25
	20-Sep-10	46	36	46	74	13
Sep-10	22-Sep-10	67	40	53	96	11
	24-Sep-10	79	56	70	82	17
	18-Oct-10	33	38	45	72	14
Oct-10	20-Oct-10	23	27	29	89	16
	22-Oct-10	50	53	44	88	16
	15-Nov-10	35	25	39	43	7
Nov-10	17-Nov-10	49	34	40	54	11
	19-Nov-10	40	27	49	59	3
	13-Dec-10	33	22	26	39	10
Dec-10	15-Dec-10	27	54	26	62	13
	17-Dec-10	37	NA	25	44	17
	10-Jan-11	38	32	44	23	17
Jan-11	12-Jan-11	52	34	42	26	17
	14-Jan-11	56	41	55	60	16
	7-Feb-11	54	32	43	84	17
Feb-11	9-Feb-11	68	44	51	61	17
	11-Feb-11	69	47	59	68	19
	14-Feb-11	54	48	53	64	10
	7-Mar-11	42	86	77	16	28
Mar-11	9-Mar-11	41	66	61	19	19
	11-Mar-11	49	77	83	21	18
	4-Apr-11	64	31	69	20	7
Apr-11	6-Apr-11	82	50	57	23	8
	8-Apr-11	85	42	72	31	1
	16-May-11	85	63	96	109	16
May-11	18-May-11	107	94	102	70	18
	20-May-11	101	96	144	63	13
	23-May-11	75	49	89	53	10
	13-Jun-11	27	46	54	150	17

Table 13. Total suspended solids of site water as received at the BES laboratory (cont.)

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
Jun-11	15-Jun-11	45	48	57	132	15
	17-Jun-11	47	56	85	198	17
	11-Jul-11	37	66	41	148	19
Jul-11	13-Jul-11	45	51	33	138	118
	15-Jul-11	46	65	49	124	46
	8-Aug-11	31	92	67	52	36
	10-Aug-11	27	55	73	65	37
Aug-11	12-Aug-11	16	43	71	150	29
	15-Aug-11	39	18	40	101	30
	17-Aug-11	18	33	39	34	35
	19-Sep-11	78	55	58	60	17
Sep-11	21-Sep-11	17	64	66	53	17
	23-Sep-11	25	74	90	67	25
	17-Oct-11	56	14	26	128	9
Oct-11	19-Oct-11	45	24	28	90	11
	21-Oct-11	80	37	49	69	11
	14-Nov-11	30	31	31	161	4
Nov-11	16-Nov-11	43	20	44	169	10
	18-Nov-11	35	33	27	33	9
	12-Dec-11	17	23	19	19	5
Dec-11	14-Dec-11	39	21	24	30	4
	16-Dec-11	30	23	21	29	5

Table 14. Dissolved oxygen of site waters as received at the BES laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	11-Jan-10	14.90	12.60	12.30	11.10	12.10
Jan-10	13-Jan-10	11.40	10.60	10.90	10.00	11.70
	15-Jan-10	12.10	12.20	12.00	11.80	12.30
	22-Feb-10	14.90	12.30	12.50	10.30	11.40
Feb-10	24-Feb-10	13.80	12.00	11.80	10.90	11.30
	26-Feb-10	12.60	12.20	12.30	11.70	11.30
	8-Mar-10	13.60	11.70	11.70	10.50	11.10
Mar-10	10-Mar-10	13.00	12.10	12.10	11.00	11.20
	12-Mar-10	13.20	11.30	11.80	11.00	11.20
	5-Apr-10	13.40	10.80	11.00	9.10	10.90
Apr-10	7-Apr-10	13.10	11.20	11.30	9.50	10.60
	9-Apr-10	12.80	9.50	9.80	8.20	9.90
	3-May-10	11.40	9.20	9.70	8.40	9.50
May-10	5-May-10	11.90	10.00	10.30	8.50	10.20
	7-May-10	12.20	9.70	10.80	9.40	10.40
	14-Jun-10	10.20	7.60	8.20	6.50	8.60
Jun-10	16-Jun-10	10.00	8.60	9.20	7.60	9.30
	18-Jun-10	12.10	8.10	8.90	7.50	9.00
	12-Jul-10	9.00	9.70	8.40	7.20	8.50
Jul-10	14-Jul-10	7.40	7.80	8.50	6.40	8.30
	16-Jul-10	6.40	8.80	8.10	7.00	8.60
	9-Aug-10	8.20	9.20	8.70	7.30	8.60
Aug-10	11-Aug-10	10.90	9.40	9.40	7.30	9.20
	13-Aug-10	10.90	8.90	9.90	6.90	8.90
	20-Sep-10	10.00	6.90	6.70	7.60	9.30
Sep-10	22-Sep-10	11.00	7.00	7.60	7.90	9.30
	24-Sep-10	11.90	7.60	8.20	8.60	9.50
	18-Oct-10	8.70	6.60	7.40	8.30	9.30
Oct-10	20-Oct-10	9.00	6.10	6.40	8.10	9.30
	22-Oct-10	10.30	6.80	7.00	8.20	9.60
	15-Nov-10	14	9.8	10.2	10.1	10.8
Nov-10	17-Nov-10	14.90	9.00	9.30	9.10	10.10
	19-Nov-10	8.00	7.10	7.30	7.40	7.60
	13-Dec-10	11.50	9.70	9.70	9.60	11.20
Dec-10	15-Dec-10	11.40	9.20	9.80	9.40	11.00
	17-Dec-10	11.7	NA	11	10.3	11.4
	10-Jan-11	13.70	12.60	12.60	11.50	12.00
Jan-11	12-Jan-11	13.10	12.30	12.30	11.60	12.10
	14-Jan-11	11.70	10.80	11.40	11.00	11.60
	7-Feb-11	12.70	10.40	11.10	10.50	11.80
Feb-11	9-Feb-11	12.70	11.20	11.50	10.90	11.80
	11-Feb-11	11.80	10.30	10.50	10.20	11.20
	14-Feb-11	12.40	10.40	10.80	10.10	12.50
	7-Mar-11	11.50	10.40	10.40	8.90	11.30
Mar-11	9-Mar-11	11.60	10.30	10.60	9.00	11.40
	11-Mar-11	11.10	10.10	10.40	8.50	10.90
	4-Apr-11	12.90	10.20	10.70	9.20	9.70
Apr-11	6-Apr-11	12.70	9.30	9.10	8.40	10.30
	8-Apr-11	12.20	10.20	10.50	9.60	10.40
	16-May-11	15.20	10.10	10.30	9.70	11.10
May-11	18-May-11	13.50	10.70	10.60	9.30	10.90
	20-May-11	12.00	9.40	9.50	8.20	9.80
	23-May-11	12.80	9.70	9.80	8.90	10.50
	13-Jun-11	13.30	9.10	9.00	8.00	9.60

Table 14. Dissolved oxygen of site waters as received at the BES laboratory (cont.)

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
Jun-11	15-Jun-11	12.90	9.20	8.60	7.70	10.00
	17-Jun-11	8.90	9.00	8.50	8.70	7.50
	11-Jul-11	11.40	7.90	8.00	7.30	9.00
Jul-11	13-Jul-11	11.40	9.50	10.10	7.70	10.30
	15-Jul-11	9.40	8.40	9.50	7.50	8.90
	8-Aug-11	13.70	10.00	9.10	9.80	9.80
	10-Aug-11	10.90	9.00	8.70	7.20	8.50
Aug-11	12-Aug-11	10.50	8.80	8.90	6.70	8.60
	15-Aug-11	12.80	10.80	10.80	8.30	10.70
	17-Aug-11	13.10	10.00	9.90	9.00	10.00
	19-Sep-11	13.60	7.10	8.30	6.40	8.90
Sep-11	21-Sep-11	13.10	8.00	8.60	7.10	9.10
	23-Sep-11	11.20	7.40	7.90	6.90	8.70
	17-Oct-11	14.60	7.00	6.90	6.90	9.60
Oct-11	19-Oct-11	9.00	6.80	6.80	6.70	9.60
	21-Oct-11	10.60	6.80	7.30	7.30	9.60
	14-Nov-11	11.80	9.60	10.00	8.20	11.00
Nov-11	16-Nov-11	13.20	10.50	10.20	8.40	11.20
	18-Nov-11	12.00	9.70	9.50	8.30	10.60
	12-Dec-11	13.60	11.40	11.50	8.50	12.00
Dec-11	14-Dec-11	12.50	11.30	11.50	8.70	11.70
	16-Dec-11	12.60	11.80	11.90	9.50	12.80

Table 15. pH of site waters as received at the BES laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		Site B	Site C	Site D	Site F	Delta-Mendota Canal
	11-Jan-10	8.10	8.00	8.00	7.80	8.00
Jan-10	13-Jan-10	8.10	7.90	8.00	7.70	8.00
	15-Jan-10	8.00	8.10	7.90	7.90	8.10
	22-Feb-10	8.60	8.10	8.20	7.80	7.90
Feb-10	24-Feb-10	8.40	8.00	8.10	7.60	7.90
	26-Feb-10	8.30	7.90	8.10	7.70	7.90
	8-Mar-10	8.40	8.20	8.20	7.8	8.00
Mar-10	10-Mar-10	8.40	8.20	8.20	7.8	7.90
	12-Mar-10	8.30	8.10	8.10	7.7	7.70
	5-Apr-10	8.60	8.20	8.20	7.70	8.00
Apr-10	7-Apr-10	8.90	8.30	8.40	7.70	7.90
	9-Apr-10	8.60	8.10	8.20	7.70	7.90
	3-May-10	8.50	7.90	8.10	7.70	7.70
May-10	5-May-10	8.50	8.00	8.20	7.80	8.00
	7-May-10	8.80	8.00	8.40	7.70	7.50
	14-Jun-10	9.10	7.90	8.20	7.70	7.80
Jun-10	16-Jun-10	9.00	7.80	8.40	7.50	7.60
	18-Jun-10	9.40	8.00	8.70	7.60	7.70
	12-Jul-10	8.80	8.30	8.50	7.60	7.80
Jul-10	14-Jul-10	8.60	7.90	8.50	7.60	7.70
	16-Jul-10	8.60	8.20	8.40	7.60	7.80
	9-Aug-10	8.70	8.30	8.40	7.50	7.60
Aug-10	11-Aug-10	9.00	8.50	8.90	7.80	7.90
	13-Aug-10	8.80	7.90	8.90	7.70	7.60
	20-Sep-10	8.50	7.80	7.90	7.80	8.00
Sep-10	22-Sep-10	8.80	7.80	7.90	7.70	7.80
	24-Sep-10	8.90	7.80	8.00	7.80	8.00
	18-Oct-10	7.80	7.70	7.50	7.50	7.70
Oct-10	20-Oct-10	8.10	7.80	7.80	7.80	7.90
	22-Oct-10	8.00	7.70	7.50	7.80	7.50
	15-Nov-10	8.30	8.00	7.90	7.80	8.00
Nov-10	17-Nov-10	8.50	8.00	8.00	7.80	8.10
	19-Nov-10	8.10	7.80	7.90	7.60	8.20
	13-Dec-10	8.00	8.10	8.00	8.00	8.20
Dec-10	15-Dec-10	7.70	7.80	7.80	7.80	7.90
	17-Dec-10	7.80	NA	7.90	7.70	7.80
	10-Jan-11	8.00	8.00	8.00	7.70	7.80
Jan-11	12-Jan-11	8.00	7.90	8.00	7.70	7.50
	14-Jan-11	8.00	7.90	8.00	7.60	7.50
	7-Feb-11	8.10	7.90	8.00	7.60	7.60
Feb-11	9-Feb-11	8.20	8.00	8.10	7.70	7.70
	11-Feb-11	8.20	8.00	8.00	7.70	7.90
	14-Feb-11	8.00	8.00	8.10	7.80	7.90
	7-Mar-11	7.90	7.90	7.90	7.70	7.60
Mar-11	9-Mar-11	8.00	8.00	8.00	7.70	7.70
	11-Mar-11	8.10	8.00	8.00	7.60	7.70
	4-Apr-11	8.40	8.10	8.10	7.70	7.70
Apr-11	6-Apr-11	8.30	8.10	8.00	7.60	7.40
	8-Apr-11	8.60	8.30	8.30	7.80	7.50
	16-May-11	9.00	8.00	8.40	7.80	7.90
May-11	18-May-11	8.80	7.80	8.30	7.70	7.70
	20-May-11	8.50	7.90	8.30	7.50	7.30
	23-May-11	8.70	8.00	8.30	7.80	7.80
	13-Jun-11	8.60	7.90	8.00	7.60	7.60

Table 15. pH of site waters as received at the BES laboratory (cont.)

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
Jun-11	15-Jun-11	8.80	8.00	8.10	7.50	7.60
	17-Jun-11	8.60	7.90	8.00	7.50	7.50
	11-Jul-11	8.80	8.20	8.30	7.50	7.50
Jul-11	13-Jul-11	8.90	8.20	8.40	7.30	7.40
	15-Jul-11	8.60	8.20	8.60	7.30	7.20
	8-Aug-11	8.60	8.20	8.50	7.60	7.60
	10-Aug-11	8.70	7.80	8.40	7.30	7.10
Aug-11	12-Aug-11	8.90	7.80	8.30	7.40	7.40
	15-Aug-11	9.10	8.10	8.60	7.50	7.50
	17-Aug-11	9.00	7.90	8.60	7.40	7.50
	19-Sep-11	8.80	7.70	8.00	7.50	7.70
Sep-11	21-Sep-11	8.70	7.70	8.00	7.50	7.50
	23-Sep-11	8.70	7.60	7.90	7.40	7.50
	17-Oct-11	8.60	7.70	7.80	7.50	7.60
Oct-11	19-Oct-11	8.30	7.70	7.70	7.50	7.60
	21-Oct-11	8.10	7.50	7.60	7.30	7.60
	14-Nov-11	7.80	7.90	7.80	7.70	7.80
Nov-11	16-Nov-11	8.10	7.80	7.80	7.60	7.70
	18-Nov-11	8.20	7.80	7.80	7.40	7.50
	12-Dec-11	7.90	7.90	7.90	7.60	7.80
Dec-11	14-Dec-11	8.00	7.90	7.90	7.60	7.70
	16-Dec-11	8.00	7.90	7.80	7.50	7.60

Table 16. Salinity of site waters as received at the BES laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		Site B	Site C	Site D	Site F	Delta-Mendota Canal
	11-Jan-10	2.30	1.20	1.50	1.00	0.40
Jan-10	13-Jan-10	2.30	1.10	1.40	1.00	0.40
	15-Jan-10	2.20	1.10	1.10	1.10	0.40
	22-Feb-10	2.50	1.10	1.50	0.90	0.30
Feb-10	24-Feb-10	2.30	1.20	1.70	0.80	0.40
	26-Feb-10	2.50	1.00	1.60	0.80	0.40
	8-Mar-10	2.50	0.90	1.30	0.80	0.30
Mar-10	10-Mar-10	2.60	0.90	1.20	0.80	0.30
	12-Mar-10	2.40	1.10	1.40	0.90	0.30
	5-Apr-10	2.10	1.30	1.50	0.80	0.50
Apr-10	7-Apr-10	2.40	1.10	1.30	0.80	0.30
	9-Apr-10	2.80	1.40	1.80	0.90	0.50
	3-May-10	2.30	2.10	2.30	0.70	0.20
May-10	5-May-10	2.40	2.20	2.50	0.80	0.20
	7-May-10	2.30	2.30	2.70	0.70	0.20
	14-Jun-10	2.80	0.90	1.70	0.40	0.10
Jun-10	16-Jun-10	2.60	1.00	1.80	0.50	0.10
	18-Jun-10	2.10	0.90	1.60	0.60	0.10
	12-Jul-10	3.00	1.00	2.70	0.50	0.10
Jul-10	14-Jul-10	3.00	0.80	2.20	0.50	0.20
	16-Jul-10	2.60	0.70	1.90	0.50	0.10
	9-Aug-10	3.00	0.60	2.20	0.40	0.20
Aug-10	11-Aug-10	3.10	0.60	2.30	0.40	0.10
	13-Aug-10	2.40	1.70	2.60	0.40	0.10
	20-Sep-10	2.10	0.50	1.10	0.60	0.20
Sep-10	22-Sep-10	2.00	0.60	1.20	0.60	0.30
	24-Sep-10	2.00	0.60	1.20	0.60	0.20
	18-Oct-10	1.30	0.60	0.70	0.50	0.20
Oct-10	20-Oct-10	1.40	0.50	0.70	0.50	0.30
	22-Oct-10	1.40	0.60	0.80	0.60	0.20
	15-Nov-10	2.1	0.8	1.00	0.8	0.2
Nov-10	17-Nov-10	2.10	0.80	1.00	0.70	0.30
	19-Nov-10	2.00	0.80	1.00	0.70	0.40
	13-Dec-10	2.10	0.70	0.90	0.80	0.20
Dec-10	15-Dec-10	2.10	0.80	1.00	0.80	0.20
	17-Dec-10	2.1	NA	0.9	0.8	0.2
	10-Jan-11	2.40	0.70	0.90	0.80	0.10
Jan-11	12-Jan-11	2.30	0.70	0.90	0.80	0.10
	14-Jan-11	2.50	0.80	1.00	0.80	0.10
	7-Feb-11	2.60	1.10	1.60	0.70	0.10
Feb-11	9-Feb-11	2.80	1.00	1.50	0.70	0.10
	11-Feb-11	2.70	1.00	1.50	0.70	0.20
	14-Feb-11	2.50	1.10	1.50	0.70	0.20
	7-Mar-11	2.20	0.80	1.10	0.60	0.10
Mar-11	9-Mar-11	2.10	0.90	1.20	0.60	0.10
	11-Mar-11	2.30	0.90	1.30	0.60	0.10
	4-Apr-11	2.60	0.90	1.10	0.80	0.10
Apr-11	6-Apr-11	2.80	1.00	1.20	0.80	0.10
	8-Apr-11	3.00	0.90	1.30	0.90	0.10
	16-May-11	2.90	0.90	1.60	0.50	0.10
May-11	18-May-11	2.90	0.60	1.30	0.50	0.10
	20-May-11	2.70	0.60	1.40	0.40	0.10
	23-May-11	2.70	0.70	1.60	0.40	0.10
	13-Jun-11	2.40	0.80	1.20	0.50	0.10

Table 16. Salinity of site waters as received at the BES laboratory (cont.)

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
Jun-11	15-Jun-11	2.40	0.80	1.20	0.60	0.10
	17-Jun-11	2.50	0.80	1.30	0.50	0.10
	11-Jul-11	2.90	0.60	0.90	5.00	8.50
Jul-11	13-Jul-11	3.10	0.50	0.70	8.40	3.70
	15-Jul-11	3.20	0.50	1.00	6.40	7.50
	8-Aug-11	3.00	0.50	1.30	0.40	0.10
	10-Aug-11	3.10	0.40	1.60	0.40	0.10
Aug-11	12-Aug-11	2.80	0.50	1.40	0.40	0.10
	15-Aug-11	2.90	0.50	1.60	0.40	0.10
	17-Aug-11	2.90	0.50	1.70	0.40	0.10
	19-Sep-11	2.30	0.40	1.10	0.40	0.10
Sep-11	21-Sep-11	2.60	0.40	1.10	0.40	0.10
	23-Sep-11	2.80	0.40	1.10	0.50	0.10
	17-Oct-11	2.10	0.40	0.70	0.50	0.10
Oct-11	19-Oct-11	2.40	0.40	0.70	0.50	0.10
	21-Oct-11	2.40	0.50	0.80	0.40	0.10
	14-Nov-11	2.20	0.50	0.70	0.40	0.10
Nov-11	16-Nov-11	2.30	0.50	0.70	0.40	0.10
	18-Nov-11	2.10	0.50	0.70	0.40	0.10
	12-Dec-11	2.50	0.80	1.20	1.10	0.10
Dec-11	14-Dec-11	2.50	0.70	1.20	1.00	0.20
	16-Dec-11	2.90	0.80	1.10	1.00	0.20

Table 17. Alkalinity of site waters as received at the BES laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	11-Jan-10	198	306	282	138	110
Jan-10	13-Jan-10	96	290	260	210	118
	15-Jan-10	200	282	252	236	116
	22-Feb-10	200	270	230	214	96
Feb-10	24-Feb-10	200	318	286	186	116
	26-Feb-10	182	278	238	174	102
	8-Mar-10	180	250	240	190	102
Mar-10	10-Mar-10	198	284	272	214	110
	12-Mar-10	186	314	276	208	98
	5-Apr-10	142	336	326	180	136
Apr-10	7-Apr-10	136	264	264	192	104
	9-Apr-10	156	320	308	136	132
	3-May-10	128	418	266	190	70
May-10	5-May-10	147	402	216	186	80
	7-May-10	120	432	190	178	76
	14-Jun-10	84	194	154	124	60
Jun-10	16-Jun-10	80	220	152	13	60
	18-Jun-10	88	210	152	152	62
	12-Jul-10	100	196	144	142	64
Jul-10	14-Jul-10	100	146	120	130	80
	16-Jul-10	94	134	110	138	58
	9-Aug-10	100	140	120	124	56
Aug-10	11-Aug-10	80	136	106	120	58
	13-Aug-10	84	278	90	114	50
	20-Sep-10	134	160	170	160	72
Sep-10	22-Sep-10	78	212	162	162	80
	24-Sep-10	80	212	476	162	72
	18-Oct-10	220	210	202	156	80
Oct-10	20-Oct-10	228	218	220	154	86
	22-Oct-10	210	230	278	164	70
	15-Nov-10	200	236	244	184	70
Nov-10	17-Nov-10	234	244	244	190	94
	19-Nov-10	220	246	244	194	114
	13-Dec-10	202	228	244	200	58
Dec-10	15-Dec-10	210	248	248	202	54
	17-Dec-10	210	NA	220	186	70
	10-Jan-11	242	240	230	188	54
Jan-11	12-Jan-11	242	226	220	194	50
	14-Jan-11	240	266	248	196	50
	7-Feb-11	246	266	266	168	62
Feb-11	9-Feb-11	234	254	256	176	62
	11-Feb-11	200	280	270	168	60
	14-Feb-11	232	280	290	160	64
	7-Mar-11	194	224	218	144	60
Mar-11	9-Mar-11	184	238	238	152	60
	11-Mar-11	198	238	220	154	56
	4-Apr-11	194	274	285	214	58
Apr-11	6-Apr-11	190	278	258	224	58
	8-Apr-11	230	256	250	200	48
	16-May-11	114	180	178	134	44
May-11	18-May-11	120	146	140	134	42
	20-May-11	140	136	126	110	46
	23-May-11	138	160	154	112	50

Table 17. Alkalinity of site waters as received at the BES laboratory (cont.)

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	13-Jun-11	60	184	168	138	46
Jun-11	15-Jun-11	88	156	156	154	48
	17-Jun-11	104	150	142	120	46
	11-Jul-11	168	176	176	112	44
Jul-11	13-Jul-11	110	166	168	100	36
	15-Jul-11	120	142	172	96	40
	8-Aug-11	80	110	102	112	42
	10-Aug-11	86	108	100	114	58
Aug-11	12-Aug-11	76	114	104	122	58
	15-Aug-11	84	116	106	118	52
	17-Aug-11	84	112	102	116	54
	19-Sep-11	96	156	138	124	62
Sep-11	21-Sep-11	100	172	146	146	68
	23-Sep-11	104	168	158	138	66
	17-Oct-11	130	184	172	154	60
Oct-11	19-Oct-11	202	176	182	154	56
	21-Oct-11	150	178	206	152	60
	14-Nov-11	216	188	196	138	52
Nov-11	16-Nov-11	222	198	196	136	66
	18-Nov-11	238	198	194	140	64
	12-Dec-11	234	218	250	256	70
Dec-11	14-Dec-11	244	230	234	262	84
	16-Dec-11	234	236	238	256	88

Table 18. Hardness (as $CaCO_3$) of Site Waters as Received at the BES Laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	11-Jan-10	>1000	466	624	396	170
Jan-10	13-Jan-10	>1000	416	574	370	160
	15-Jan-10	>1000	410	594	414	196
	22-Feb-10	>1000	426	630	370	128
Feb-10	24-Feb-10	>1000	436	676	334	186
	26-Feb-10	>1000	382	678	334	172
	8-Mar-10	>1000	438	536	398	154
Mar-10	10-Mar-10	>1000	380	600	376	164
	12-Mar-10	>1000	386	558	384	152
	5-Apr-10	866	420	336	326	216
Apr-10	7-Apr-10	876	360	424	312	176
	9-Apr-10	1000	452	584	216	192
	3-May-10	>1000	668	870	300	104
May-10	5-May-10	>1000	728	>1000	348	108
	7-May-10	>1000	756	>1000	300	104
	14-Jun-10	>1000	420	658	198	82
Jun-10	16-Jun-10	>1000	386	720	224	74
	18-Jun-10	>1000	458	654	254	68
	12-Jul-10	>1000	362	>1000	234	70
Jul-10	14-Jul-10	>1000	296	>1000	224	104
	16-Jul-10	>1000	292	>1000	236	96
	9-Aug-10	>1000	260	908	208	152
Aug-10	11-Aug-10	>1000	274	972	210	82
	13-Aug-10	>1000	600	>1000	194	58
	20-Sep-10	890	224	478	240	94
Sep-10	22-Sep-10	890	272	168	232	102
	24-Sep-10	850	264	490	240	100
	18-Oct-10	658	120	278	222	114
Oct-10	20-Oct-10	768	230	316	234	114
	22-Oct-10	908	270	380	258	104
	15-Nov-10	>1000	322	442	336	96
Nov-10	17-Nov-10	>1000	310	428	318	130
	19-Nov-10	>1000	304	416	296	174
	13-Dec-10	990	324	394	334	78
Dec-10	15-Dec-10	778	296	416	316	74
	17-Dec-10	954	NA	434	324	90
	10-Jan-11	>1000	308	372	334	74
Jan-11	12-Jan-11	>1000	332	384	346	66
	14-Jan-11	>1000	310	392	344	58
	7-Feb-11	>1000	400	408	278	76
Feb-11	9-Feb-11	>1000	380	638	316	78
	11-Feb-11	>1000	384	604	308	98
	14-Feb-11	>1000	452	628	292	144
	7-Mar-11	>1000	300	434	266	76
Mar-11	9-Mar-11	>1000	350	482	260	72
	11-Mar-11	>1000	350	516	280	72
	4-Apr-11	>1000	370	458	348	68
Apr-11	6-Apr-11	>1000	388	494	364	58
	8-Apr-11	>1000	340	506	380	60
	16-May-11	>1000	352	682	230	46
May-11	18-May-11	>1000	360	548	218	50
	20-May-11	>1000	246	596	204	60
	23-May-11	>1000	298	676	210	64

Table 18. Hardness (as $CaCO_3$) of Site Waters as Received at the BES Laboratory (cont.)

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
Jun-11	15-Jun-11	>1000	348	480	252	60
	17-Jun-11	>1000	328	506	204	58
	11-Jul-11	>1000	290	290	170	42
Jul-11	13-Jul-11	>1000	210	302	154	42
	15-Jul-11	>1000	214	422	148	42
	8-Aug-11	>1000	226	540	166	60
	10-Aug-11	>1000	194	626	174	60
Aug-11	12-Aug-11	>1000	202	616	188	66
	15-Aug-11	>1000	214	648	182	68
	17-Aug-11	>1000	200	712	184	62
	19-Sep-11	>1000	198	478	192	64
Sep-11	21-Sep-11	>1000	214	460	198	72
	23-Sep-11	>1000	208	464	206	66
	17-Oct-11	960	222	304	222	62
Oct-11	19-Oct-11	>1000	214	300	196	58
	21-Oct-11	>1000	212	348	194	54
	14-Nov-11	>1000	228	334	208	56
Nov-11	16-Nov-11	>1000	228	302	202	68
	18-Nov-11	>1000	228	304	198	78
	12-Dec-11	>1000	300	500	402	72
Dec-11	14-Dec-11	>1000	288	470	396	100
	16-Dec-11	>1000	300	428	398	110

Table 19. Temperature of site waters as received at the BES laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	11-Jan-10	2.00	2.00	2.00	2.90	2.20
Jan-10	13-Jan-10	4.00	3.00	3.00	5.00	3.00
	15-Jan-10	1.90	1.90	1.40	1.90	1.90
	22-Feb-10	2.50	2.80	2.80	4.80	3.00
Feb-10	24-Feb-10	2.00	1.60	2.20	3.30	2.90
	26-Feb-10	3.40	3.40	3.00	3.20	2.90
	8-Mar-10	0.50	1.00	1.00	1.50	2.30
Mar-10	10-Mar-10	1.80	1.30	1.50	1.60	NA
	12-Mar-10	1.50	1.20	1.10	1.20	2.10
	5-Apr-10	1.00	1.00	1.00	1.00	1.90
Apr-10	7-Apr-10	3.00	1.80	1.80	3.40	3.00
	9-Apr-10	2.50	1.40	1.40	2.40	3.40
	3-May-10	5.50	4.20	4.20	5.50	5.50
May-10	5-May-10	4.20	8.20	2.80	4.50	3.00
	7-May-10	3.80	3.50	3.50	4.00	3.20
	14-Jun-10	9.50	9.50	9.50	9.80	5.00
Jun-10	16-Jun-10	6.30	5.60	5.60	6.60	4.50
	18-Jun-10	5.60	5.80	5.50	5.60	7.60
	12-Jul-10	3.80	2.00	3.00	4.10	3.00
Jul-10	14-Jul-10	4.00	2.50	3.80	4.50	3.10
	16-Jul-10	4.50	4.50	4.50	4.50	3.50
	9-Aug-10	8.50	6.80	6.80	8.50	5.50
Aug-10	11-Aug-10	6.70	6.70	6.70	6.80	4.50
	13-Aug-10	7.60	4.80	4.60	7.60	6.00
	20-Sep-10	7.50	6.90	7.80	5.00	4.20
Sep-10	22-Sep-10	4.00	3.80	3.90	3.80	3.50
	24-Sep-10	3.50	3.50	3.50	3.50	10.80
	18-Oct-10	1.50	1.50	1.50	1.50	1.50
Oct-10	20-Oct-10	3.10	2.20	1.80	2.90	7.10
	22-Oct-10	3.00	1.00	2.00	2.50	3.00
	15-Nov-10	3.00	3.00	3.00	3.00	3.00
Nov-10	17-Nov-10	1.80	1.80	1.30	2.50	1.90
	19-Nov-10	1.00	1.00	1.00	1.00	1.00
	13-Dec-10	1.50	1.50	1.00	1.00	1.50
Dec-10	15-Dec-10	2.90	2.20	2.30	2.30	2.80
	17-Dec-10	0.50	NA	0.50	0.50	0.50
	10-Jan-11	1.20	1.00	0.80	0.80	1.30
Jan-11	12-Jan-11	0.80	1.10	1.30	1.00	1.90
	14-Jan-11	3.90	3.60	2.80	3.20	4.80
	7-Feb-11	2.10	1.60	2.10	2.20	2.80
Feb-11	9-Feb-11	1.50	2.00	2.00	1.50	3.50
	11-Feb-11	1.80	1.70	2.10	1.80	2.80
	14-Feb-11	1.10	0.50	1.30	1.20	1.90
	7-Mar-11	1.10	1.10	1.20	1.00	1.10
Mar-11	9-Mar-11	1.80	2.00	2.00	1.80	3.00
	11-Mar-11	2.00	2.00	2.00	2.00	2.00
	4-Apr-11	2.00	2.00	1.90	2.10	3.30
Apr-11	6-Apr-11	3.00	3.00	2.80	2.70	3.60
	8-Apr-11	1.00	1.50	1.50	1.00	5.00
	16-May-11	1.50	1.50	1.50	1.50	2.90
May-11	18-May-11	1.50	1.50	2.00	1.50	2.50
	20-May-11	3.60	3.60	4.70	3.80	6.60
	23-May-11	3.00	3.00	3.20	3.20	3.80

Table 19. Temperature of site waters as received at the BES laboratory (cont.)

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	23-May-11	3.00	3.00	3.20	3.20	3.80
	13-Jun-11	2.40	10.70	10.50	10.70	14.50
Jun-11	15-Jun-11	2.40	1.10	1.20	1.50	3.30
	17-Jun-11	2.50	7.50	8.00	7.50	7.50
	11-Jul-11	5.00	4.50	5.00	5.00	8.50
Jul-11	13-Jul-11	7.50	8.70	9.50	8.40	3.70
	15-Jul-11	6.80	7.60	7.60	6.40	7.50
	8-Aug-11	4.00	3.20	3.80	4.00	4.00
	10-Aug-11	2.90	3.10	3.00	3.00	8.50
Aug-11	12-Aug-11	7.50	6.00	6.50	8.00	6.50
	15-Aug-11	2.50	2.80	3.20	2.50	3.00
	17-Aug-11	1.50	2.50	2.50	2.00	2.50
	19-Sep-11	9.60	8.10	8.00	8.80	10.00
Sep-11	21-Sep-11	1.20	1.00	1.50	1.60	3.50
	23-Sep-11	7.60	8.60	8.60	8.10	8.10
	17-Oct-11	3.10	3.50	3.50	3.10	4.00
Oct-11	19-Oct-11	3.50	2.50	2.00	2.60	5.00
	21-Oct-11	1.60	1.60	1.60	2.00	3.50
	14-Nov-11	0.70	0.60	0.80	0.80	2.00
Nov-11	16-Nov-11	1.60	1.10	1.00	0.90	2.90
	18-Nov-11	1.00	1.00	2.00	1.20	2.00
	12-Dec-11	0.40	0.40	0.50	0.60	1.20
Dec-11	14-Dec-11	0.50	0.30	1.00	0.50	2.00
	16-Dec-11	1.00	2.00	2.00	1.50	4.00

Table 20. Ammonia of site waters as received at the BES laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	11-Jan-10	0.06	0.15	0.07	0.11	0.12
Jan-10	13-Jan-10	0.15	0.17	0.17	0.15	0.07
	15-Jan-10	0.17	0.14	0.17	0.17	0.07
	22-Feb-10	0.05	0.09	0.10	0.10	0.06
Feb-10	24-Feb-10	ND	0.17	0.13	0.10	0.06
	26-Feb-10	ND	0.11	0.08	0.06	0.05
	8-Mar-10	0.11	0.31	ND	0.15	0.10
Mar-10	10-Mar-10	0.05	0.26	0.22	0.04	0.08
	12-Mar-10	ND	0.13	0.10	ND	ND
	5-Apr-10	0.60	0.16	0.12	0.53	0.07
Apr-10	7-Apr-10	1.20	0.19	0.30	0.35	0.09
	9-Apr-10	0.04	0.15	0.19	0.07	0.08
	3-May-10	0.03	0.12	0.04	0.17	0.04
May-10	5-May-10	ND	0.08	0.04	0.10	0.03
	7-May-10	ND	0.06	0.04	0.10	ND
	14-Jun-10	0.05	0.10	0.04	0.42	0.03
Jun-10	16-Jun-10	0.07	0.04	0.06	0.14	0.03
	18-Jun-10	0.05	0.06	0.05	0.18	0.04
	12-Jul-10	0.57	0.08	0.55	0.13	0.05
Jul-10	14-Jul-10	0.60	0.09	0.52	0.12	ND
	16-Jul-10	0.60	0.04	0.58	0.11	ND
	9-Aug-10	0.24	0.03	0.04	0.08	0.03
Aug-10	11-Aug-10	0.05	ND	0.04	0.10	ND
	13-Aug-10	0.09	0.03	0.07	0.12	0.03
	20-Sep-10	0.12	0.05	0.04	0.11	ND
Sep-10	22-Sep-10	0.14	0.05	0.04	0.13	0.04
	24-Sep-10	0.06	ND	0.05	0.13	ND
	18-Oct-10	0.28	0.07	0.16	0.12	0.03
Oct-10	20-Oct-10	0.54	0.16	0.21	0.15	ND
	22-Oct-10	0.23	0.23	0.27	0.21	0.04
	15-Nov-10	0.08	0.15	0.12	0.12	0.04
Nov-10	17-Nov-10	0.03	0.14	0.11	0.12	0.03
	19-Nov-10	0.03	0.14	0.11	0.11	0.04
	13-Dec-10	0.27	0.08	0.18	0.11	ND
Dec-10	15-Dec-10	0.30	0.16	0.18	0.17	0.03
	17-Dec-10	0.37	NA	0.22	0.07	0.04
	10-Jan-11	0.24	0.19	0.16	0.09	0.09
Jan-11	12-Jan-11	0.18	0.18	0.26	0.11	0.11
	14-Jan-12	0.21	0.16	0.16	0.12	0.06
	7-Feb-11	0.04	0.11	0.08	0.13	0.04
Feb-11	9-Feb-11	0.03	0.17	0.16	0.13	0.03
	11-Feb-11	0.07	0.14	0.12	0.11	0.03
	14-Feb-11	0.04	0.04	0.05	0.16	ND
	7-Mar-11	0.21	0.27	0.23	0.13	0.09
Mar-11	9-Mar-11	0.25	0.16	0.3	0.1	0.06
	11-Mar-11	0.08	0.17	0.19	0.12	0.03
	4-Apr-11	0.04	0.07	0.1	0.04	0.07
Apr-11	6-Apr-11	ND	0.06	0.07	0.05	0.04
	8-Apr-11	0.04	0.07	ND	0.04	ND
	16-May-11	0.05	0.15	0.1	0.22	0.06
May-11	18-May-11	0.05	0.16	0.11	0.15	0.05
	20-May-11	ND	0.09	0.07	0.09	0.04
	23-May-11	0.05	0.06	0.05	0.15	0.04

Table 20. Ammonia of site waters as received at the BES laboratory (cont.)

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	13-Jun-11	0.03	0.04	0.05	0.14	0.08
Jun-11	15-Jun-11	0.08	0.1	0.07	0.24	0.04
	17-Jun-11	0.17	0.07	0.08	0.14	0.05
	11-Jul-11	0.05	0.1	0.09	0.12	ND
Jul-11	13-Jul-11	ND	0.04	0.07	0.09	0.04
	15-Jul-11	0.08	0.1	0.1	0.16	0.5
	8-Aug-11	0.12	0.23	0.16	0.24	0.11
	10-Aug-11	0.03	0.13	0.1	0.13	0.03
Aug-11	12-Aug-11	0.09	0.14	0.16	0.08	0.04
	15-Aug-11	0.04	0.1	0.07	0.05	ND
	17-Aug-11	0.04	0.06	0.04	0.1	0.05
	19-Sep-11	0.03	0.04	0.04	0.08	ND
Sep-11	21-Sep-11	0.05	0.16	0.14	0.11	0.04
	23-Sep-11	0.08	0.11	0.09	0.05	ND
	17-Oct-11	0.15	0.04	0.05	0.09	0.03
Oct-11	19-Oct-11	0.18	0.07	0.08	0.12	0.05
	21-Oct-11	0.09	0.05	0.12	0.05	ND
	14-Nov-11	0.13	0.11	0.12	0.08	ND
Nov-11	16-Nov-11	0.03	0.08	0.07	0.1	0.05
	18-Nov-11	0.04	0.11	0.1	0.06	0.03
	12-Dec-11	0.1	0.05	0.06	0.06	0.07
Dec-11	14-Dec-11	0.06	0.05	0.05	0.13	0.04
	16-Dec-11	ND	ND	0.04	0.07	0.05

Table 21. Total chlorine of site waters as received at the BES laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	11-Jan-10	0.04	ND	ND	ND	ND
Jan-10	13-Jan-10	0.08	ND	0.03	ND	ND
	15-Jan-10	ND	ND	ND	0.05	ND
	22-Feb-10	0.11	0.07	0.05	ND	0.05
Feb-10	24-Feb-10	0.08	0.06	0.06	0.03	0.03
	26-Feb-10	0.07	0.04	0.07	ND	0.03
	8-Mar-10	ND	0.04	0.05	0.15	0.10
Mar-10	10-Mar-10	0.08	0.15	0.07	0.04	0.08
	12-Mar-10	0.10	0.15	0.07	ND	ND
	5-Apr-10	0.27	0.16	0.20	0.03	0.05
Apr-10	7-Apr-10	0.19	1.30	0.12	0.03	ND
	9-Apr-10	0.16	0.14	0.10	0.04	ND
	3-May-10	0.10	0.05	0.07	0.03	0.03
May-10	5-May-10	0.06	0.04	0.07	ND	ND
	7-May-10	0.08	0.04	0.06	ND	0.03
	14-Jun-10	0.21	0.05	0.10	0.04	0.03
Jun-10	16-Jun-10	0.21	0.19	0.13	0.11	0.10
	18-Jun-10	0.23	0.07	0.17	0.05	0.04
	12-Jul-10	0.22	0.08	0.16	ND	0.04
Jul-10	14-Jul-10	0.18	0.04	0.11	ND	ND
	16-Jul-10	0.25	0.13	0.15	0.06	0.05
	9-Aug-10	0.26	0.08	0.19	ND	0.04
Aug-10	11-Aug-10	0.15	0.06	0.14	0.03	0.03
	13-Aug-10	0.17	0.05	0.22	0.07	0.05
	20-Sep-10	0.23	ND	0.06	ND	0.03
Sep-10	22-Sep-10	0.16	ND	0.07	ND	ND
	24-Sep-10	0.20	0.07	0.05	0.10	0.04
	18-Oct-10	0.13	ND	ND	ND	0.05
Oct-10	20-Oct-10	0.10	ND	0.03	0.03	ND
	22-Oct-10	0.15	ND	0.04	0.06	0.06
	15-Nov-10	0.09	0.07	0.06	0.03	ND
Nov-10	17-Nov-10	0.04	0.05	0.04	ND	ND
	19-Nov-10	0.05	0.06	0.04	ND	ND
	13-Dec-10	0.08	0.04	0.04	0.04	0.03
Dec-10	15-Dec-10	0.08	0.03	0.04	ND	0.05
	17-Dec-10	0.08	NA	ND	ND	0.04
	10-Jan-11	0.09	0.07	0.05	ND	0.04
Jan-11	12-Jan-11	0.04	0.03	0.03	0.03	0.04
	14-Jan-11	0.05	0.06	0.04	ND	ND
	7-Feb-11	0.08	0.05	0.05	0.03	0.03
Feb-11	9-Feb-11	0.04	0.05	0.05	ND	0.04
	11-Feb-11	ND	0.07	0.06	0.03	ND
	14-Feb-11	0.06	0.05	0.04	0.03	0.04
	7-Mar-11	0.07	0.05	0.07	0.06	ND
Mar-11	9-Mar-11	0.09	0.04	0.03	ND	ND
	11-Mar-11	0.06	0.07	0.08	0.03	0.03
	4-Apr-11	0.14	0.15	0.13	0.05	0.04
Apr-11	6-Apr-11	0.11	0.07	0.07	ND	ND
	8-Apr-11	0.17	0.08	0.1	0.03	ND
	16-May-11	0.13	0.04	0.08	0.03	ND
May-11	18-May-11	0.15	0.05	0.07	ND	ND
	20-May-11	0.06	ND	0.05	ND	ND
	23-May-11	0.12	0.12	0.06	0.04	ND

Table 21. Total chlorine of site waters as received at the BES laboratory (cont.)

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	13-Jun-11	0.12	0.04	0.04	ND	ND
Jun-11	15-Jun-11	0.14	0.03	0.06	0.04	ND
	17-Jun-11	0.23	0.04	0.06	0.06	ND
	11-Jul-11	0.13	0.13	0.12	0.05	0.05
Jul-11	13-Jul-11	0.17	0.15	0.11	0.04	0.03
	15-Jul-11	ND	0.07	0.14	ND	0.07
	8-Aug-11	0.17	0.1	0.13	0.05	0.06
	10-Aug-11	0.21	0.05	0.11	0.04	0.04
Aug-11	12-Aug-11	0.11	0.05	0.06	ND	0.04
	15-Aug-11	0.16	0.06	0.08	ND	0.04
	17-Aug-11	0.13	0.05	0.08	ND	ND
	19-Sep-11	0.21	ND	0.06	ND	ND
Sep-11	21-Sep-11	0.18	0.03	0.08	0.03	0.03
	23-Sep-11	0.2	0.05	0.08	0.03	ND
	17-Oct-11	0.2	ND	0.04	ND	ND
Oct-11	19-Oct-11	0.19	0.04	0.04	0.04	ND
	21-Oct-11	0.19	ND	ND	ND	ND
	14-Nov-11	0.11	ND	0.03	ND	ND
Nov-11	16-Nov-11	0.08	0.04	ND	0.14	ND
	18-Nov-11	0.12	ND	0.04	ND	0.03
	12-Dec-11	0.05	0.04	0.04	0.04	ND
Dec-11	14-Dec-11	0.03	ND	0.03	0.03	ND
	16-Dec-11	0.05	ND	0.07	ND	0.03

Figure 1. Site B compared to Delta-Mendota Canal – *Daphnia magna* Short-term Acute Survival

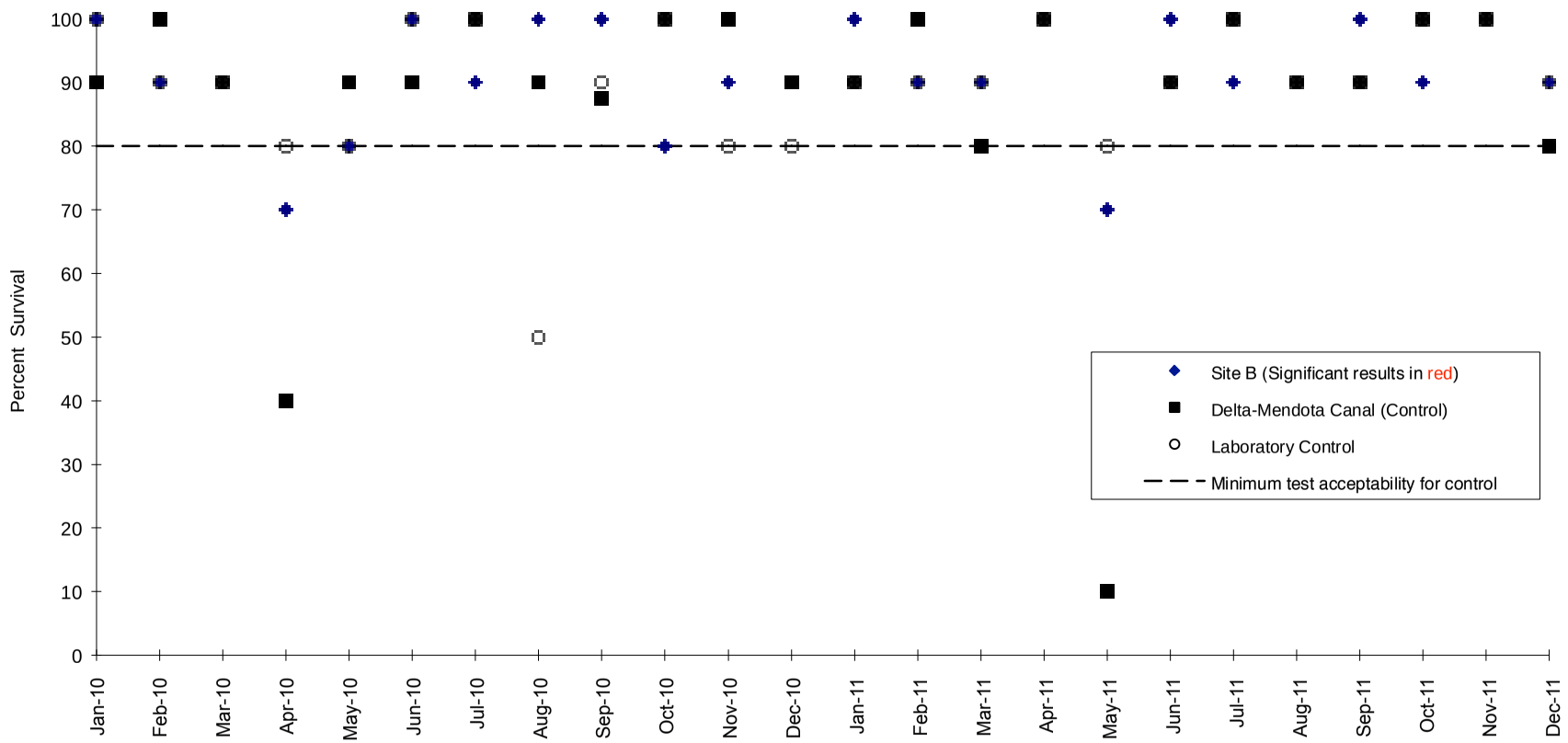


Figure 2. Site B compared to Delta-Mendota Canal – Fathead Minnow 7-Day Acute Larval Survival

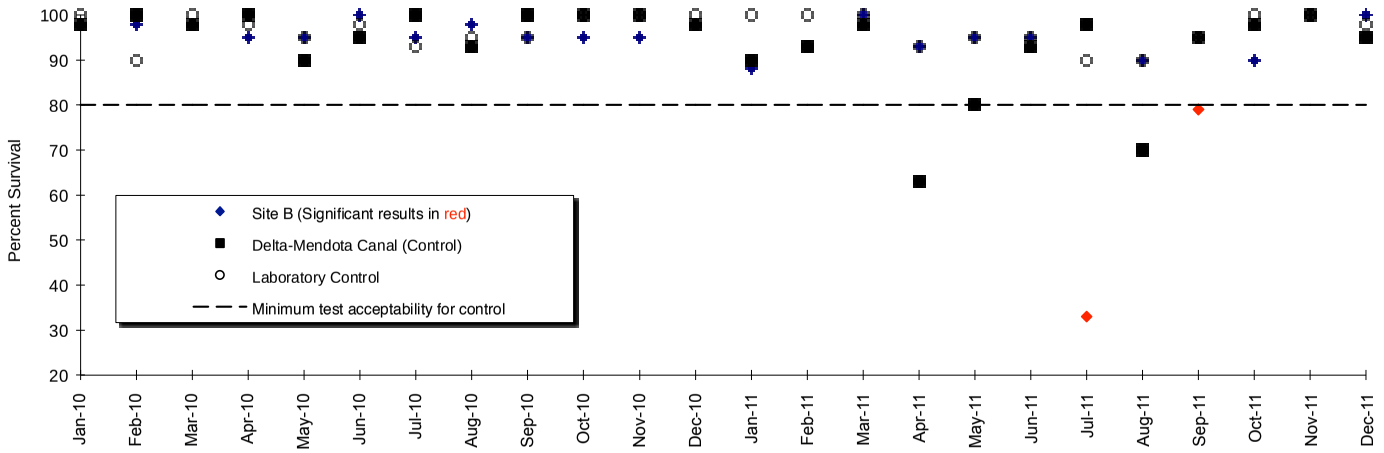


Figure 3. Site B compared to Delta-Mendota Canal – *Daphnia magna* Short-term Chronic Reproduction

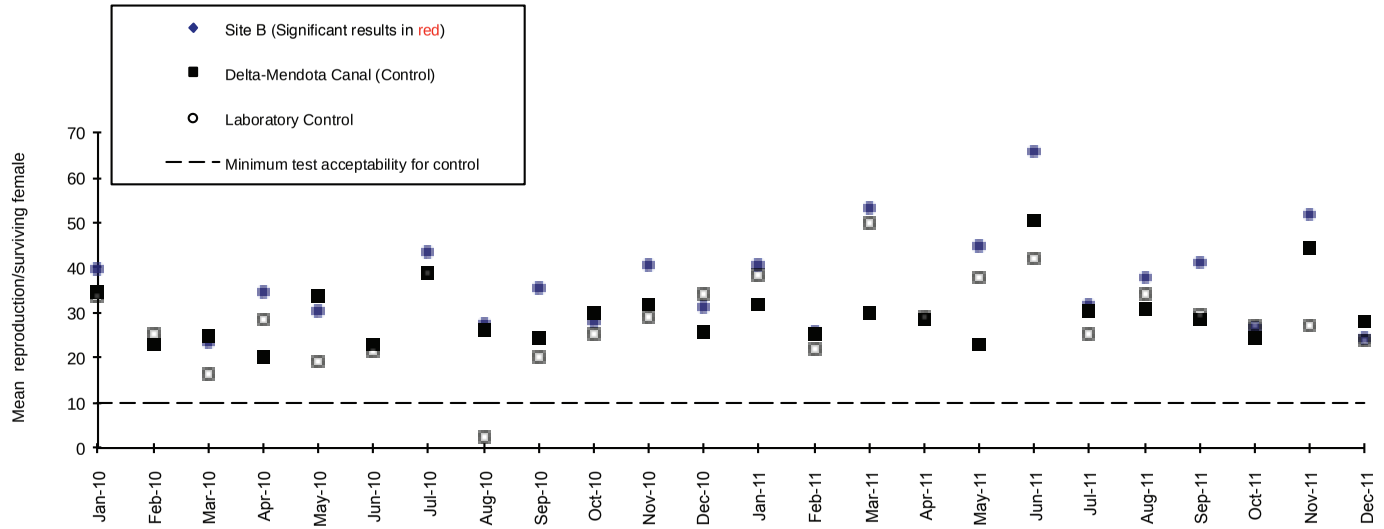


Figure 4. Site B compared to Delta-Mendota Canal – Fathead Minnow 7-Day Chronic Larval Growth

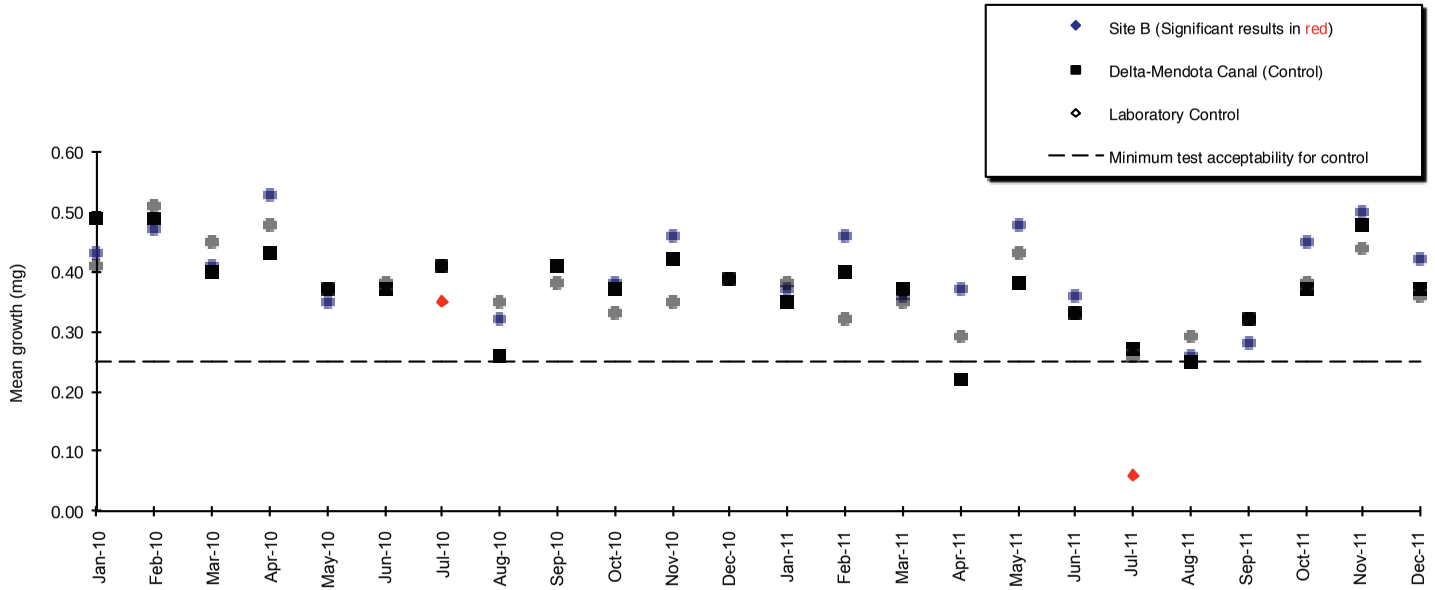


Figure 5. Site B compared to Delta-Mendota Canal – *Selenastrum capricornutum* 96-hour Growth Test

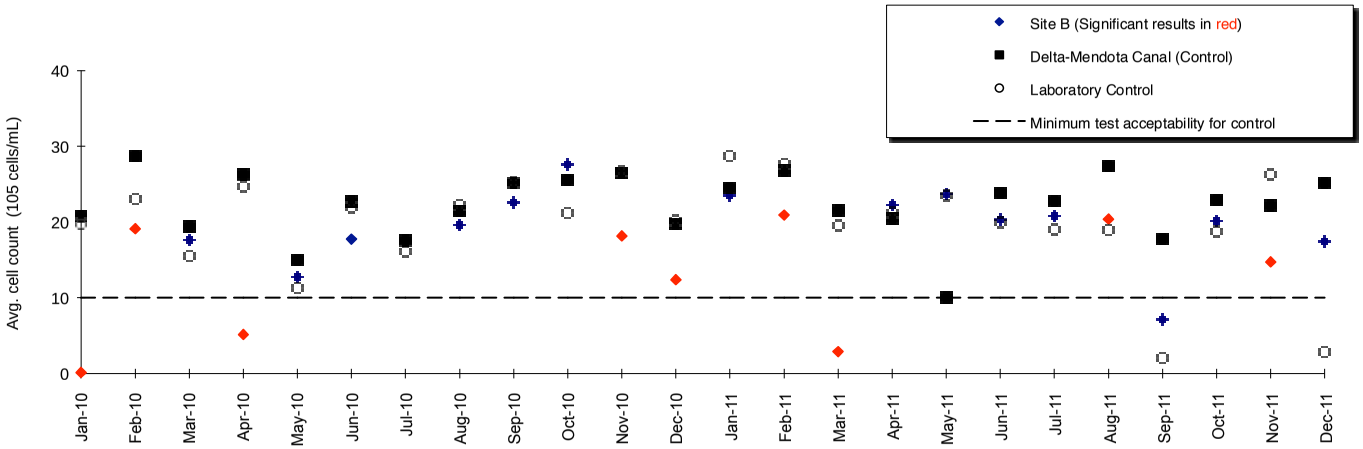


Figure 6. Site C compared to Delta-Mendota Canal – *Daphnia magna* Short-term Acute Survival

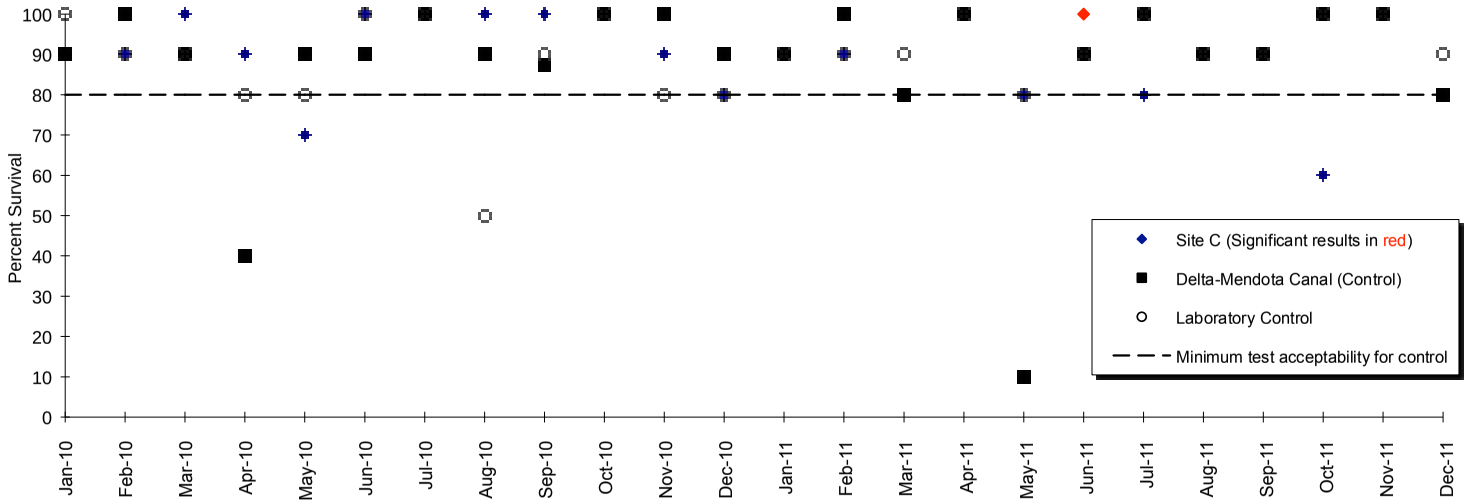


Figure 7. Site C compared to Delta-Mendota Canal – Fathead Minnow 7-Day Acute Larval Survival

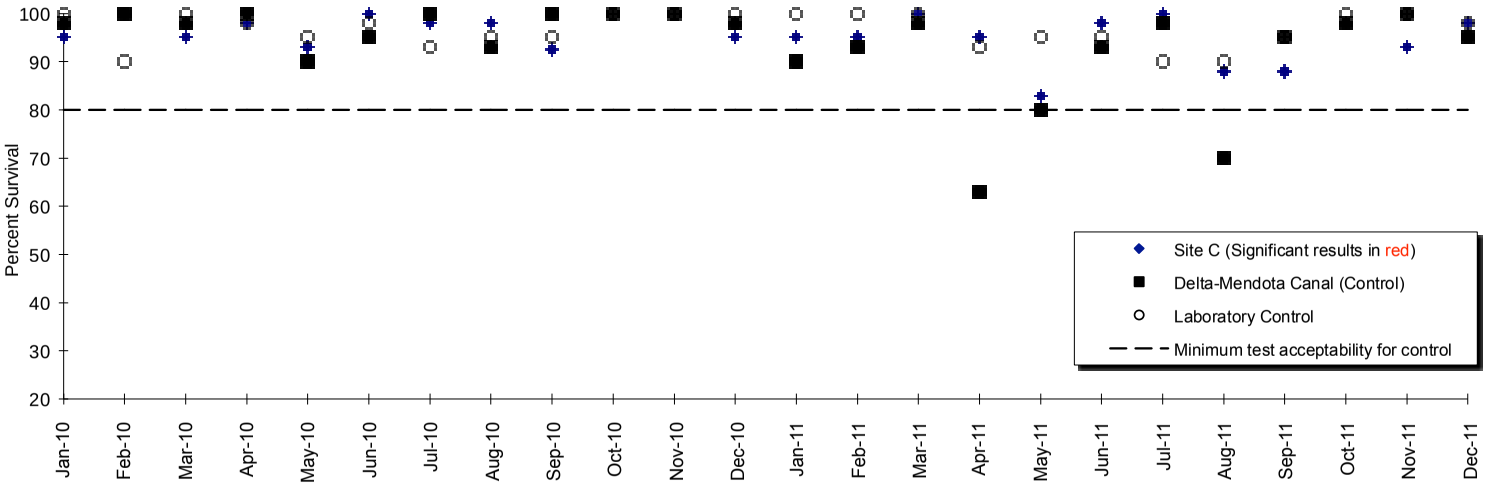


Figure 8. Site C compared to Delta-Mendota Canal – *Daphnia magna* Short-term Chronic Reproduction

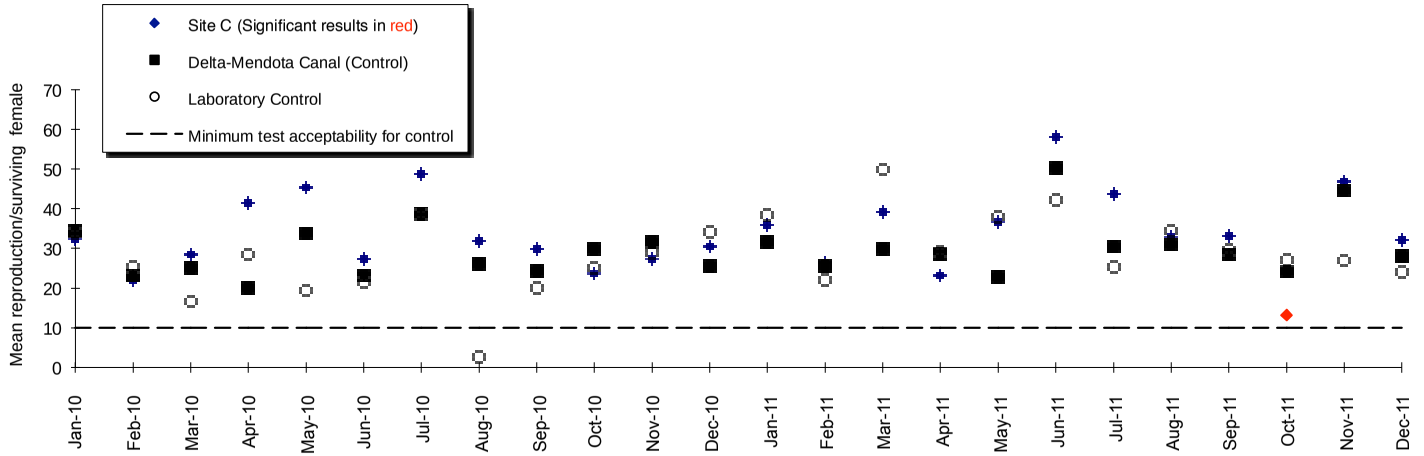


Figure 9. Site C compared to Delta-Mendota Canal – Fathead Minnow 7-Day Chronic Larval Growth

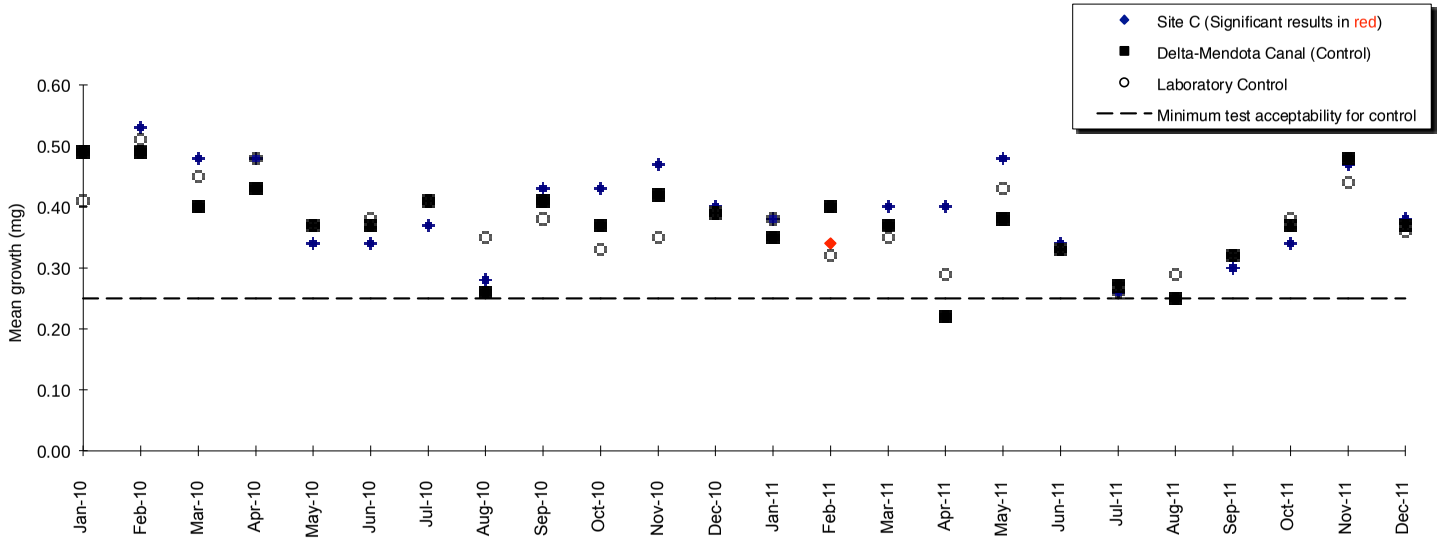


Figure 10. Site C compared to Delta-Mendota Canal – *Selenastrum capricornutum* 96-hour Growth Test

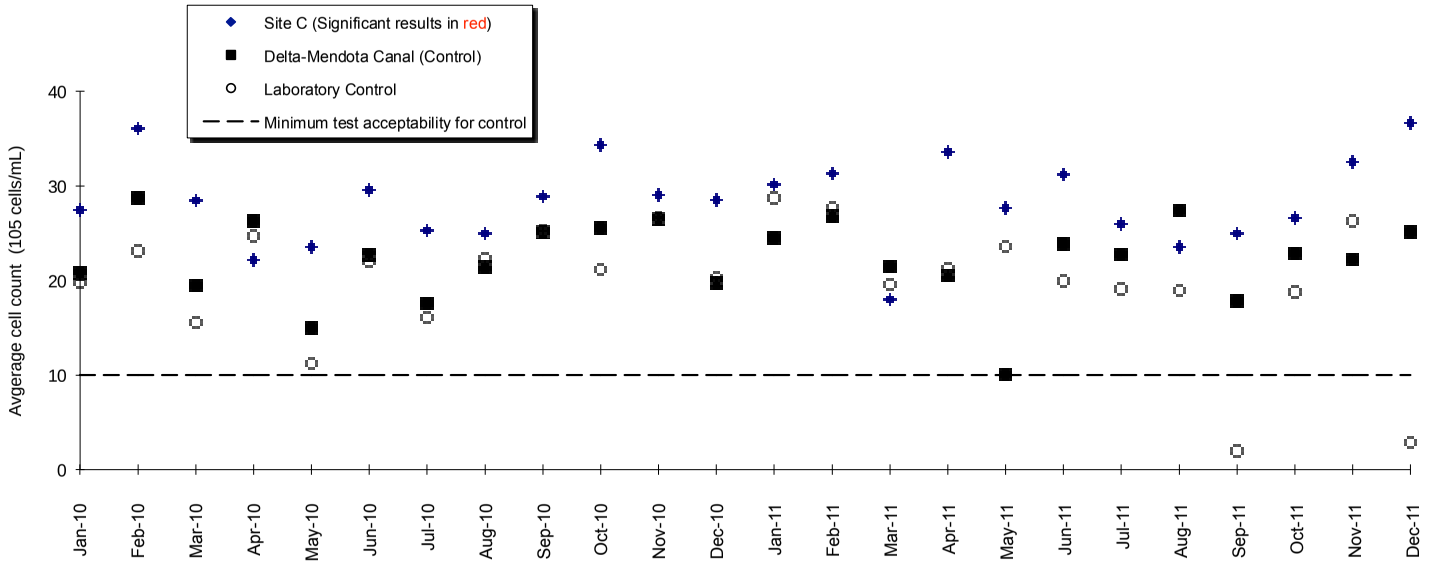


Figure 11. Site D compared to Delta-Mendota Canal – *Daphnia magna* Short-term Acute Survival

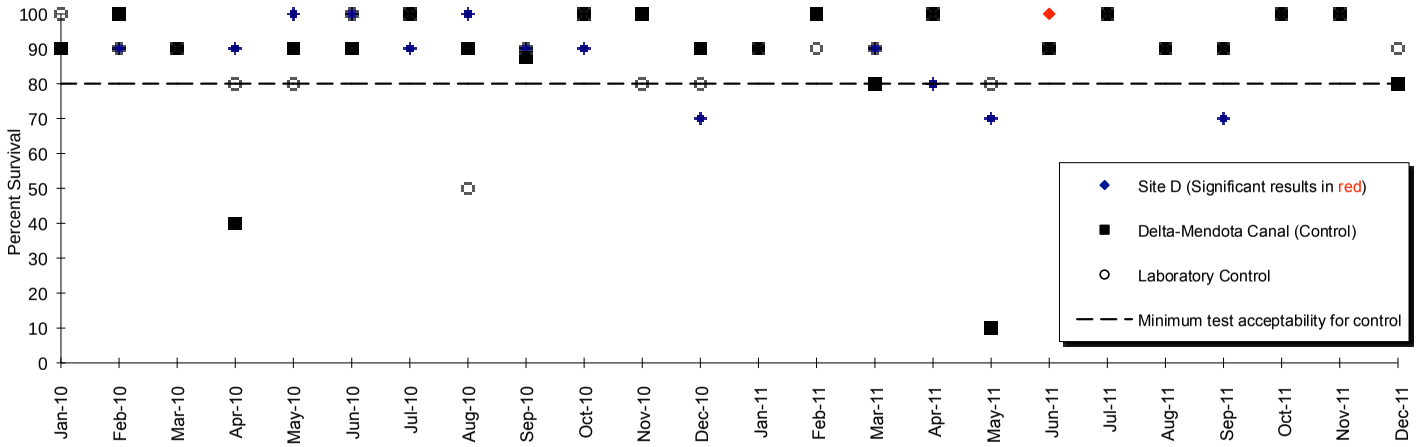


Figure 12. Site D compared to Delta-Mendota Canal – Fathead Minnow 7-Day Acute Larval Survival

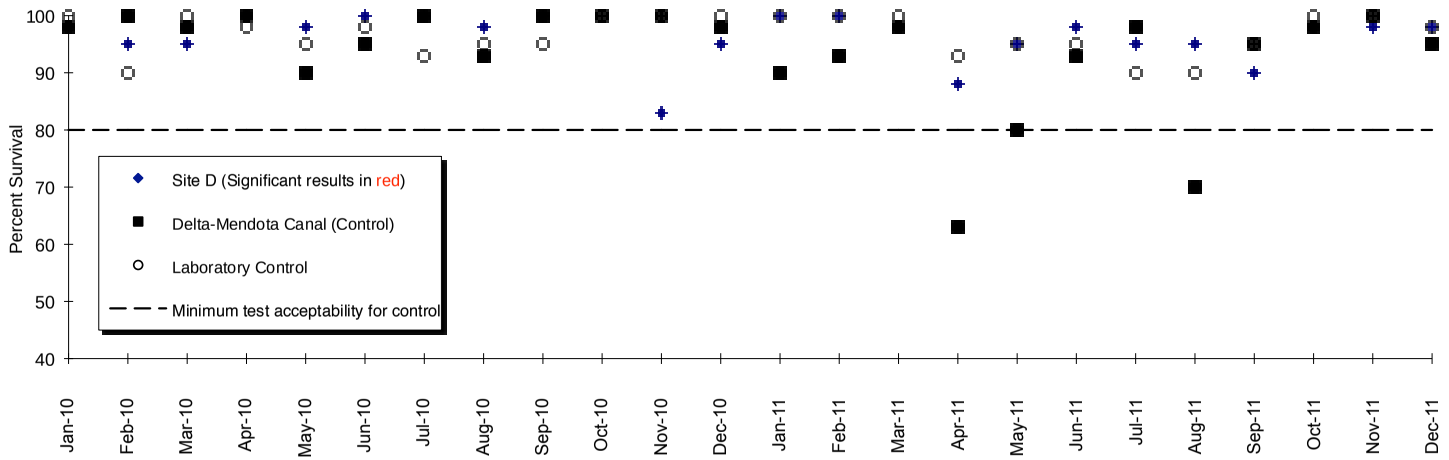


Figure 13. Site D compared to Delta-Mendota Canal – *Daphnia magna* Short-term Chronic Reproduction

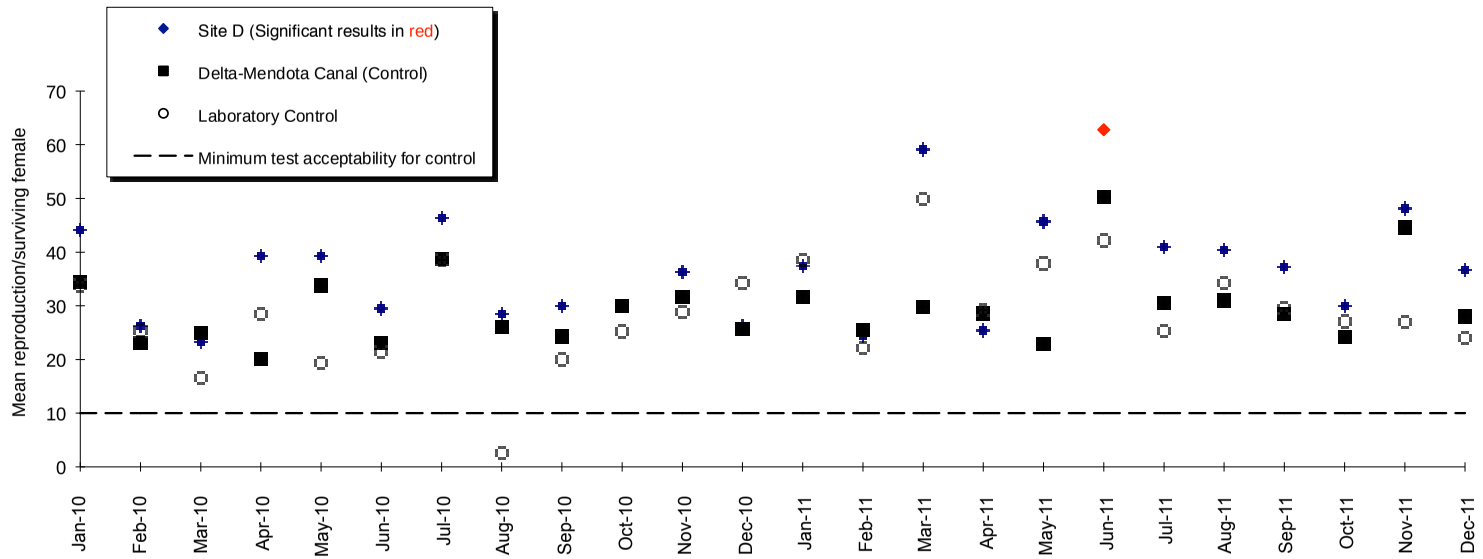


Figure 14. Site D compared to Delta-Mendota Canal – Fathead Minnow 7-Day Chronic Larval Growth

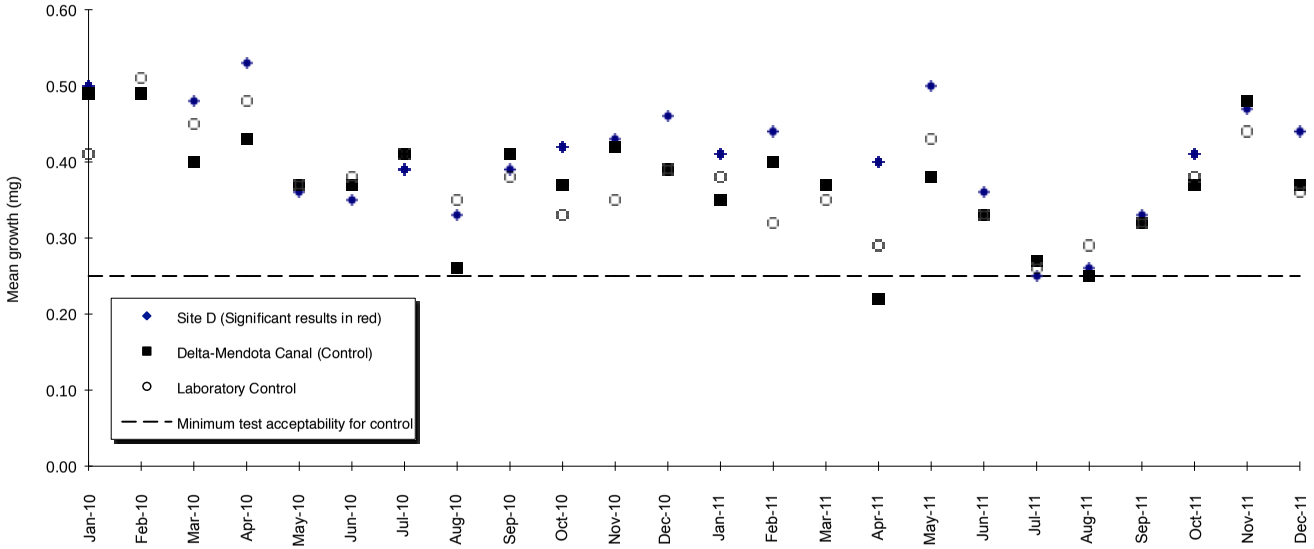


Figure 15. Site D compared to Delta-Mendota Canal – *Selenastrum capricornutum* 96-hour Growth Test

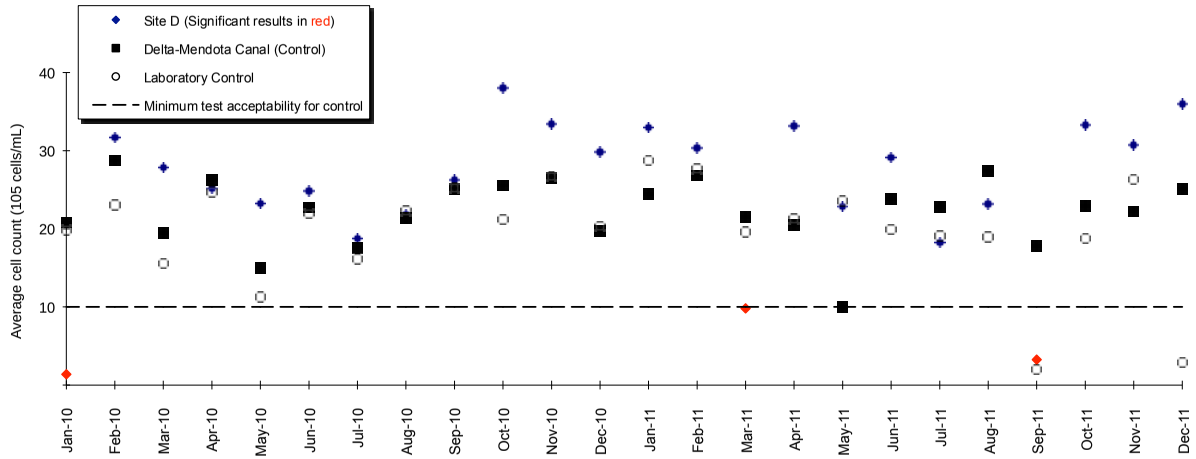


Figure 16. Site F compared to Delta-Mendota Canal – *Daphnia magna* Short-term Acute Survival

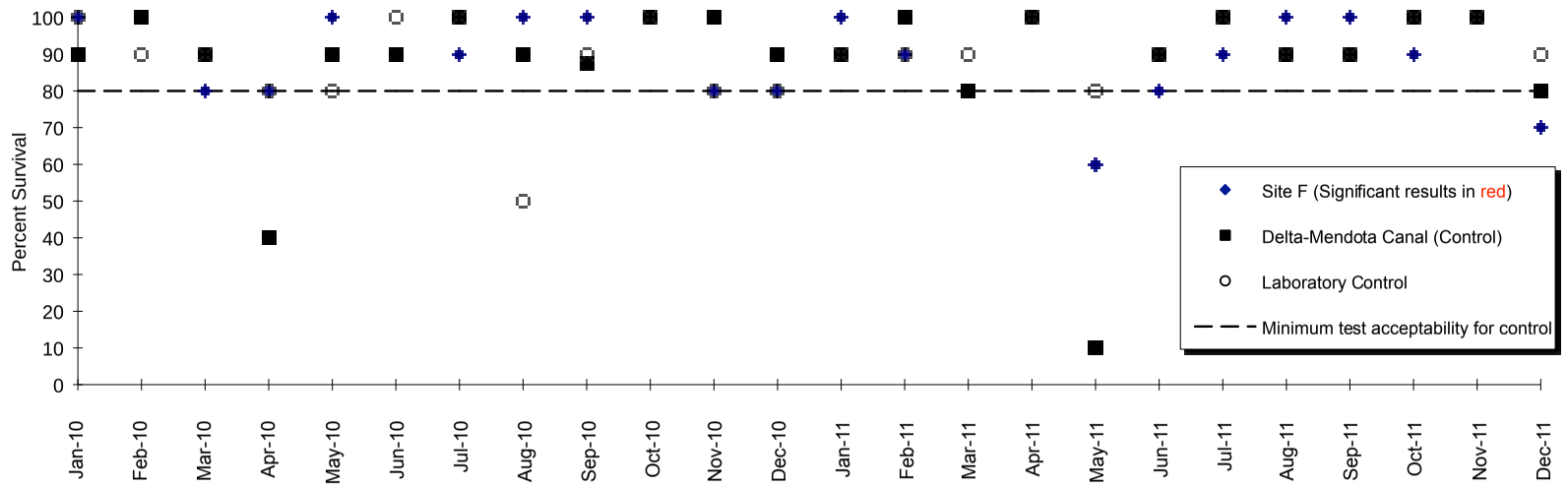


Figure 17. Site F compared to Delta-Mendota Canal – Fathead Minnow 7-Day Acute Larval Survival

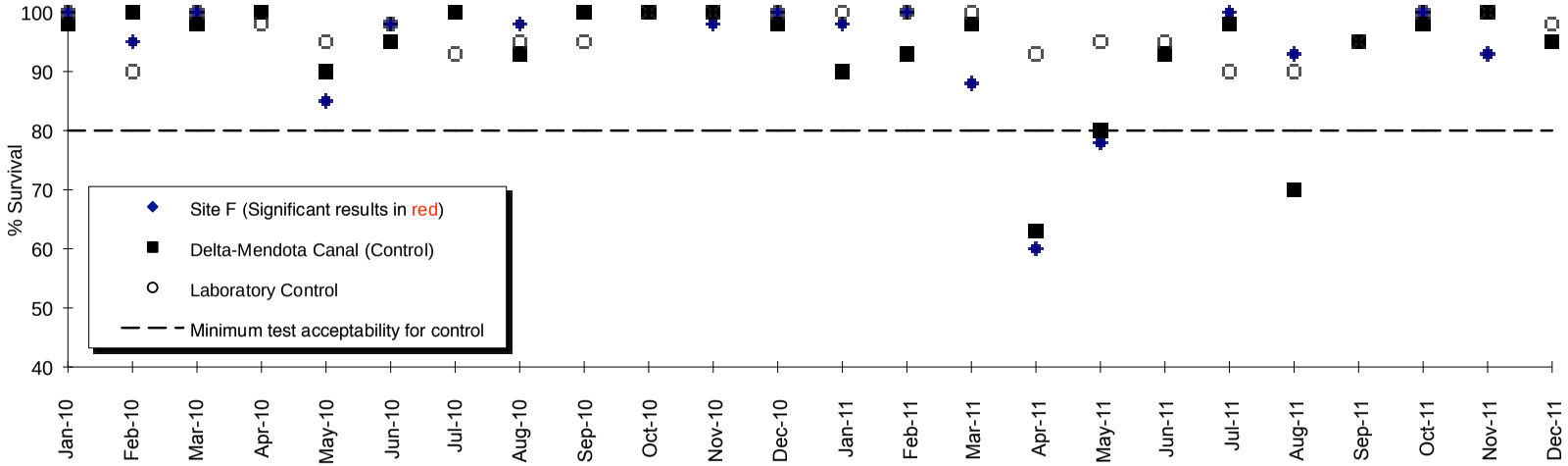


Figure 18. Site F compared to Delta-Mendota Canal – *Daphnia magna* Short-term Chronic Reproduction

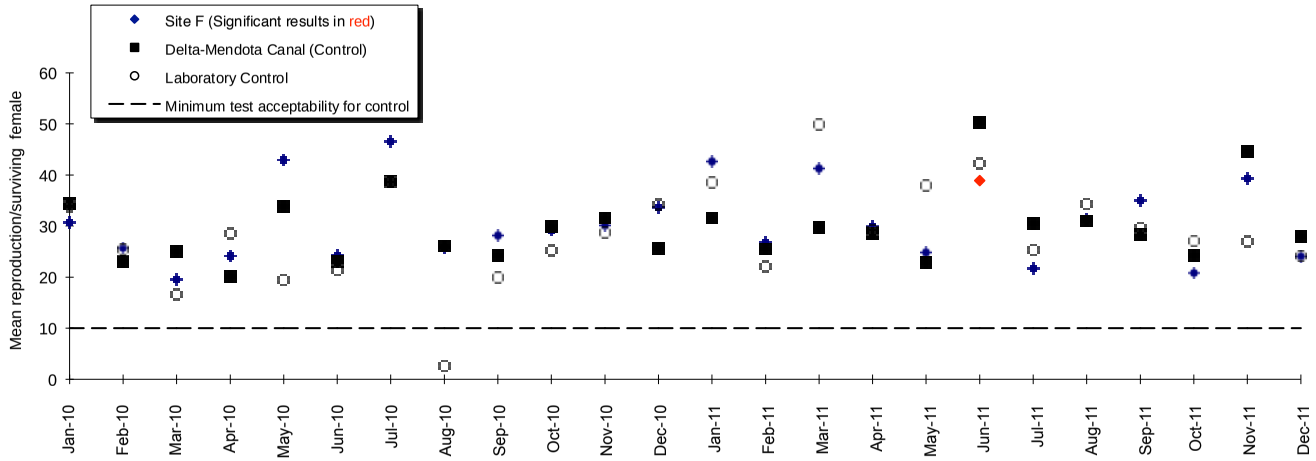


Figure 19. Site F compared to Delta-Mendota Canal – Fathead Minnow 7-Day Chronic Larval Growth

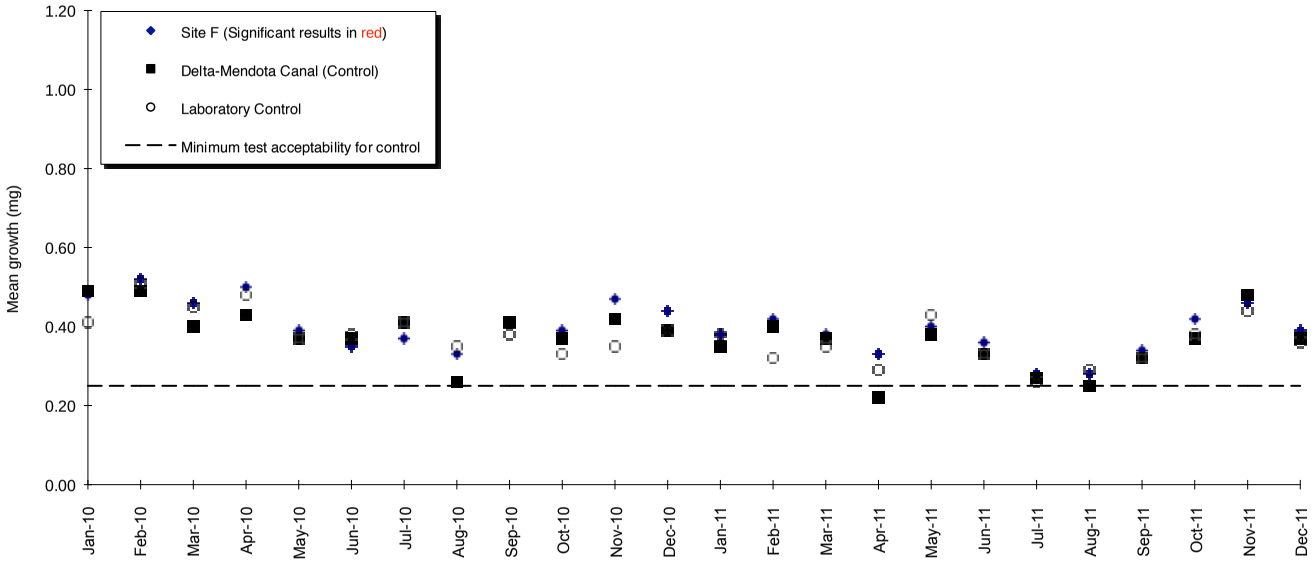


Figure 20. Site F compared to Delta-Mendota Canal – *Selenastrum capricornutum* 96-hour Growth Test

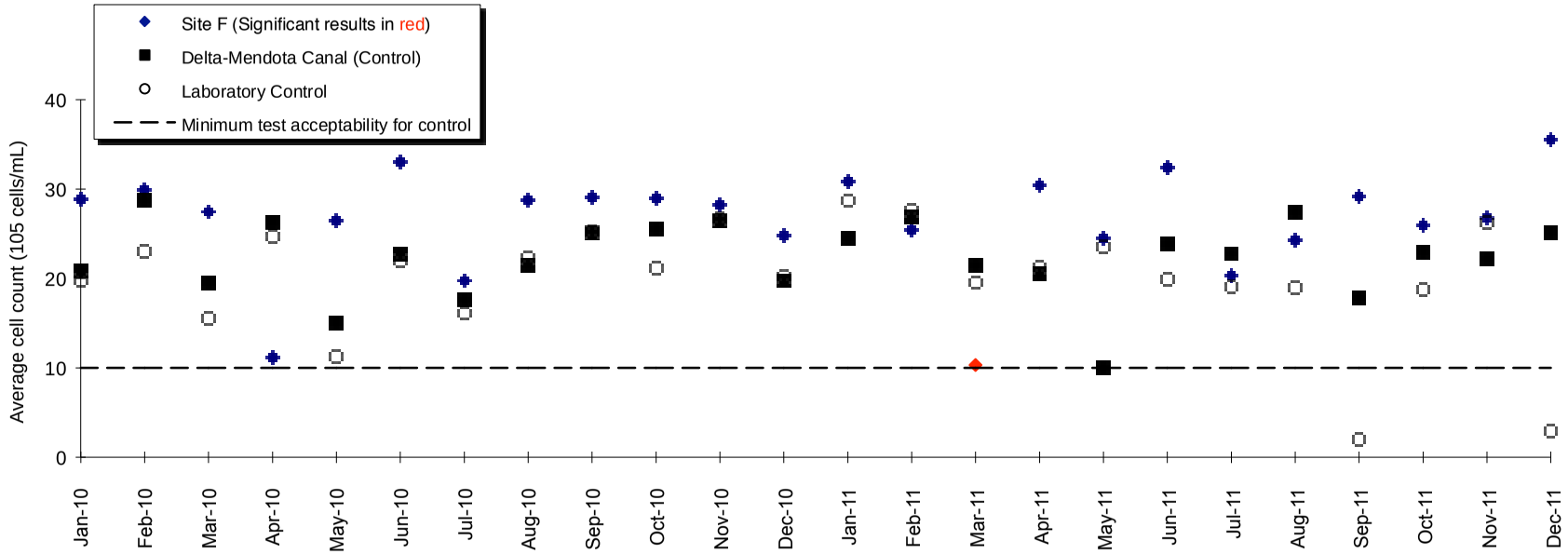


Figure 21a. Selenium concentration in site waters – San Luis Drain and Mud Slough (Sites B and D). Analyses by US Bureau of Reclamation

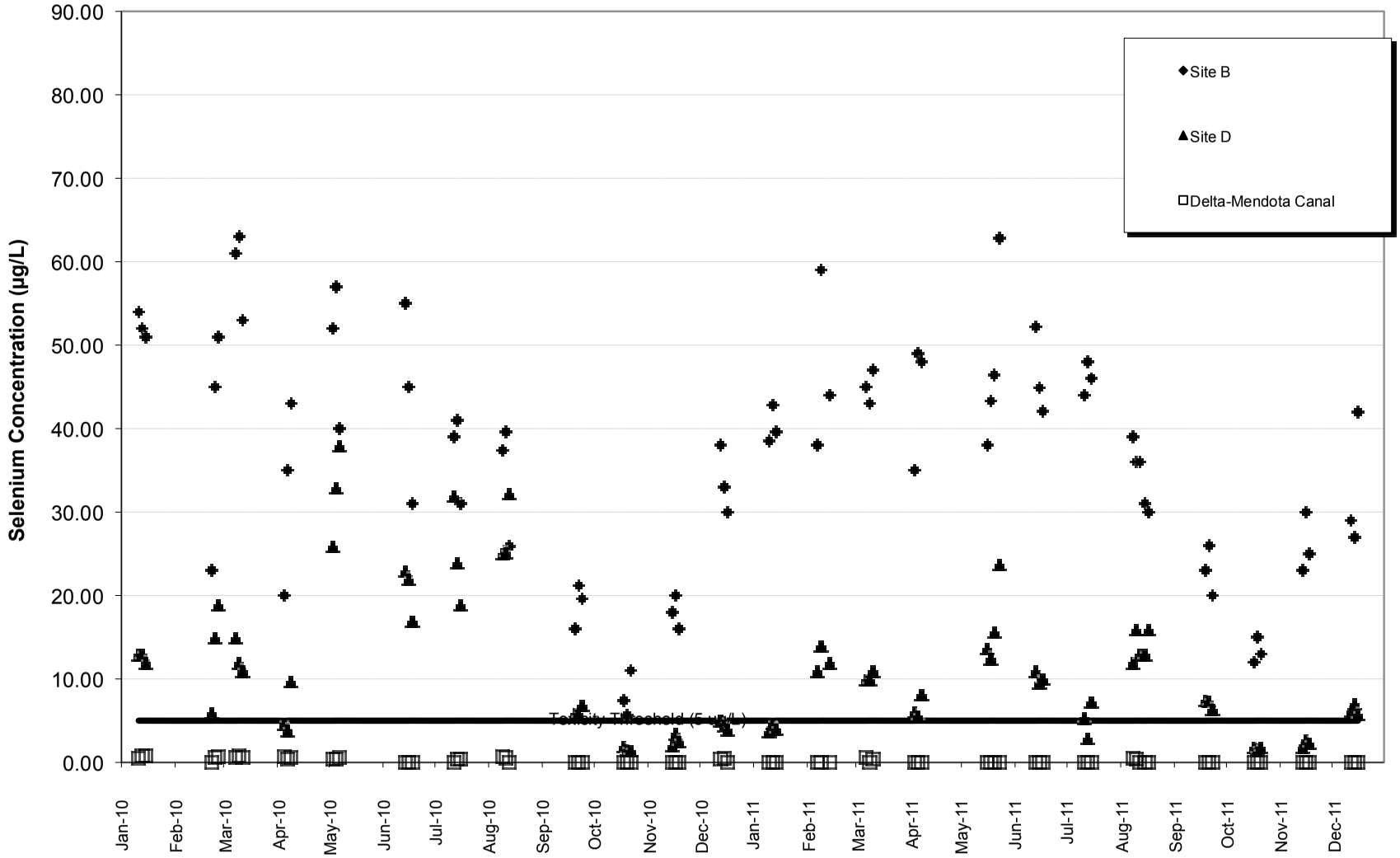
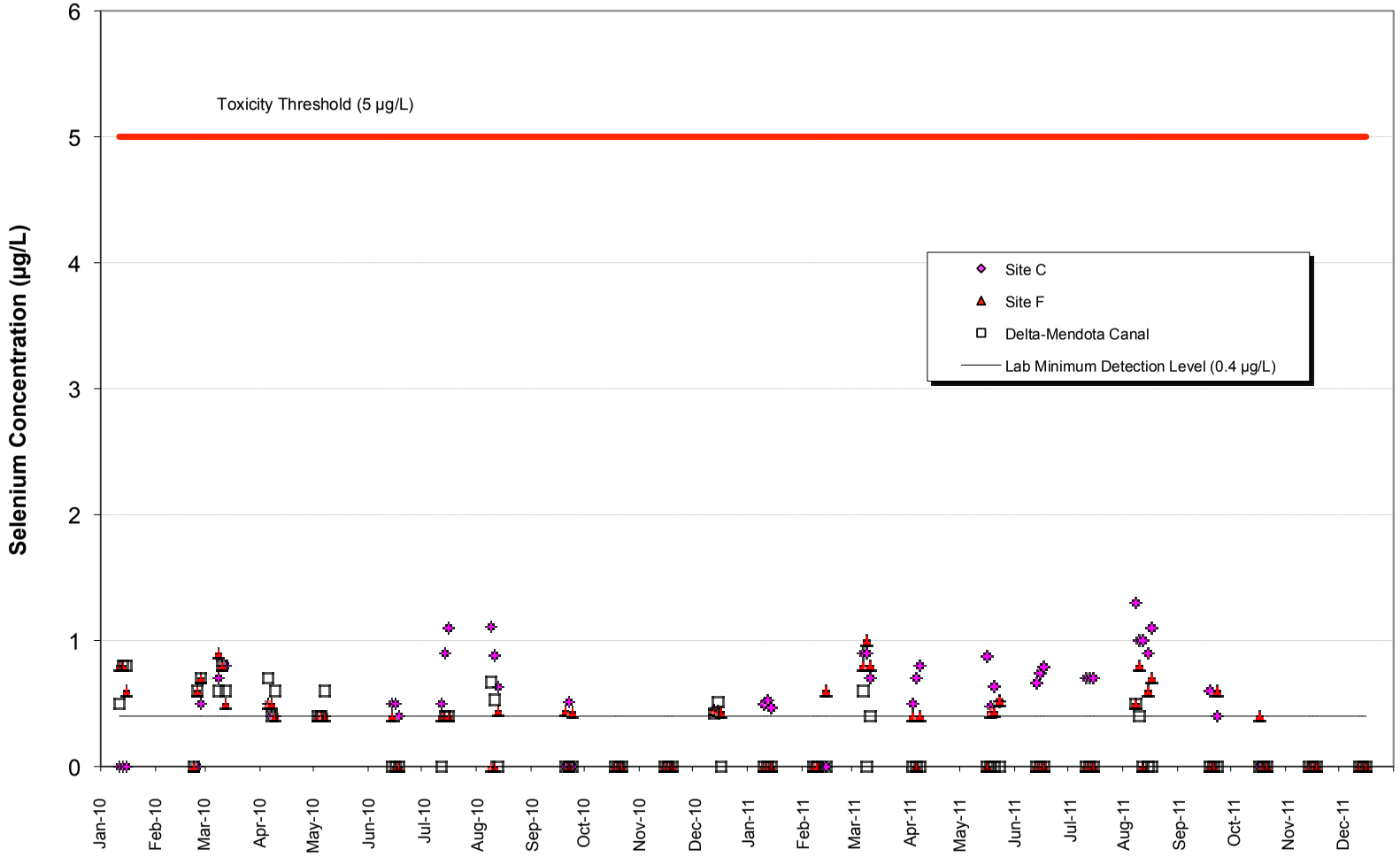


Figure 21b. Selenium concentration in site waters – Grassland Wetland Supply Channels (Sites C and F)
Analyses by US Bureau of Reclamation



GBP

CHAPTER 9

Sediment Monitoring in the San Luis Drain, Mud and Salt Sloughs

January 1, 2010 – December 31, 2011

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Grassland Bypass Project

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This chapter presents the results of measuring selenium in sediments in the San Luis Drain, Mud Slough, and Salt Slough. The Grassland Bypass Project conveys agricultural drainage water in the Drain to Mud Slough, a tributary of the San Joaquin River in central California. The Project has removed this drainage water from more than 93 miles of water supply channels, including Salt Slough, which delivers clean water to local wetlands and wildlife refuges.

Purpose

Sediment monitoring for the Grassland Bypass Project focuses on measuring selenium and organic carbon in the San Luis Drain (SLD), Mud Slough, and Salt Slough. The purpose of the monitoring is to assess the changes in selenium concentrations in the sediment during the project.

The measurements within the SLD provide selenium concentration estimates for comparison with California Department of Health Services' hazardous waste criterion.

The measurements in Mud and Salt Slough provide selenium concentrations for comparison with US Fish and Wildlife Service thresholds for ecological risk.

Guidelines (for Mud and Salt Slough)

Based on a review of 27 studies, Van Derveer and Canton[3] concluded that sedimentary selenium is a reliable predictor of adverse biological effects and that a preliminary toxic threshold existed at about 2.5 mg/kg (the 10th percentile for effects). They also noted that, in the literature they reviewed, adverse effects were always observed at selenium concentrations greater than 4.0 mg/kg in sediments[4].

For this report, the ecological risk guidelines for selenium concentrations in sediment are as follows:

"no effect"	less than 2 mg/kg, dry weight,
"level of concern"	2 to 4 mg/kg, dry weight
"toxic"	greater than 4 mg/kg, dry weight.

Criteria (for the San Luis Drain):

The State of California[5] has established a characteristic of toxicity for hazardous waste containing selenium with a concentration of 100 mg/kg(wet weight)[6]. Should the selenium concentrations in sediment from the San Luis Drain exceed this value, the sediment would be considered a hazardous material. Any material dredged from the drain would have to be deposited in a hazardous waste site.

3 Van Derveer, W. D. and S. Canton. 1997. Selenium sediment toxicity thresholds and derivation of water 1quality criteria for freshwater biota of western stream. Environ. Toxicol. Chem. 16:1260-1268.

4 National Irrigation Water Quality Program, November 1998. Information Report No. 3 - Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water, and Sediment.

5 California Code of Regulations. Title 22. Division 4.5. Chapter 11. Article 3. §66261.24 (a)(2)(A) Table II – List of Inorganic Persistent and Bioaccumulative Toxic Substances and their Soluble and Total Threshold Limit Concentration Values

6 Wet weight (mg/kg) = dry weight (mg/kg)* (1 – percent moisture/100)

Sampling Locations

Sampling locations for sediment monitoring were located at

Site C - Mud Slough upstream of the SLD discharge

Site D - Mud Slough downstream of the SLD discharge

Site I2 - a backwater in Mud Slough below the SLD discharge

Site E - Mud Slough at Highway 140

Site F - Salt Slough at Highway 165 (Lander Ave)

Twenty locations in the SLD were selected based on a probability sampling scheme associated with the amount of sediment estimated within each check. The estimated cubic yards for each check came from the annual survey made each November by the San Luis & Delta-Mendota Water Authority.

Sampling Frequency

Sediment samples were collected quarterly from the sloughs in March, June, September, and November. Samples of sediment are collected annually from the San Luis Drain in June of each year.

Sampling Methods

Sediment samples were collected using an acrylic coring device (4.5 cm diameter, 38 cm internal length). After collecting the sediment, sections of the core, 0-3 cm and 3-8 cm, were slowly extruded using a non metallic internal pushing device and placed in distinct quart sized mixing bowls. An additional sample was collected near the same spot for the whole core sample and placed into a third mixing bowl. The process was repeated at two other points across the slough. Materials from the second and third samples were placed in the corresponding 0-3 cm, 3-8 cm and whole core mixing bowls containing the first samples. Each of the mixing bowls contains material from the transect. The 0-3 cm, 3-8 cm, and whole core samples were then mixed well in their mixing bowls in a manner similar to kneading bread. The mixing objective was to obtain one homogeneous sample in each of the bowls.

Only whole core samples were collected in the San Luis Drain.

Composite samples were then placed in a wide mouth polyethylene container and stored in an ice chest at 4°C.

Results

Tables 1 through 8b show the results of sediment analysis of samples collected between 1996 and 2011 from Mud Slough, Salt Slough, and the San Luis Drain. All values are based on dry weight.

Figures 1 through 8 depict the selenium information in bar charts. **Figure 8** depicts the results of annual sediment whole core analysis at locations in the San Luis Drain.

Ecological Risk: Mud and Salt Slough

Selenium concentrations in the sediment from Mud Slough (Sites C, D, and E) and Salt Slough (Site F) continue to be below the 2.0 mg/kg "no effect level" for all samples collected during the 2010 through 2011 sampling period. The results are listed in **Tables 3, 4 and 5**, and shown in **Figures 3, 4, 5, 6a and 6b**.

Selenium concentrations in the sediment from Mud Slough Site I2 continued to exceed the 2.0 to 4.0 mg/kg "Level of Concern", and the greater than 4.0 mg/kg "Toxic Level" over the duration of the 2010 sampling period and partially in 2011. Specifically, two times for "Level of Concern", and seven for "Toxic Level". This site is a backwater that is flooded in the winter and spring. The area dries out in the summer, leaving selenium in the sediment as the water evaporates. The results are listed in **Table 7 and Figure 7a and 7b**.

Hazardous Waste Criteria: San Luis Drain

Results from the annual in-drain survey for 2010 through 2011 are depicted in **Tables 8**. In general, the concentration of selenium in sediment tends to be higher at the north end of the drain, particularly between Checks 10 and 1. During the 2010 sampling period, the highest concentration was at Check 7 with a result of 25 mg/kg, dry weight. In 2011 the highest concentration was at check 10 with a result of 34 mg/kg, dry weight. To make the comparison for hazardous waste criteria, the data needs to be converted to a wet weight basis. The formula used to make the comparison is as follows:

wet weight = (dry weight μg Se/g) * (1.0 - percent moisture/100).

The conversion for the values of 51 ug/L (38.6% moisture) at Check 2, and 42 ug/L (45.1% moisture) at Check 4, provide wet weight concentrations of 31.3 and 23.0 ug/g, respectively. Both are well below the hazardous waste criteria of 100 mg/kg.

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Table 1. San Luis Drain (Station A) Sediment Monitoring Results

	Selenium Concentration			Organic Carbon			Percent Moisture		
Sampling Date	0-3 cm mg/kg, dry weight	3-8 cm mg/kg, dry weight	Whole Core mg/kg, dry weight	0-3 cm %	3-8 cm %	Whole Core %	0-3 cm %	3-8 cm %	Whole Core %
Jun-09-2010			1.8			0.59			37.8
Nov-09-2011			2.3			0.49			34.6
Summary data, March 1996 - present									
Maximum	43.0	150.0	98.0	4.4	5.0	4.1	83.8	79.1	80.5
Minimum	2.0	2.4	1.8	0.6	0.8	0.4	35.2	44.4	34.6
Median	3.2	15.5	6.4	1.2	1.5	1.2	55.0	59.1	52.4
Average	11.5	31.5	19.4	1.7	1.9	1.5	59.5	59.6	55.0
Count	20	20	30	20	20	30	19	19	28

Notes:
All samples collected by the US Bureau of Reclamation, Sacramento CA
March - September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - March 2010 samples analyzed by the US Geological Survey, Lakewood CO
After June 2010, samples analyzed by Cal Dept Fish and Game lab, Rancho Cordova CA for selenium and percent moisture; and by California Lab Services, Rancho Cordova CA for total organic carbon.

Table 2. San Luis Drain near terminus (Station B) Sediment Monitoring Results

	Selenium Concentration			Organic Carbon			Percent Moisture		
Sampling Date	0-3 cm mg/kg, dry weight	3-8 cm mg/kg, dry weight	Whole Core mg/kg, dry weight	0-3 cm %	3-8 cm %	Whole Core %	0-3 cm %	3-8 cm %	Whole Core %
Jun-10-2010			4.2			3.20			29.0
Nov-08-2011			12.0			0.73			49.3
Summary data, June 1996 - present									
Maximum	65.0	61.0	110.0	3.9	3.8	3.5	85.9	80.8	72.7
Minimum	11.0	12.0	4.2	0.7	1.0	0.1	31.5	44.2	0.0
Median	18.0	28.0	23.5	1.7	1.9	1.6	58.8	55.6	55.1
Average	21.3	30.5	27.9	1.8	2.1	1.6	57.7	58.5	51.9
Count	17	17	26	17	17	27	15	15	25

Notes:
All samples collected by the US Bureau of Reclamation, Sacramento CA
March - September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - March 2010 samples analyzed by the US Geological Survey, Lakewood CO
After June 2010, samples analyzed by Cal Dept Fish and Game lab, Rancho Cordova CA for selenium and percent moisture; and by California Lab Services, Rancho Cordova CA for total organic carbon.

Table 3. Mud Slough above drainage discharge (Station C): Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm mg/kg, dry weight	3-8 cm mg/kg, dry weight	Whole Core mg/kg, dry weight	0-3 cm %	3-8 cm %	Whole Core %	0-3 cm %	3-8 cm %	Whole Core %
Mar-16-2010	<0.10	<0.10	<0.10	0.16	0.25	0.38	28.1	28.3	34.0
Jun-10-2010	<0.27	<0.27	<0.30	0.24	0.39	0.45	25.6	26.2	32.5
Sep-23-2010	<0.11	<0.13	<0.15	0.62	0.24	0.57	16.4	18.0	31.3
Dec-07-2010	<0.15	0.19	0.29	0.28	0.76	0.44	31.3	39.6	28.9
Mar-08-2011	<0.14	<0.15	0.30	0.31	0.19	0.81	32.2	25.9	36.7
Nov-08-2011			<0.13			0.38			27.5
Summary data, May 1996 - present									
Maximum	3.90	0.59	0.62	2.08	1.69	1.78	45.2	61.9	65.5
Minimum	0.05	0.05	0.05	0.02	0.07	0.07	16.2	17.3	19.3
Median	0.11	0.10	0.10	0.31	0.29	0.34	29.9	28.3	29.1
Average	0.23	0.15	0.16	0.40	0.36	0.43	30.0	29.7	30.4
Count	59	59	60	59	59	60	57	57	58

Notes:
All samples collected by the US Bureau of Reclamation, Sacramento CA
March - September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - March 2010 samples analyzed by the US Geological Survey, Lakewood CO
After June 2010, samples analyzed by Cal Dept Fish and Game lab, Rancho Cordova CA for selenium and percent moisture; and by California Lab Services, Rancho Cordova CA for total organic carbon.

Table 4. Mud Slough below drainage discharge (Station D): Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm mg/kg, dry weight	3-8 cm mg/kg, dry weight	Whole Core mg/kg, dry weight	0-3 cm %	3-8 cm %	Whole Core %	0-3 cm %	3-8 cm %	Whole Core %
Mar-16-2010	0.10	0.17	0.14	0.20	0.15	0.06	19.0	24.0	16.9
Jun-10-2010	<0.27	<0.26	<0.28	0.18	0.19	0.18	26.2	20.6	26.5
Sep-23-2010	0.15	0.14	0.17	0.22	0.15	0.13	19.5	17.9	17.2
Dec-07-2010	0.28	0.30	0.32	0.06	0.11	0.08	19.1	18.9	26.9
Mar-08-2011	0.30	0.23	0.23	0.01	0.02	0.05	26.4	23.9	20.7
Nov-08-2011			0.14			0.07			27.0
Summary data, April 1996 - present									
Maximum	1.80	1.20	1.30	1.23	1.10	0.85	76.50	38.80	39.80
Minimum	0.05	0.05	0.05	0.01	0.01	0.01	16.50	16.60	16.20
Median	0.25	0.20	0.20	0.15	0.15	0.16	25.90	23.90	23.50
Average	0.31	0.25	0.27	0.21	0.21	0.19	27.42	24.23	24.10
Count	59	59	60	59	59	60	56	56	57

Notes:
All samples collected by the US Bureau of Reclamation, Sacramento CA
March - September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - March 2010 samples analyzed by the US Geological Survey, Lakewood CO
After June 2010, samples analyzed by Cal Dept Fish and Game lab, Rancho Cordova CA for selenium and percent moisture; and by California Lab Services, Rancho Cordova CA for total organic carbon.

Table 5. Mud Slough at Highway 140 (Station E): Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm mg/kg, dry weight	3-8 cm mg/kg, dry weight	Whole Core mg/kg, dry weight	0-3 cm %	3-8 cm %	Whole Core %	0-3 cm %	3-8 cm %	Whole Core %
Mar-16-2010	0.54	1.34	1.59	0.37	0.48	0.56	33.2	24.2	36.4
Jun-10-2010									
Sep-23-2010	0.73	0.30	0.73	0.19	0.07	0.24	24.1	25.5	24.0
Dec-07-2010	1.83	1.89	1.44	0.45	0.57	0.31	36.2	40.6	37.4
Mar-08-2011	1.90	1.40	0.69	0.84	0.77	0.72	43.4	50.2	33.0
Nov-08-2011			0.30			0.55			28.6
Summary Data, May 1996 - present									
Maximum	1.90	2.00	1.90	1.08	1.00	1.02	44.7	50.2	49.7
Minimum	0.10	0.10	0.10	0.07	0.07	0.06	16.8	17.5	8.2
Median	0.56	0.51	0.64	0.30	0.30	0.31	31.4	29.6	30.4
Average	0.67	0.69	0.74	0.35	0.36	0.39	31.9	30.4	31.7

Notes:
All samples collected by the US Bureau of Reclamation, Sacramento CA
March - September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - March 2010 samples analyzed by the US Geological Survey, Lakewood CO
After June 2010, samples analyzed by Cal Dept Fish and Game lab, Rancho Cordova CA for selenium and percent moisture; and by California Lab Services, Rancho Cordova CA for total organic carbon.

Table 6. Salt Slough at Highway 165 (Station F): Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm mg/kg, dry weight	3-8 cm mg/kg, dry weight	Whole Core mg/kg, dry weight	0-3 cm %	3-8 cm %	Whole Core %	0-3 cm %	3-8 cm %	Whole Core %
Mar-16-2010	<0.10	<0.10	0.22	0.42	0.47	0.51	25.8	25.0	23.2
Jun-10-2010	0.34	0.51	0.31	0.08	0.06	0.36	28.1	27.4	30.1
Sep-23-2010	0.67	0.40	0.40	0.33	0.24	0.09	27.6	21.2	20.1
Dec-07-2010	0.15	0.26	<0.41	0.25	0.64	0.86	28.4	32.2	53.4
Mar-08-2011									
Nov-08-2011			<0.14			0.10			30.8
Summary data, June 1996 - present									
Maximum	2.10	1.90	1.60	2.32	1.97	2.11	47.3	70.0	53.4
Minimum	0.10	0.10	0.14	0.05	0.06	0.05	20.8	18.9	17.9
Median	0.36	0.45	0.46	0.29	0.25	0.26	28.4	27.7	27.0
Average	0.43	0.49	0.51	0.40	0.35	0.36	30.0	29.1	27.8

Notes:
All samples collected by the US Bureau of Reclamation, Sacramento CA
March - September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - March 2010 samples analyzed by the US Geological Survey, Lakewood CO
After June 2010, samples analyzed by Cal Dept Fish and Game lab, Rancho Cordova CA for selenium and percent moisture; and by California Lab Services, Rancho Cordova CA for total organic carbon.

Table 7. Mud Slough backwater (Station I and I2): Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core
	mg/kg, dry weight	mg/kg, dry weight	mg/kg, dry weight	%	%	%	%	%	%
Mar-16-2010	8.41	3.60	3.49	3.65	2.33	2.18	61.3	50.9	54.0
Jun-10-2010	4.28	4.92	4.44	2.20	2.10	2.00	56.1	59.1	59.4
Sep-23-2010	7.78	7.74	4.42	4.40	4.40	3.50	59.6	59.3	52.3
Dec-07-2010									
Mar-08-2011	0.46	0.38	0.32	0.52	0.51	0.30	31.80	28.40	27.40
Nov-08-2011	na	na	6.90	na	na	3.00	na	na	53.90
Summary data, June 1996 - present									
Maximum	15.00	11.00	8.80	4.40	4.40	3.50	67.6	62.3	59.4
Minimum	0.16	0.20	0.20	0.26	0.28	0.14	4.1	13.1	20.1
Median	4.80	4.50	3.05	2.01	2.02	1.80	50.6	48.2	48.6
Average	4.89	4.08	3.34	2.02	1.91	1.76	45.0	42.9	42.7

Notes:
All samples collected by the US Bureau of Reclamation, Sacramento CA
March - September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - March 2010 samples analyzed by the US Geological Survey, Lakewood CO
After June 2010, samples analyzed by Cal Dept Fish and Game lab, Rancho Cordova CA for selenium and percent moisture; and by California Lab Services, Rancho Cordova CA for total organic carbon.

Table 8a. Annual sediment sampling in the San Luis Drain, June 2010

San Luis Drain Check Number	San Luis Drain Mile Post	Landmark	Volume survey results Nov-09			Sample Selection (2)			Sediment Analysis (5) 2010			
			Miles Between Checks	Estimated Cubic Yards (1)	Accumulated Cubic yards	Sample Allocation 20 samples (3)	n = 20 Sample Numbers (3)	Selected "cubic yard" (3)	Sampling Date (4)	Selenium Concentration Whole Core mg/kg, dry weight	Total Organic Carbon Whole Core %	Percent Moisture Whole Core %
0	78.64	Terminus at Mud Slough	2.64	10,975	10,975	1	1	8,500	6/10/10	9.1	2.3	63.4
	80.64	Station B							6/10/10	4.2	3.2	29.0
1	81.28	Gun Club Road	1.82	11,888	22,863	2	2	20,586				
2	83.10	Hwy 165	0.28	3,516	26,379	3	3	32,671				
3	83.38		2.57	16,050	42,429	4	4	44,757				
4	85.95		1.80	18,676	61,105	5	5	56,842	6/10/10	19	2.6	57.8
	85.97					6	6	68,928	6/10/10	9.3	2.8	63.3
5	87.75	Wolfsen Road	2.06	12,809	73,914							
6	89.81		0.83	5,289	79,203							
7	90.64		0.45	3,073	82,276				6/10/10	25	2.4	67.7
8	91.09	Henry Miller Road	0.47	3,891	86,167							
9	91.56	Santa Fe Canal	3.20	16,376	102,543	7	7	81,013				
10	94.76	Hwy 152	1.46	9,413	111,956	8	8	93,099	6/10/10	8.4	1.5	62
11	96.22		2.50	30,654	142,610	9	9	105,184				
12	98.72		0.46	7,004	149,614	10	10	117,270	6/10/10	4.7	0.88	55.1
	98.74								6/10/10	4.3	0.74	53.8
13	99.18	Sierra Gun Club Rd	0.91	18,220	167,834	11	11	129,355	6/9/10	4.6	0.51	51.6
	99.20					12	12	141,441	6/9/10	3.9	1.3	51.2
	99.22					13	13	153,526				

Table 8a. Annual sediment sampling in the San Luis Drain, June 2010 (cont.)

San Luis Drain Check Number	San Luis Drain Mile Post	Landmark	Volume survey results Nov-09			Sample Selection (2)			Sediment Analysis (5) 2010			
			Miles Between Checks	Estimated Cubic Yards (1)	Accumulated Cubic yards	Sample Allocation 20 samples (3)	n = 20 Sample Numbers (3)	Selected "cubic yard" (3)	Sampling Date (4)	Selenium Concentration Whole Core mg/kg, dry weight	Total Organic Carbon Whole Core %	Percent Moisture Whole Core %
15	101.43	Torchina Grade	0.96	17,411	208,903	17	17	201,868	6/9/10	2.7	1.20	54.1
	101.45								6/9/10	5.8	1.30	36.9
	101.47								6/9/10	3.6	1.40	44.8
16	102.39		1.68	22,225	231,128	18	18	213,954	6/9/10	2.9	1.00	42.6
17	104.07		0.68	6,462	237,590	19	19	226,039	6/9/10	2.1	0.76	36.1
	104.09								6/9/10	1.8	0.59	37.8
18	104.75	Aqua Vista Rd	0.97	4,120	241,710	20	20	238,125				
	104.76	Station A										
19	105.72	Russell Avenue										
Total			27.08	241,710								

Notes: (1) Sediment volume and distribution measured by San Luis and Delta-Mendota Water Authority, November 2009 revised: 20 Apr 2011

(2) Sampling program designed by Bob Young, US Bureau of Reclamation

(3) Sampling interval using 20 samples 12,086 feet

(4) All samples collected by the US Bureau of Reclamation, Sacramento CA

(5) All samples analyzed by the Cal Dept Fish and Game Lab, Rancho Cordova CA (Selenium & Percent moisture) and CLS, Rancho Cordova CA (Total organic carbon)

Table 8b. Annual sediment sampling in the San Luis Drain, June 2011

San Luis Drain Check Number	San Luis Drain Mile Post	Landmark	Miles Between Checks	Volume survey results Oct-10			Sample Selection (2)		Sediment Analysis (5) 2011			
				Estimated Cubic Yards (1)	Accumulated Cubic yards		n = 20 Sample Numbers (3)	Selected "cubic yard" (3)	Sampling Date (4)	Selenium Concentration Whole Core mg/kg, dry weight	Total Organic Carbon Whole Core %	Percent Moisture Whole Core %
0	78.64	Terminus at Mud Slough	2.64	11,978	11,978	4,537		6,343				
	79.15	0.5 M south of terminus					1	19,029				
	80.64	Station B							11/8/11	12	0.73	49.3
1	81.28	Gun Club Road	1.82	12,965	24,943	13,705						
2	83.10	Hwy 165	0.28	3,823	28,766	102,736						
	83.27	0.25 M south of Check 2					2	31,715				
	83.00	0.4 M North of Check 3					3	44,402				
3	83.38		2.57	15,700	44,466	17,302						
	83.74	0.4 M south of Check 3					4	57,088				
4	85.95		1.80	18,673	63,139	35,077			11/8/11	19	3.10	51.4
	86.13	0.2 M south of Check 4					5	69,774	11/8/11	5.2	2.90	66.2
5	87.75	Wolfsen Road	2.06	13,129	76,268	37,023						
6	89.81		0.83	5,750	82,018	98,817						
	89.81	0.1 M south of Check 6					6	82,460				
7	90.64		0.45	3,407	85,425	189,833			11/8/11	3.8	2.20	50.8
8	91.09	Henry Miller Road	0.47	4,343	89,768	190,995						
	91.25	0.2 M south of Check 8					7	95,146				
	91.63	0.4 M south of Check 8					8	107,833				
9	91.56	Santa Fe Canal	3.20	18,193	107,960	33,738						
10	94.76	Hwy 152	1.46	10,072	118,032	80,844			11/9/11	34	3.90	64
	94.80	0.1 M south of Check 10					9	120,519				
	95.01	0.3 M south of Check 10					10	133,205				
	95.21	0.5 M south of Check 10					11	145,891				
11	96.22		2.50	35,751	153,783	61,513						
	96.23	0.1 M south of Check 11					12	158,577				
12	98.72		0.46	7,192	160,975	349,945			11/9/11	6.2	3.00	55.4
	98.77	0.1 M south of Check 12					13	171,264	11/9/11	4.1	2.10	53.1
	98.84	0.2 M South of Check 12					14	183,950				
	98.90	0.3 M south of Check 12					15	196,636				
13	99.18	Sierra Gun Club Rd	0.91	18,616	179,590	197,352			11/9/11	7.2	3.20	48.2
	99.20								11/9/11	3.4	1.50	50.2

Table 8b. Annual sediment sampling in the San Luis Drain, June 2011 (cont.)

San Luis Drain Check Number	San Luis Drain Mile Post	Landmark	Miles Between Checks	Volume survey results Oct-10			Sample Selection (2)		Sediment Analysis (5) 2011			
				Estimated Cubic Yards (1)	Accumulated Cubic yards		n = 20 Sample Numbers (3)	Selected "cubic yard" (3)	Sampling Date (4)	Selenium Concentration Whole Core mg/kg, dry weight	Total Organic Carbon Whole Core %	Percent Moisture Whole Core %
14	100.09		1.34	24,083	203,673	151,995			11/9/11	16	2.60	54.4
	100.11	0.1 M south of Check 14					16	209,322	11/9/11	4.1	1.70	48.1
	100.17	0.2 M south of Check 14					17	222,008				
15	101.43	Torchina Grade	0.96	17,422	221,096	230,308			11/9/11	6.7	2.30	54.7
	101.52	0.1 M south of Check 15					18	234,695	11/9/11	3.5	1.20	38.5
16	102.39		1.68	22,403	243,498	144,939			11/9/11	2.6	0.84	36
	102.40	0.1 M south of Check 16					19	247,381				
17	104.07		0.68	6,401	249,899	367,499			11/9/11	2.3	0.49	34.6
									11/9/11	2.1	0.35	33.2
18	104.75	Aqua Vista Rd	0.97	3,825	253,724	261,571						
	104.76	Station A										
	104.85	footbridge south of Check 18					20	253,724				
19	105.72	Russell Avenue										
		Site B-2							11/8/11	14.0	0.53	69.4
Total			27.08	253,724								

Notes:
(1) Sediment volume and distribution measured by San Luis and Delta-Mendota Water Authority, November 2009 — revised: 01 June 2012
(2) Sampling program designed by Bob Young, US Bureau of Reclamation
(3) Sampling interval using 20 samples 12,686 feet
(4) All samples collected by the US Bureau of Reclamation, Sacramento CA
(5) All samples analyzed by the Cal Dept Fish and Game Lab, Rancho Cordova CA (Selenium & Percent moisture) and CLS, Rancho Cordova CA (Total organic carbon)

Figure 1. Selenium in Sediment in the San Luis Drain at Station A

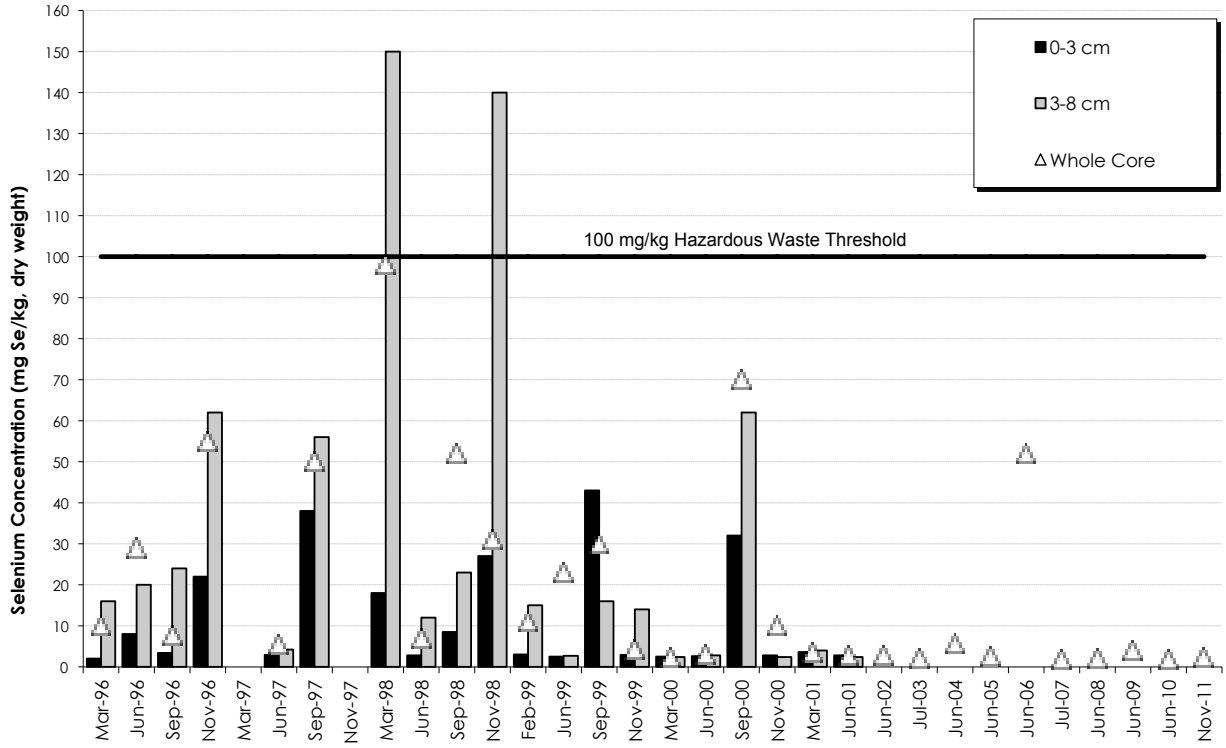


Figure 2. Selenium in Sediment in the San Luis Drain at Station B

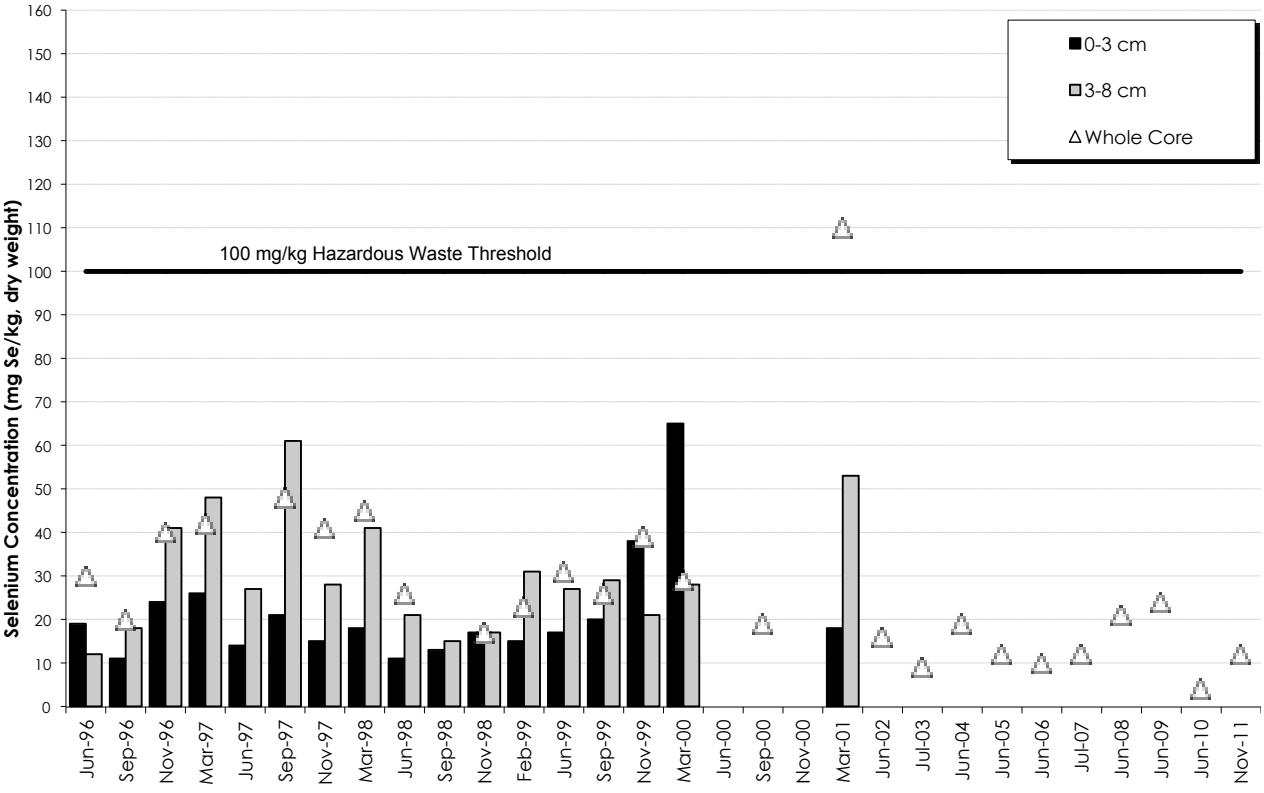


Figure 3. Selenium in Sediment in Mud Slough at Station C

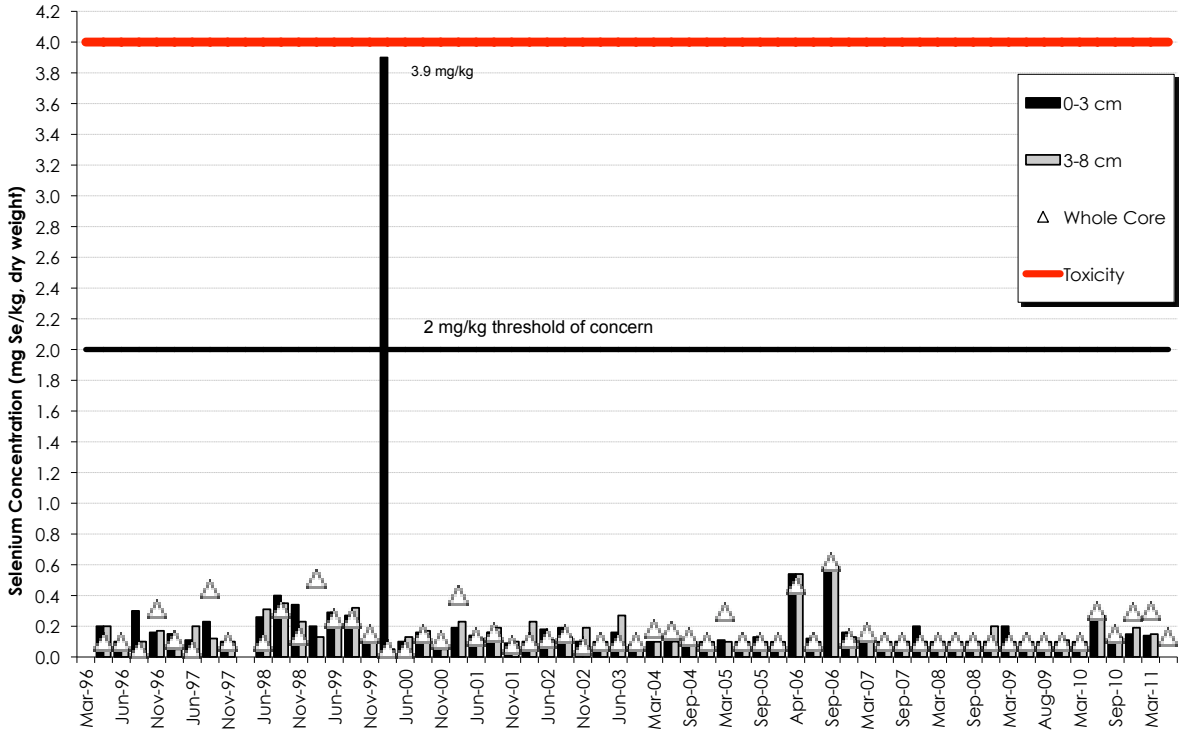


Figure 4. Selenium in Sediment in Mud Slough at Station D

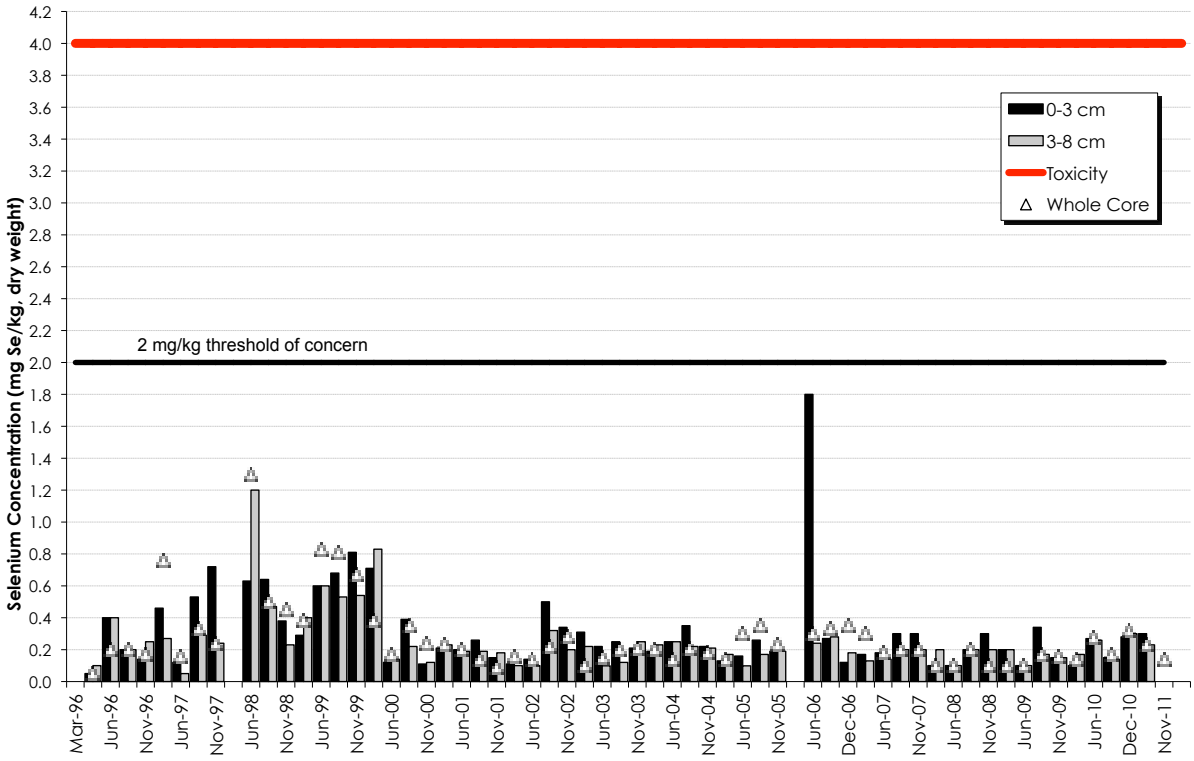


Figure 5. Selenium in Sediment in Mud Slough at Station E

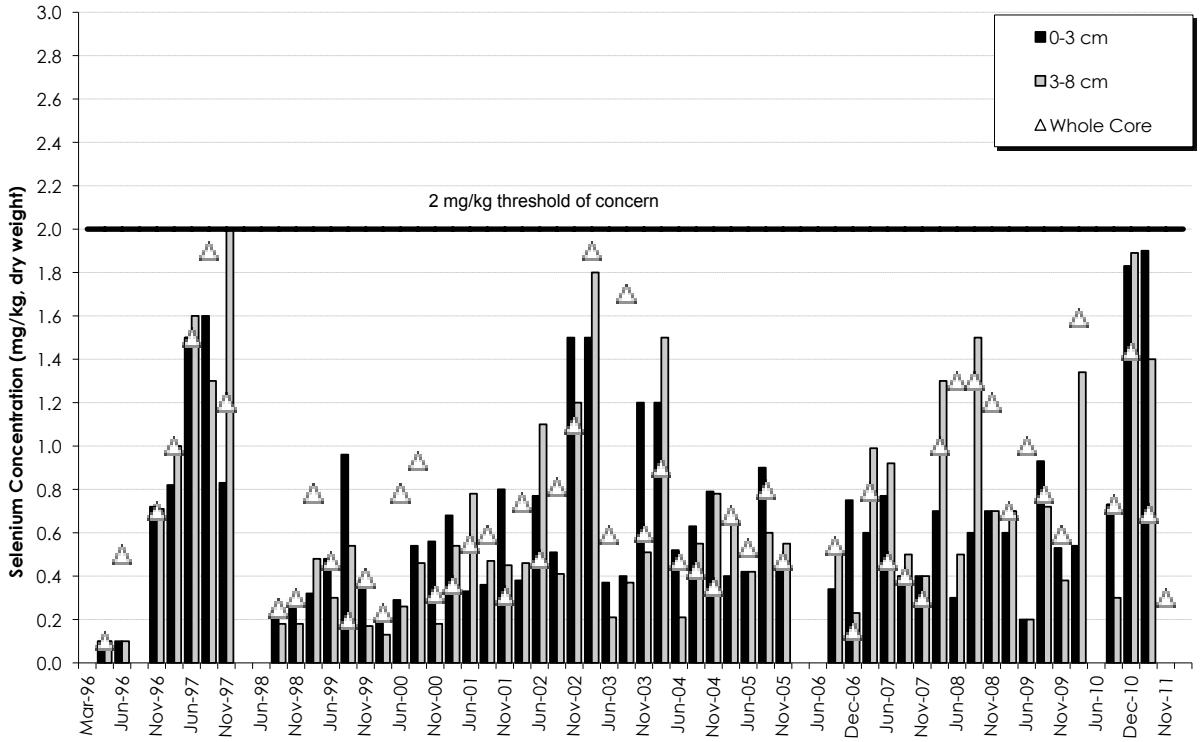


Figure 6a. Selenium in Sediment in Salt Slough at Station F

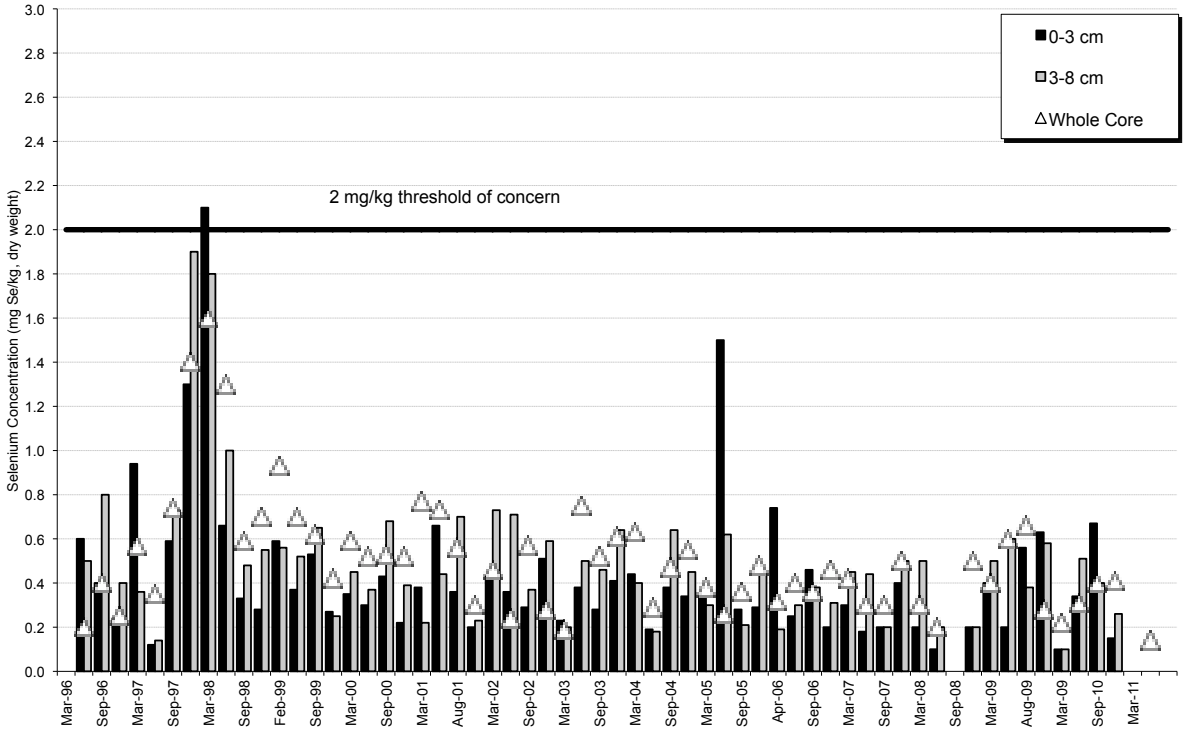


Figure 6b. Selenium in Sediment in Salt Slough at Station F (whole core)

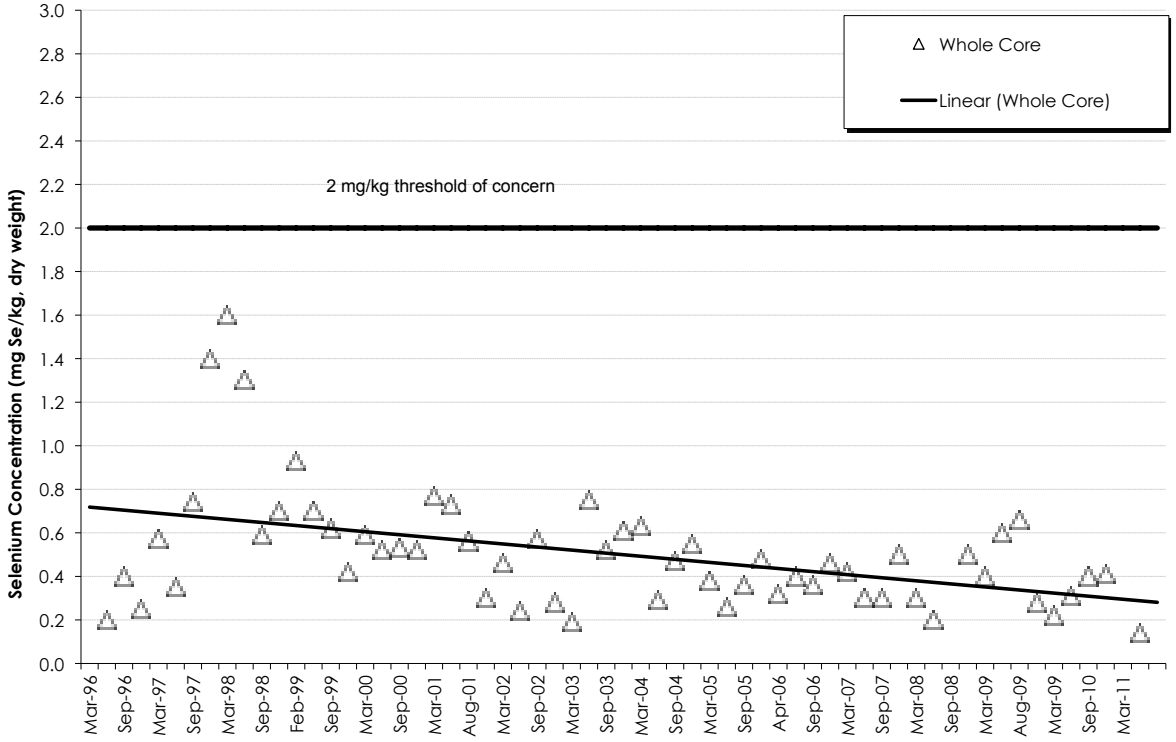


Figure 7a. Selenium in Sediment in Mud Slough at Stations I and I2

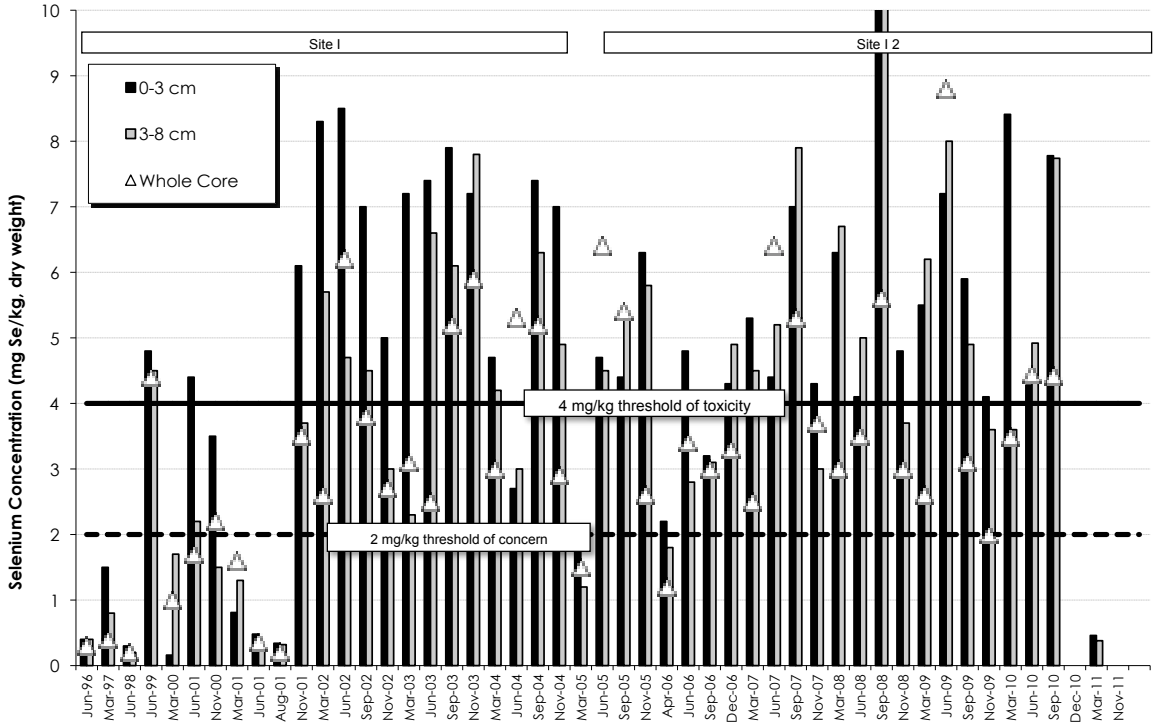


Figure 7b. Selenium in Sediment in Mud Slough at Stations I and I2 (whole core)

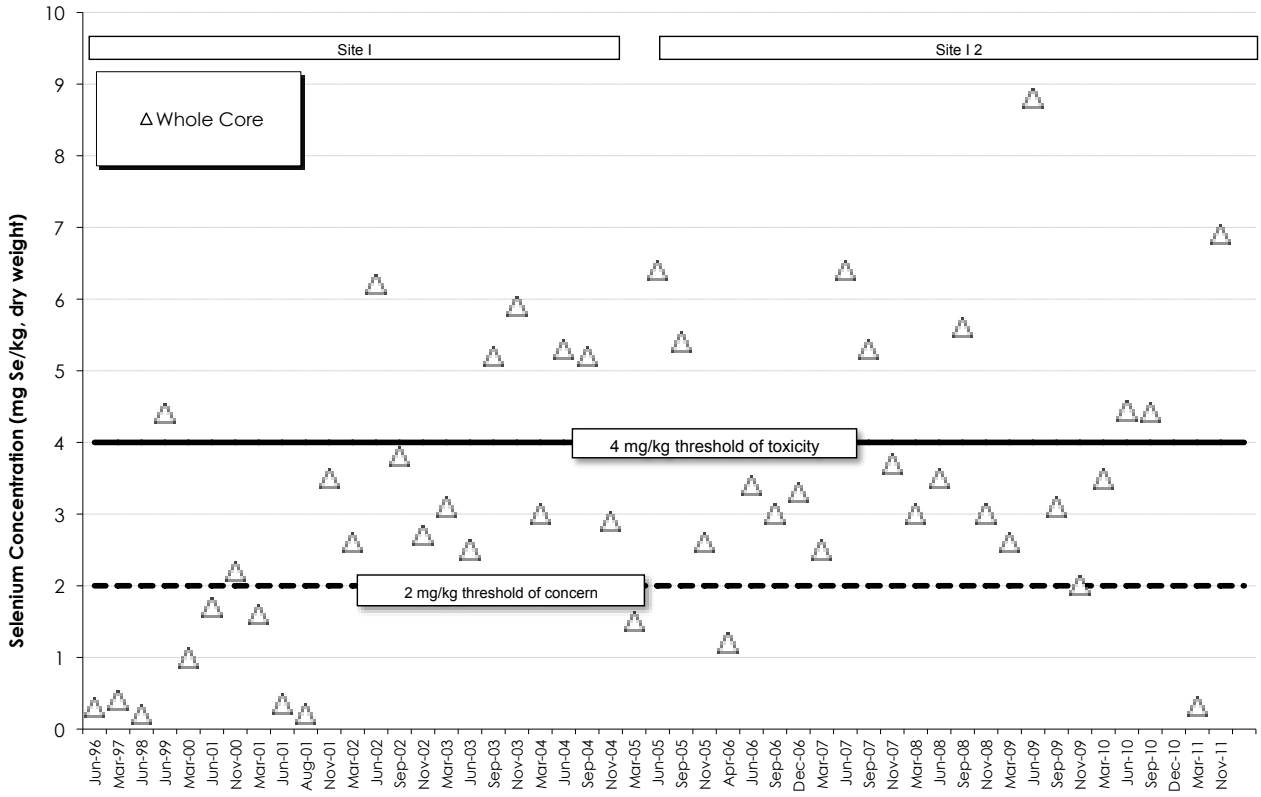
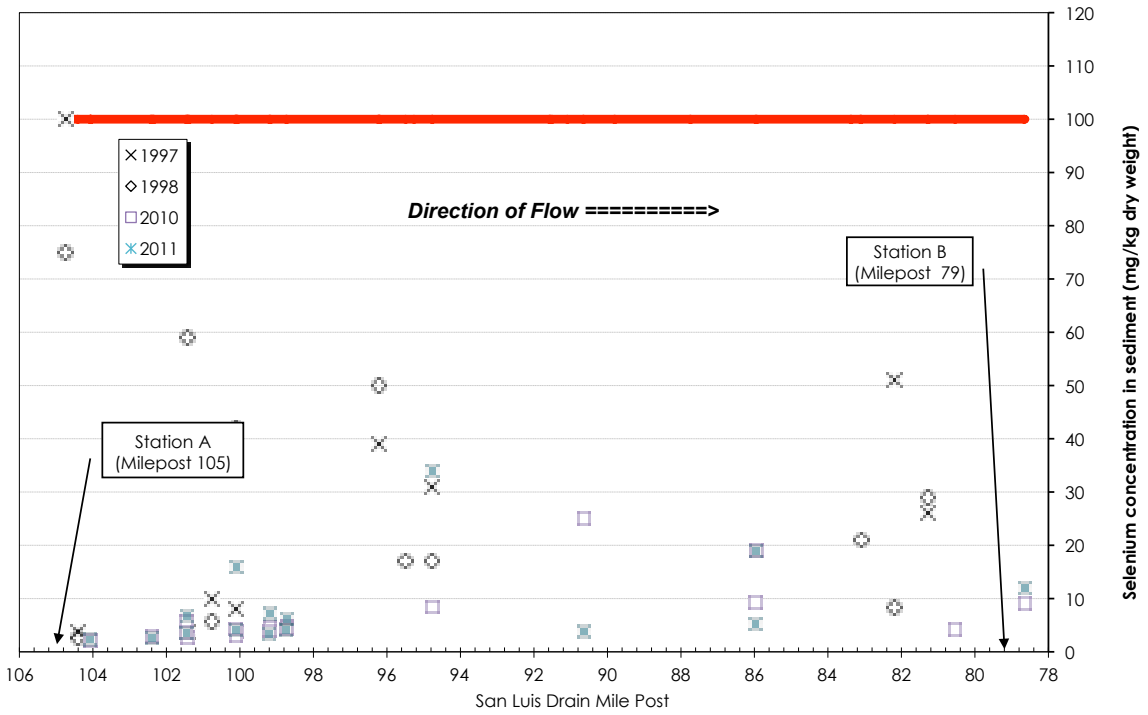
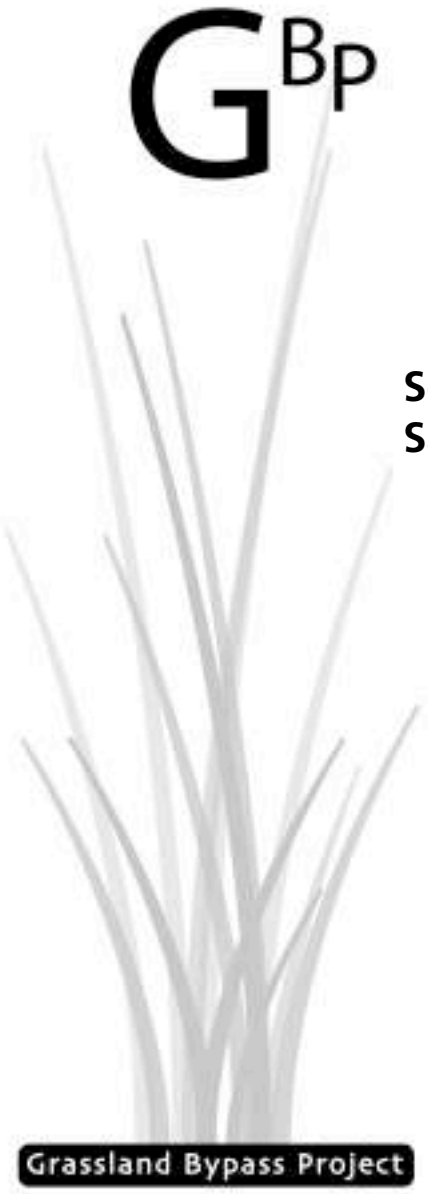


Figure 8. Concentration of Selenium in Sediment in the San Luis Drain





CHAPTER 10

Sediment Quantity in the San Luis Drain

January 1, 2010 – December 31, 2011

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Grassland Area Farmers

The purpose of this aspect of the Grassland Bypass Monitoring Program (Monitoring Program) is to determine the changes in quantity and movement of sediment in the San Luis Drain (SLD). This is accomplished by actual measurement of the bed sediment and using total suspended solids measurements at the inlet and outlet of the SLD.

Sediment Quantity Monitoring Procedure

Section 11.4 of the Compliance Monitoring Program Phase II (USBR et al., 2001) describes the procedure to measure the quantity of sediment in the SLD. The Monitoring Program calls for the measurement of sediment in four reaches of the SLD (Reaches 1, 10, 14, and 17). The locations of the sediment measurement points duplicated those of the March of 1987 survey performed by Summers Engineering. San Luis & Delta-Mendota Water Authority Personnel performed the sediment survey in October of 2010 and November of 2011. The sediment bed was cross-sectioned at regular intervals in all 19 reaches of the SLD, with depth-to-sediment measurements taken at both banks and in the middle of the channel. These three measurements were used to calculate an average volume of sediment per foot of channel, which was then used to estimate the total volume of sediment in the SLD from Check 19 to the outlet at Mud Slough (North).

Table 1 summarizes the results. The results are also shown graphically in **Figure 1.**

2010: For 2010, the results indicate a net increase of 12,142 cubic yards from November 2009 to October of 2010 (approximately 436 cy/month), compared to a net increase of 12,657 cubic yards from October 2008 to November 2009 (approximately 480 cy/month). An estimated total of 193,129 cubic yards of sediment has accumulated in the SLD since July 1998.

During the 2010 period Pool 11 gained the largest volume of sediment at 35,751 cubic yards. The 2010 average depth of sediment measured 3.6 feet with the maximum depth of 8.3 feet measured in Pool 13. Sediment accumulation is generally occurring in the upstream quarter (Pools 9 through 13, about 8,200 cubic yards) of the drain.

2011: For 2011, the results indicate a net increase of 23,428 cubic yards from October 2010 to November 2011 (622 cy/month), compared to a net increase of 12,142 cubic yards from November 2009 to October 2010 (approximately 436 cy/month). An estimated total of 216,686 cubic yards of sediment has accumulated in the SLD since July 1998.

During the 2011 period, the reach from the San Luis Drain End to Pool 11 gained the largest volume of sediment at 39,213 cubic yards. The 2011 average depth of sediment measured 3.8 feet with the maximum depth of 7.5 feet measured in Pool 14. As with previous years, sediment accumulation is occurring in the upstream quarter (Pools 9 through 13, about 7,200 cubic yards) of the drain, with a lesser accumulation in the last three pools (from Pool 2 to the end of the SLD). During the 2011 period, the sediment accumulation increased the most in the last five pools of the drain (from Pool 5 to the end - about 17,100 cubic yards in total).

Total Suspended Solids Measurements

The Monitoring Program calls for total suspended solids (TSS) measurements as part of the water quality monitoring. These measurements were to be taken just downstream of the inlet to the SLD (Site A) and just upstream of the outlet (Site B). Measurements were taken on a weekly basis at these sites. The monthly averages are shown for January 2010 through December 2011 in **Table 2**. Overall, the data shows that TSS concentrations at Site A are higher than at Site B by a factor of 2.2:1 for 2010 and 1.8:1 for 2011 (averaged over the 12 month period). One commitment of the Monitoring Program was to minimize flows so as to not cause sediment movement or suspension of sediments from the bottom of the SLD. The data suggests that the suspended sediments are settling in the SLD and that there is no net movement or suspension of sediments.

References

U.S. Bureau of Reclamation et al. 2001. Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project, Phase II, March 2002. U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

U.S. Bureau of Reclamation et al. 1996. Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project, September 1996. U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

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Table 1. San Luis Drain Sediment Survey

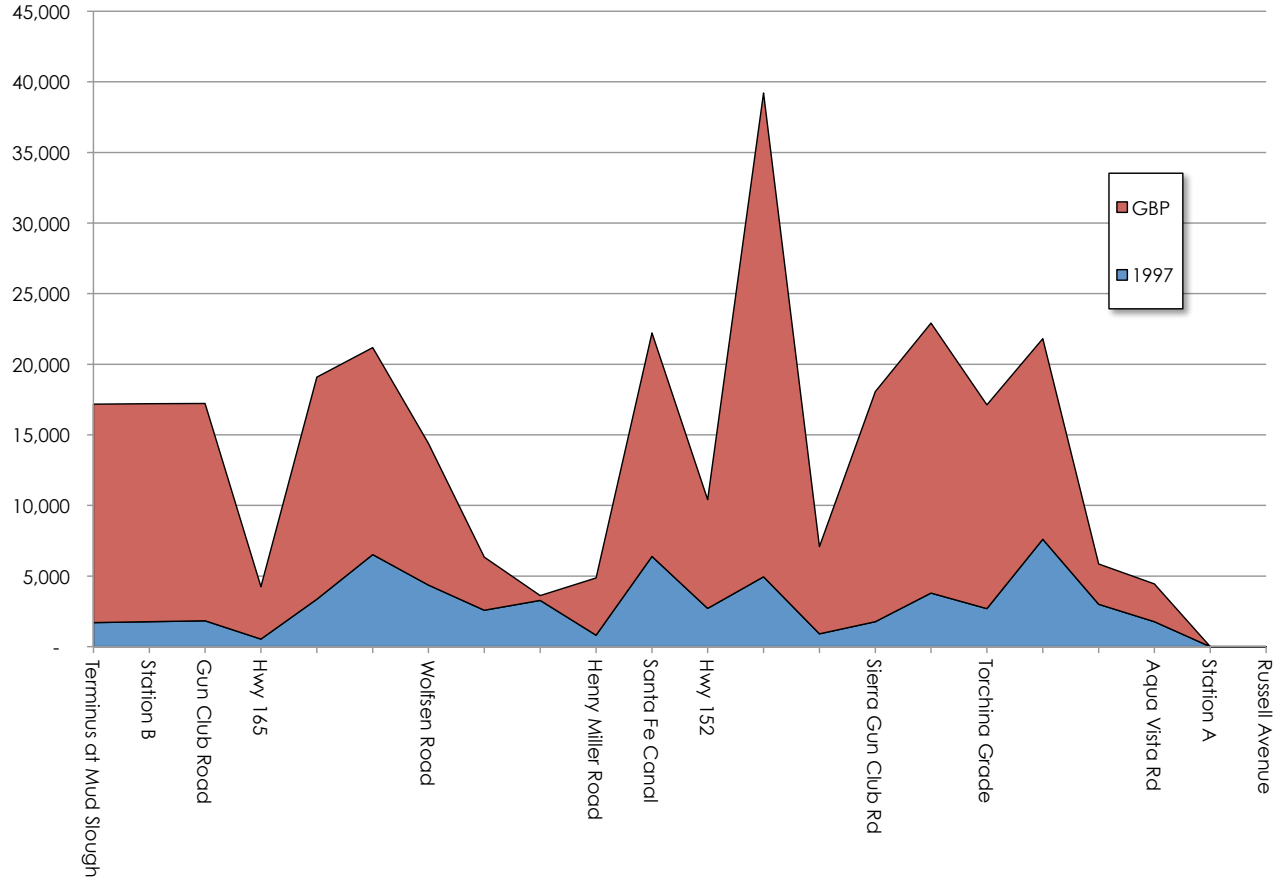
1987 to 2011 Survey Summary and Comparison

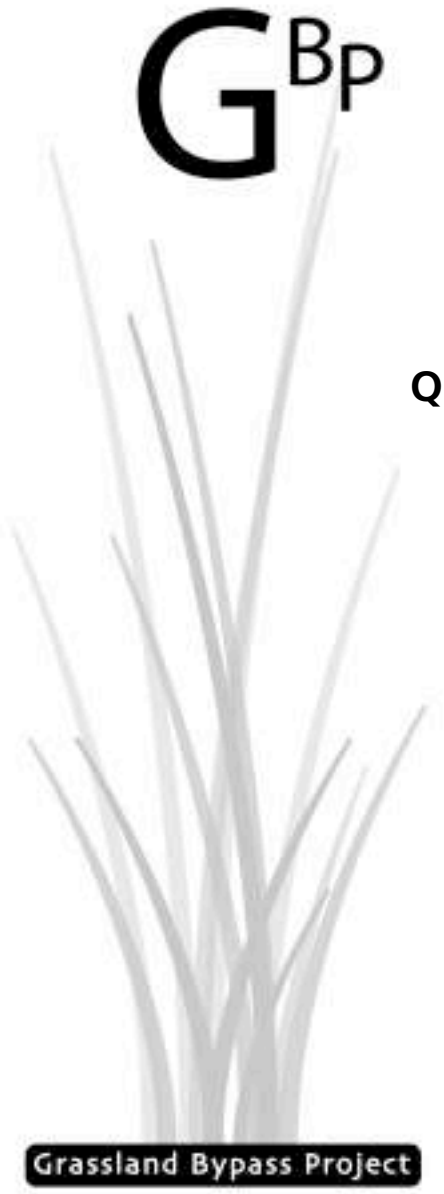
Pool	Checks	Distance (miles)	Landmark	March 1987 Volume (cu yd)	Jun - Sep 1997 Volume (cu yd)	October 2007 Volume (cu yd)	October 2008 Volume (cu yd)	November 2009 Volume (cu yd)	October 2010 Volume (cu yd)	November 2011 Volume (cu yd)
End	End to 1	2.64		3,176	1,697	11,013	11,425	10,975	11,978	17,177
1*	1 to 2	1.82	Site B Gun Club Road	2,567	1,840	10,555	11,164	11,888	12,965	17,220
2	2 to 3	0.28	Hwy 165	1,059	531	3,852	3,408	3,516	3,823	4,255
3	3 to 4	2.57		4,909	3,350	14,133	14,679	16,050	15,700	19,088
4	4 to 5	1.80		4,440	6,521	18,293	17,459	18,676	18,673	21,184
5	5 to 6	2.06	Wolfsen Road	4,242	4,370	12,965	12,423	12,809	13,129	14,400
6	6 to 7	0.83		2,160	2,584	5,040	4,894	5,289	5,750	6,341
7	7 to 8	0.45		3,935	3,278	2,860	2,721	3,073	3,407	3,614
8	8 to 9	0.47	Henry Miller Road	907	816	3,120	3,376	3,891	4,343	4,869
9	9 to 10	3.20	Santa Fe Canal	6,963	6,390	14,496	14,393	16,376	18,193	22,214
10*	10 to 11	1.46	Hwy 152	2,647	2,708	8,386	8,816	9,413	10,072	10,406
11	11 to 12	2.50		4,835	4,947	21,596	23,540	30,654	35,751	39,213
12	12 to 13	0.46		784	909	5,144	5,678	7,004	7,192	7,091
13	13 to 14	0.91	Sierra Gun Club Rd	2,038	1,771	12,597	18,169	18,220	18,616	18,063
14*	14 to 15	1.34		2,304	3,803	27,917	24,833	23,658	24,083	22,907
15	15 to 16	0.96	Torchina Grade	1,822	2,700	19,216	18,240	17,411	17,422	17,117
16	16 to 17	1.68		5,863	7,605	21,750	23,636	22,225	22,403	21,819
17*	17 to 18	0.68		1,885	3,006	5,447	6,161	6,462	6,401	5,853
18		0.97	Aqua Vista Rd	1,558	1,768	3,645	4,038	4,120	3,954	4,447
	18 to 19		Site A							
19			Russell Ave							
Totals		27.08		58,094	60,594	222,025	229,053	241,710	253,852	277,280
	change			58,094	2,500	6,152	7,028	12,657	12,142	23,428

Table 2. Total Suspended Solids

Date	Flow		Total Suspended Solids		Sediment Load		
	Site A	Site B	Site A	Site B	Site A	Site B	Difference
	Acre-feet	Acre-feet	mg/L	mg/L	tons	tons	tons
January-10	1,100	1,430	145	39	217	76	-140
February-10	1,330	1,580	108	54	195	115	-79
March-10	1,560	1,850	118	57	251	143	-108
April-10	980	950	34	56	46	72	26
May-10	1,760	1,630	144	52	345	115	-231
June-10	1,310	1,210	107	60	190	98	-92
July-10	1,070	870	80	56	116	66	-50
August-10	1,120	930	105	45	161	57	-104
September-10	670	700	61	49	56	47	-9
October-10	330	680	75	29	34	27	-7
November-10	1,220	1,070	93	34	154	49	-105
December-10	1,400	1,810	178	30	339	74	-265
January-11	1,240	1,600	97	31	164	67	-97
February-11	1,930	2,190	128	61	337	180	-156
March-11	2,700	3,010	133	39	489	161	-328
April-11	1,840	2,000	63	47	158	128	-29
May-11	1,610	1,680	107	67	235	154	-82
June-11	1,540	1,610	88	48	184	104	-80
July-11	1,010	980	41	37	56	49	-7
August-11	1,040	1,050	120	61	169	88	-81
September-11	680	830	122	50	112	56	-56
October-11	630	980	92	68	79	90	11
November-11	610	980	58	40	48	53	5
December-11	820	1,110	50	20	56	31	-25

Figure 1a - San Luis Drain Sediment Survey Comparison





CHAPTER 11

Quantity Assurance

January 1, 2010 – December 31, 2011

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Data Quality Objectives

The Data Collection and Reporting Team (DCRT) uses the laboratory data from this project to support the determination of whether selenium levels in the Grassland Bypass exceed regulatory compliance levels. Because individuals use the data generated by this program for regulatory compliance and baseline monitoring purposes, the data must be of the highest degree of validity. Sample collection of different environmental media and analytical methods performed by the laboratories must adhere to the guidelines established in the Quality Assurance Project Plan (QAPP).

Quality Assurance Project Plan

On August 22, 2002, the U.S. Bureau of Reclamation (Reclamation) and the DCRT completed and released the QAPP for Phase II of the use and operation of the Grassland Bypass Project (GBP). RECLAMATION initiated a review and revision of the QAPP in 2005. The QAPP was reviewed and revised from 2005 through 2006; an updated version was issued November 20, 2006. The QAPP provides the protocols for documenting the Quality Assurance/Quality Control (QA/QC) activities carried out by the agencies responsible for the separate components of the Compliance Monitoring Program (CMP II). The QAPP describes the organization and membership of the project participants and defines the data quality objectives (DQOs) for CMP II. This plan describes the QA/QC activities associated with each agency's monitoring program, provides the QA/QC protocol of each laboratory participating in the program, provides acceptance criteria for data validation procedures, and describes corrective actions to be taken when the data fail to meet such criteria. The QAPP addresses both quantitative goals, including precision, accuracy, and completeness, and qualitative goals, including representativeness and comparability.

The QAPP follows the format described in the May 1994 *Guidelines for Preparing Quality Assurance Project Plans*, published by the State of California Department of Water Resources. The QAPP includes all the requirements identified in the August 1994 Draft Interim Final, U.S. EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations, EPA QA/R-5. The QAPP will be updated and revised when a new Waste Discharge Requirement is issued.

Quality Assurance Oversight

QA/QC oversight for CMP II is the responsibility of a QA/QC oversight manager (QAQCOM) working for RECLAMATION. The QAQCOM oversees the implementation of commitments, guidelines, practices, and protocols outlined in the QAPP in compliance with the goals and objectives of the project. The QAQCOM uses guidelines, protocols, and criteria established in the QAPP to monitor and validate data collected by Reclamation personnel and to audit the data collection and validation processes used by the other participating agencies, including the U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), California Department of Fish and Game (CDFG), California Regional Water Quality Control Board (CRWQCB), and San Luis Delta-Mendota Water Authority (SLDMWA). When the QAQCOM identifies a noncompliance issue, the appropriate QA Officer is notified, and the responsible agency implements corrective actions to resolve the problem. The QAQCOM brings any unresolved issues

between the QAQCOM and a participating agency's QA Officer to the attention of the DCRT for resolution. Reclamation QA personnel conduct audits of all participating analytical laboratories and review the data collection activities of the participating agencies for adherence to protocol. Additionally, Reclamation QA personnel conduct field audits on agencies participating in CMP II by evaluating sampling methods in the field.

Laboratory Performance and System Audits

During 2010-2011, Reclamation conducted performance and system audits on laboratories that perform work in support of the Grassland Bypass Project (**Table 1 and Table 2**). The laboratories performed well and provided acceptable corrective actions for any deficiencies noted during the audits.

Laboratories are audited by Reclamation every three - four years. The audit consists of performing a documentation review, submitting performance evaluation (PE) samples to the laboratory, and conducting an on-site system audit of the laboratory.

Documentation Review

Prior to the audit, the laboratory's QA Manual and a copy of the last three years of approved round-robin performance study results are reviewed. Any deficiencies in the QA manual, performance study results, or corrective actions for unacceptable values on PE samples are addressed in the audit report.

Performance Evaluation Samples

Prior to the on-site audit, PE samples are submitted by Reclamation to the laboratories for a more direct evaluation of the laboratory's performance. The purpose of the PE samples is to evaluate the laboratory's ability to generate accurate data. The parameters selected for the PE samples were tailored to reflect those analyzed by the laboratories in support of the Grassland Bypass Project. Unacceptable PE sample results are addressed in the audit report. The results of the PE samples submitted by Reclamation to California Laboratory Services and South Dakota Agricultural Laboratories in support of the Grassland Bypass Project are presented in **Table 2.**

On-Site System Audit

An on-site system audit is conducted to assess the laboratory's expertise in performing sample analyses, their capability for producing valid data, their ability to effectively support the data, and the integrity of their QA/QC practices. During the on-site audit, the QA Officer, analysts, and other key laboratory personnel are questioned to determine their overall understanding of the methods and laboratory procedures. Documentation practices are also reviewed. In general, the auditors are ensuring that laboratory procedures follow the laboratory's QA manual guidelines and the analytical method protocols. Any deviations are addressed in the audit report.

Audit Report

The auditors send a report addressing deficiencies identified during the audit to the laboratory with a time frame for the laboratory to respond to the findings and to implement and document the corrective actions.

Sample Collection System Audits

The sample collection system audits focus on the quality of the environmental samples collected and the ability of field personnel to adequately support and document the sample collection process. The purpose of the sample collection system audits is to identify and prevent problems in the field that could compromise sample integrity. On November 17, 2010, RECLAMATION conducted a field audit of the CRWQCB who collected samples in support of the Grassland Bypass Project. All aspects of the sample collection process were audited including equipment calibration and use, equipment decontamination, sample collection protocol, and documentation practices. Any deviations were addressed in the audit report. No field audits were conducted in 2011 in support of the Grassland Bypass Project.

Data Validation and Review Audit

The QAQCOM is responsible for ensuring the participating agencies properly validate their analytical data, identify problems with their analytical data, and contact the respective laboratories to initiate corrective actions. The QAQCOM is also responsible for ensuring the participating agencies properly calibrate their instruments and document their field work. To accomplish this oversight, RECLAMATION reviewed and audited the laboratory and field data generated by the participating agencies as discussed below. Any deviations from the QAPP were addressed in writing to the agencies.

Laboratory Data

RECLAMATION audited the CRWQCB data on November 19, 2010. RECLAMATION reviewed the data validation procedures employed by the CRWQCB to assess the validity of the analytical results per Table 10 of the QAPP. The guidelines in the QAPP address both internal and external QC sample results. The QAPP defines internal QC samples as those check samples incorporated by the laboratories performing the work and defines external QC samples as those check samples submitted to the laboratories by the participating agencies. During the data review, validation, and audit process, RECLAMATION performs the following:

- verify that agencies are correctly incorporating external QC samples (i.e., spikes, references, duplicates, blanks) into batches of field samples
- bring laboratory QC summary report problems to the attention of each agency's QA Officer
- check data packages to ensure laboratories are documenting the details of their corrective actions
- check to ensure the laboratories are analyzing project samples within required holding times
- identify possible outliers (analytical results that are outside of the established historical range)

No laboratory data audits were conducted in 2011 in support of the Grassland Bypass Project.

Field Data

In November 2010, RECLAMATION personnel conducted an audit on field data generated by CRWQCB field personnel. This review ensured proper documentation was in place to support CRWQCB's instrument calibration and sample collection procedures. No field data audits were conducted in 2011 in support of the Grassland Bypass Project.

Data Validation and Review Activities

The following routine data validation, review, and audit activities were performed in 2010-2011 to ensure data validity as stated in the QAPP:

Type of data	Review and Validation Group
Laboratory and field data from RECLAMATION (sediment and water)	RECLAMATION
Laboratory and field data from CRWQCB (water)	CRWQCB
Laboratory data from Block Environmental Services (water)	Block Environmental Services
Laboratory and field data from USFWS and CDFG (biota)	USFWS

QA Issues

The USGS-Denver Laboratory informed RECLAMATION that they would no longer be able to analyze sediment samples for selenium or total organic carbon in support of the Grassland Bypass Project.

In March 2010, RECLAMATION conducted a comparison study to find a replacement laboratory for total organic carbon analysis in sediment samples. All samples, including QA samples, were split and sent to the USGS-Denver Laboratory and ALS Laboratory Group (ALS) to compare the percent moisture and total organic carbon results. Upon comparing the percent moisture and total organic carbon results from both laboratories, it was determined that ALS's total organic carbon method was suitable for the Grassland Bypass Project sediment samples; analysis of the sediment samples for total organic carbon was switched to ALS. However, shortly after switching to ALS, RECLAMATION was informed by ALS that they were having problems with their total organic carbon instrument. RECLAMATION performed another comparison study between ALS and California Laboratory Services (CLS) in June 2010 and September 2010. Based on this comparison study, it was determined that CLS's total organic carbon method was suitable for the Grassland Bypass Project sediment samples; the analysis of the sediment samples for total organic carbon was switched to CLS.

Selenium analysis for sediment samples was switched from the USGS-Denver Laboratory to the Department of Fish and Game Water Pollution Control Laboratory (WPCL). This switch was based on a comparison study between USGS-Denver and WPCL performed in 2008.

In October 2011, Olson Agriculture Analytical Services Laboratory (Olson) was forced to shut down because the laboratory could no longer use the space they were occupying at South Dakota State University. Olson was performing the selenium analysis for the Grassland Bypass Project. As such, the

laboratory was forced to relocate. The laboratory was re-opened under the name South Dakota Agricultural Laboratories. South Dakota Agricultural Laboratories uses the same QA Manual, Standard Operating Procedures, analysts, and instrumentation as Olson. Before samples were submitted to South Dakota Agricultural Laboratories, a set of PE samples was submitted to the laboratory (**Table 2**). The PE samples varied in concentration from approximately 2 ppb to approximately 1,600 ppb to get an assessment of the laboratory's ability to generate accurate data at different selenium concentrations. All PE samples results were within the 80% - 120% acceptance criterion. An on-site system audit will be conducted in 2012, after the laboratory has completed the move to their new facility.

In June-July 2011, RECLAMATION took over the sampling that had previously been conducted by the CRWQCB. To maintain consistency and ensure the comparability of the data, RECLAMATION staff were trained on CRWQCB protocols prior to RECLAMATION collecting samples.

Uncertainty Associated with Environmental Measurement

As with all quantitative measurements, there is a degree of uncertainty associated with the values provided. This is especially true for environmental data where measurement error may be introduced in the sample collection phase as well as in the laboratory preparation and analysis phase. Program participants and the public should understand that values presented in laboratory reports are not absolute, but rather represent values with associated precision and accuracy uncertainties as defined in Table 10 of the QAPP. In addition, as the concentration of the parameter approaches the limit of detection for a particular analytical method, the level of uncertainty of the result increases significantly as shown in Figure 4 of the QAPP. The data user should understand the degree of uncertainty or the confidence limits associated with the data.

Summary

In support of the Grassland Bypass project, RECLAMATION conducted audits on project laboratories and conducted audits on field personnel responsible for collecting samples. In addition, RECLAMATION validated, reviewed, and audited the data collected. RECLAMATION also performed comparison studies to find replacement laboratories for selenium and total organic carbon analysis in sediment samples and performed a performance evaluation audit on South Dakota Agricultural Laboratories. In performing QA oversight, RECLAMATION serves to remind participating agencies of the need to adhere to the protocols established in the QAPP. In general, the participating agencies involved with the CMP II complied with the protocols outlined in the QAPP. Where exceptions did occur, RECLAMATION was able to identify and address the issues, thereby ensuring the validity of the project's data. Adherence to the QAPP ensures the reliability of the data collected and provides the necessary documentation to support the accuracy of the measurements.

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Table 1. Laboratory Audited in 2010

Table 2. Performance Evaluation Sample Results

Table 1. Laboratory Audited in 2010

Laboratory	Audit Date(s)	Analysis Type for GBP
California Laboratory Services Rancho Cordova, CA	December 7-8, 2010	Sediment Analysis for Total Organic Carbon

Table 2. Performance Evaluation Sample Results

California Laboratory Services

Date: 11/18/2010

Sample ID	Matrix	Parameter	Result	True Value	Percent Recovery	Acceptance Limit
QA833	Soil	Total Organic Carbon	2400 mg/kg	2580 mg/kg	93%	65% - 135%

South Dakota Agricultural Laboratories

Date: 10/24/2011

Sample ID	Matrix	Parameter	Result	True Value	Percent Recovery	Acceptance Limit
QA870	Water	Selenium	1.91 µg/L	2.10 µg/L	91%	80%-120%
QA871	Water	Selenium	2.59 µg/L	2.94 µg/L	88%	80%-120%
QA872	Water	Selenium	3.65 µg/L	3.67 µg/L	99%	80%-120%
QA873	Water	Selenium	5.18 µg/L	5.49 µg/L	94%	80%-120%
QA874	Water	Selenium	7.60 µg/L	7.60 µg/L	100%	80%-120%
QA875	Water	Selenium	10.6 µg/L	10.3 µg/L	103%	80%-120%
QA876	Water	Selenium	55.6 µg/L	49 µg/L	113%	80%-120%
QA877	Water	Selenium	104 µg/L	92 µg/L	113%	80%-120%
QA878	Water	Selenium	1954 µg/L	1655 µg/L	118%	80%-120%

CHAPTER 12

Summary of Selenium Monitoring Results from the Grassland Bypass Project (1996-2011)

January 1, 2010 – December 31, 2011

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Grassland Bypass Project

The Grassland Bypass Project (GBP) provides a set of mechanisms by which agricultural drain water can be separated from Grassland habitats. In 1994, Grassland Area Farmers entered into a Use Agreement with the U.S. Bureau of Reclamation (USBR) to reroute agricultural drainage around impacted wildlife habitat, achieving a regulatory milestone that brought together many stakeholders in an effort to improve water quality in an agriculturally dominated river system. Since 1996, a bypass intercepts and collects drainage water from the 97,000 acre Grasslands Drainage Area and carries it directly to Mud Slough, a tributary of the San Joaquin River (**Figure 1 and 2**).

The current Use Agreement (USBR 2009) includes commitments to meet Waste Discharge Requirements (WDR) issued by the Central Valley Regional Water Quality Control Board (CVRWQCB 2001). The Use Agreement and WDR specify the total monthly and annual loads and water quality objectives (WQOs) for selenium in wetland supply channels and for the San Joaquin River below the Merced River. The CVRWQCB is in the process of revising the WDR.

Background

The need to manage agricultural drain water in the San Joaquin Valley was brought to public attention in 1983, when a monitoring program uncovered selenium to be the cause of mortality and teratogenicity in adult and embryo waterbirds in a reservoir holding drain water from the Westlands Water District. The San Luis Drain (SLD), a federal conveyance, was designed by USBR in the 1970s to take agricultural drain water from irrigated farms on the west side of the Valley to the Sacramento-San Joaquin Delta. The project encountered cost overruns and political roadblocks and was not finished. As an interim measure, a series of drain water holding ponds were built in the Kesterson Wildlife Refuge. After the contamination was identified, the holding ponds were capped and all movement of drain water to the SLD was prohibited.

The 370,000-acre Grasslands watershed (**Figure 2**), north of the Westlands District, encompasses the Grasslands Drainage Area, and 80,000 acres of managed wetlands, wildlife refuges and duck hunting clubs. Soils and shallow groundwater in this area contain naturally high concentrations of selenium, boron, and other salts. Irrigation and rain mobilizes these constituents and drainage systems were built to transport them from farmland to wetland areas and the San Joaquin River. Prior to 1985, irrigation return flows and wetland supply water commingled in the complex Grasslands conveyance system (**Figure 1**).

Substantial reductions in drainage discharge were required in order to meet water quality standards (Young and Congdon 1994). The Environmental Defense Fund concluded that a combination of tiered water pricing and discharge permits for the water districts would be the most cost-effective way to reach the specified discharge goals. After initial data collection by USBR, US Fish and Wildlife Services (USFWS), US Geological Survey (USGS), California Department of Water Resources (DWR), and California Department of Fish and Wildlife (CDFW) several recommendations for drainage management, source control implementations, and monitoring were made (San Joaquin Valley Drainage Program 1990).

In collaboration with federal, state, and local agencies, the GAF developed a Use Agreement to meet the regulatory requirements (CVRWQCB 2000a, 2006; Tanji et al. 2002; USBR 2006) relating to a Total Maximum Daily Load (in this case, a Total Monthly Maximum and Annual Load) for selenium for the San Joaquin River to achieve a water quality objective of 5 µg/L 4-day average and 2 µg/L monthly average in the Grassland Ecological Area (GEA) wetland channels.

The GBP was implemented in 1996. Since then, a bypass channel collects and directs agricultural drain water from the Grasslands Drainage Area (GDA) (**Figure 2**) around the wildlife habitat areas to a portion of the SLD and the lower portion of Mud Slough. The Project objective was to reduce target loads yearly until the end of the Project in 2001 and to monitor contaminant concentrations at multiple locations in the drainage area (USBR 1996). Approval of the GBP was given with the understanding that certain benefits and risks would be associated with the Project. The primary benefit of the GBP is that aquatic biota and aquatic-dependent wildlife in approximately 90 miles of wetlands water supply channels and their associated marsh ponds, Salt Slough, and the reach of Mud Slough lying upstream from the terminus of the SLD are no longer exposed to drain water from the GDA. The risks include adverse environmental impacts to the lower nine miles of Mud Slough between the SLD and the San Joaquin River and the two-mile portion of the River between Mud Slough and the Merced River, where aquatic biota and wildlife are exposed to higher concentrations of selenium and other constituents contained in drain water.

Reaching the load limit associated with the water quality objective in Mud Slough has taken longer than expected. The Use Agreement has been extended twice, first until 2009, and, currently, to 2019. Selenium loads have steadily declined and the latest version of the Use Agreement imposes increasingly large fines, if discharge to the Drain continues after January 2016 (Use Agreement, 2009).

Selenium concentrations in the San Joaquin River below the Merced River confluence have decreased steadily and remained below 5 µg/L 4-day average since May 2004 (**Figure 3**). The current focus is on also reducing selenium concentrations in the stretch of the River between Mud Slough and the Merced River confluence.

Monitoring Program Overview and Objectives

The GBP includes a multi-agency compliance monitoring program. Data are collected by the GAF, USBR, USFWS, USGS, and CDFW. All the agencies involved in data collection, the CVRWQCB, and US Environmental Protection Agency (USEPA) review the data, which are published in monthly and annual reports.

The GBP monitoring program was designed to provide data to evaluate whether the Project is in compliance with the WDR and related commitments specified in the Use Agreement and associated documents, including the following targets:

- monthly and annual selenium load limits on discharges
- water quality objectives for wetland supply channels (2 µg/L monthly average)
- water quality objectives for the San Joaquin River below the Merced River (5 µg/L 4-day average)

- cessation of discharge of agricultural drainage to the wetland channels
- management of flows in the SLD so as to not mobilize channel sediments

The extension of the Use Agreement associated with the GBP was approved through December 31, 2019 and a revised monitoring plan for the continued operation of the GBP will be in effect starting October 2013 (USBR 2013a). The revised monitoring plan will implement monitoring of additional constituents (mercury and other trace elements, pesticides, and fecal indicator bacteria). The Grasslands Water District will monitor three sites discontinued by the GBP. A more comprehensive list of changes will be included in the next annual report after the revised monitoring plan is finalized.

The new monitoring objectives will continue to evaluate WDR compliance, assessing environmental conditions by measuring water, sediment, and biota concentrations of selenium and other constituents in the SLD, Mud Slough (North), the Grasslands wetlands water supply channels (represented by Salt Slough), and the San Joaquin River.

Drainage Control Efforts

Drainage and source control efforts have been implemented with the goal of managing all agricultural subsurface drainage in the area. These include sump pump management, deployment of more efficient irrigation systems, planting crops that require less water, lining water conveyance channels to control seepage, blending and reuse of drain water, planting of salt-tolerant crops using that water, and land retirement. A statistically significant relationship ($p= 0.0003$) between the reduction in selenium discharges and water conservation was described previously (SFEI 2009). The results indicate that more efficient water use (water deliveries) and consequent drainage volume reduction is positively correlated with lower selenium loads from the area.

The use of blended drain water to irrigate salt-tolerant crops in the project area shows promise to help meet the goals of the project. In 2001, the Panoche Drainage District (PDD) initiated the San Joaquin River Water Quality Improvement Project (SJRIP) in an area of 1,360 acres (about 5% of the total current crop acreage in the PPD)(**Figure 4**). By 2011, the acreage available for salt-tolerant crops had been expanded to 5,200 acres, with a goal of expanding to 6,200 acres. Salt-tolerant crops include Jose tall wheatgrass, paspalum grass, and pistachios.

Source control efforts include conversion to quarter-mile furrows, sprinkler systems, and drip irrigation systems. The GAF has conducted experiments with timing of pre-irrigation and shallow drainage management to reduce deep percolation. These practices and further improvements will continue to be implemented to reduce the amount of subsurface drainage water discharged to Mud Slough and the San Joaquin River to zero.

Collaboration with Other Projects

Several other water quality projects in the San Joaquin Valley are benefitting from GBP activities and data collection. Through the coordination of source control studies, the development of drainage reuse options, research with salt-tolerant crops, shared monitoring sites, and improved groundwater management strategies, the GAF contribute to and enhance the environmental mitigation efforts of other projects.

- The Westside Regional Drainage Plan objective is to reduce the volume of agricultural drain water and salinity and selenium concentrations in the San Joaquin River by implementing efficient drainage management practices and integrating them into a comprehensive program. The main components include land retirement, groundwater management (including groundwater pumping to mitigate drainage impacts), source control, salt disposal (storage of brine solution and exploring a potential market), as well as regional reuse and treatment of drain water. Implemented activities outlined in the Drainage Plan have improved water quality in the San Joaquin River.
  http://www.swrcb.ca.gov/rwqcb5/water_issues/salinity/library_reports_programs/westsd_regnl_drng_plan_may2003.pdf

- The San Joaquin River Water Quality Improvement Project (SJRIP) seeks to reduce the amount of selenium and salt delivered to the SLD and Mud Slough through the GBP. Agricultural drain water control efforts implemented through the SJRIP include the construction and maintenance of pump stations, agricultural drain water recycling, and expanding the acreage of salt-tolerant crops that can be irrigated with recycled agricultural drain water. The SJRIP includes a biological monitoring component to assess potential impacts to migratory birds resulting from exposure to elevated levels of selenium due to the project. The reports describing the results for the biological monitoring can be found at the SFEI website (http://www.sfei.org/gbp/sjrip).
  https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=5656

- The San Joaquin River Restoration Program (SJRRP) is a comprehensive long-term effort to restore a self-sustaining Chinook salmon fishery in the River while reducing or avoiding adverse water supply impacts from restoration flows (USBR 2013b). The SJRRP shares monitoring sites with the GBP in Mud and Salt Slough and in the main stem of the San Joaquin River.
  http://www.restoresjr.net/

- The Irrigated Lands Regulatory Program (ILRP) was initiated in 2003 to prevent impairment of surface water and groundwater from pollutants in agricultural runoff. Waste discharge requirements have been developed and help address discharges from irrigated lands. Data collected by the Westside Coalition under the ILRP are shared with GBP. http://www.swrcb.ca.gov/rwqcb5/water_issues/irrigated_lands/

Selenium Trends (1997-2011)

Loads

- Since the GBP began in October 1996, selenium loads to the Grassland wetlands due to DPA drainage discharges have been virtually eliminated and annual selenium load limits for discharges diverted to the SLD have been met in all but two years (**Figure 5**). No exceedances occurred within the last 13 years.
- The annual load limit exceedances occurred in 1997 and 1998, which were extremely wet years with precipitation of up to 174% above normal (DWR 2005).
- Load limits and loads were also higher in WY 2010 and 2011 (above normal and wet year, respectively), after two critical and one below normal rainfall year (WY 2007 – 2009). Annual load limits are adjusted depending on the hydrologic water year classification, because flood flows from within and outside of the GBP can contribute to discharges and potentially result in loads limit exceedances.

Concentrations

- Monthly mean selenium concentrations in Salt Slough and the Grassland wetland channels have decreased and usually meet the (monthly mean) objective for fish and wildlife as a result of the construction of the bypass in 1995 (**Figure 6**).
- Selenium concentrations in Mud Slough below the SLD (Station D) continue to exceed the water quality objective of 5 µg/L, but there has been a gradual and statistically significant decline since 1996 (r^2=0.94), indicating a positive response to drainage and source control efforts (**Chapter 7**, **Figure 4f**).

Bioaccumulation

- The GBP objective of reducing selenium exposure in wetland channels has been met. Overall reductions in selenium body burdens and ecological risks are observed in areas from which drain water has been removed.
- Exposure to drain water flowing to the San Joaquin River via Mud Slough remains a concern. Selenium concentrations in fish and invertebrates in Mud Slough below the SLD outfall continue to exceed thresholds of concern (**Figures 7** and **8**).

Toxicity

- The current toxicity test regime was not designed to characterize potential impacts of selenium to aquatic organisms and wildlife. It was designed to document whether the GDA discharges would result in increased aquatic toxicity in receiving waters.
- Five different toxicity tests are being conducted (**Table 1**, detailed results summarized in Chapter 8).
- Positive toxicity test results are defined as statistically significant reduction in acute and chronic toxicity endpoints (growth, survival, reproduction), when compared to Delta Mendota Canal control results, provided all other quality control/ quality assurance (QA/QC) requirements are met (see Chapter 8).
- *Overall trends*: Intermittent toxicity is observed at all Grassland stations sampled, both at sites receiving and not receiving drainage water from the GDA (**Figures 9** and **10**). The observed toxicity may be related to any number or combination of pesticides and other chemicals that entered the surface water system, which consists predominantly of subsurface drain discharges (**Figure 10**). The available data record does not allow conclusions about whether the toxicity was caused by the same or different toxicants (SFEI 2009, Chapter 12). A general trend of reduced toxicity at Grassland sites over the last six to seven years is evident from graphical analysis (**Figure 10**). This reduction is probably due to reduced pesticide use, reduced field discharges, and the implementation of BMPs in the drainage area.
- *San Luis Drain (Station B)*: Site B has a higher proportion of toxic events than other monitored sites in this program (Chi-Square Test, p = 0.000). Acute toxicity to fathead minnows at Site B was observed for the first time in 2011. (**Figure 10**).
- While toxicity to green algae is observed at all Grassland stations, it is most frequently observed at Site B, in the SLD (**Figure 10**). Herbicide applications are the most commonly identified cause of algal toxicity in the Central Valley region (Markewicz et al. 2012).
- *Mud Slough, upstream of the SLD confluence (Station C)*: Toxicity to fathead minnow has decreased after 2004. There is intermittent toxicity to algae and Daphnia magna without any visible trends (**Figure 10**).
- *Mud Slough, downstream of the SLD confluence (Station D)*: There has not been any observed toxicity to fathead minnows since 2008. Toxicity to green algae is reduced compared to the SLD, probably due to dilution from Mud Slough, but the proportion of toxic events is still greater at Site D below the SLD outlet than at Site C just above the confluence (Chi-Square Test, p=0.002) (**Figure 10**).
- *Salt Slough (Station F)*: Toxicity has been reduced overall after 2003. However, toxicity to algae was observed at Site F in 1997 to 25% of all samples and in all of the following years except in 2010, when no toxicity was detected (**Figure 10**). This site does not receive drainage water from the GDA.

- Toxicity identification evaluations (TIEs) have been performed to inform managers about potential causes. No definitive results were observed. Further TIEs could be initiated, if toxicity trends are observed to increase.

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Table 1. List of laboratory toxicity test performed for the Grassland Bypass Project

Organism	Test	Units of Measure
Daphnia Magna	Short-term Acute Survival	% Survival
Fathead Minnow (*Pimephales promelas*)	7-day Chronic Larval Survival	% Survival
Daphnia Magna	Short-term Chronic Reproduction	Neonates/female
Fathead Minnow (*Pimephales promelas*)	7-day Chronic Larval Survival	mg/individual
Green alga (*Selenastrum capricornutum*)	96-hour Growth Test	Cells/mL

Figure 1. Grassland Bypass Project. Schematic diagram of the Grasslands water conveyance system
Also shown are the locations of monitoring stations with long-term data relative to hydrologic features (modified from **Figure 2** in SFEI, 2006b). Data from monitoring stations D, F, J, K, L, M, and N (circled in red) were used to calculate annual averages of selenium concentrations in water (**Figure 6**).

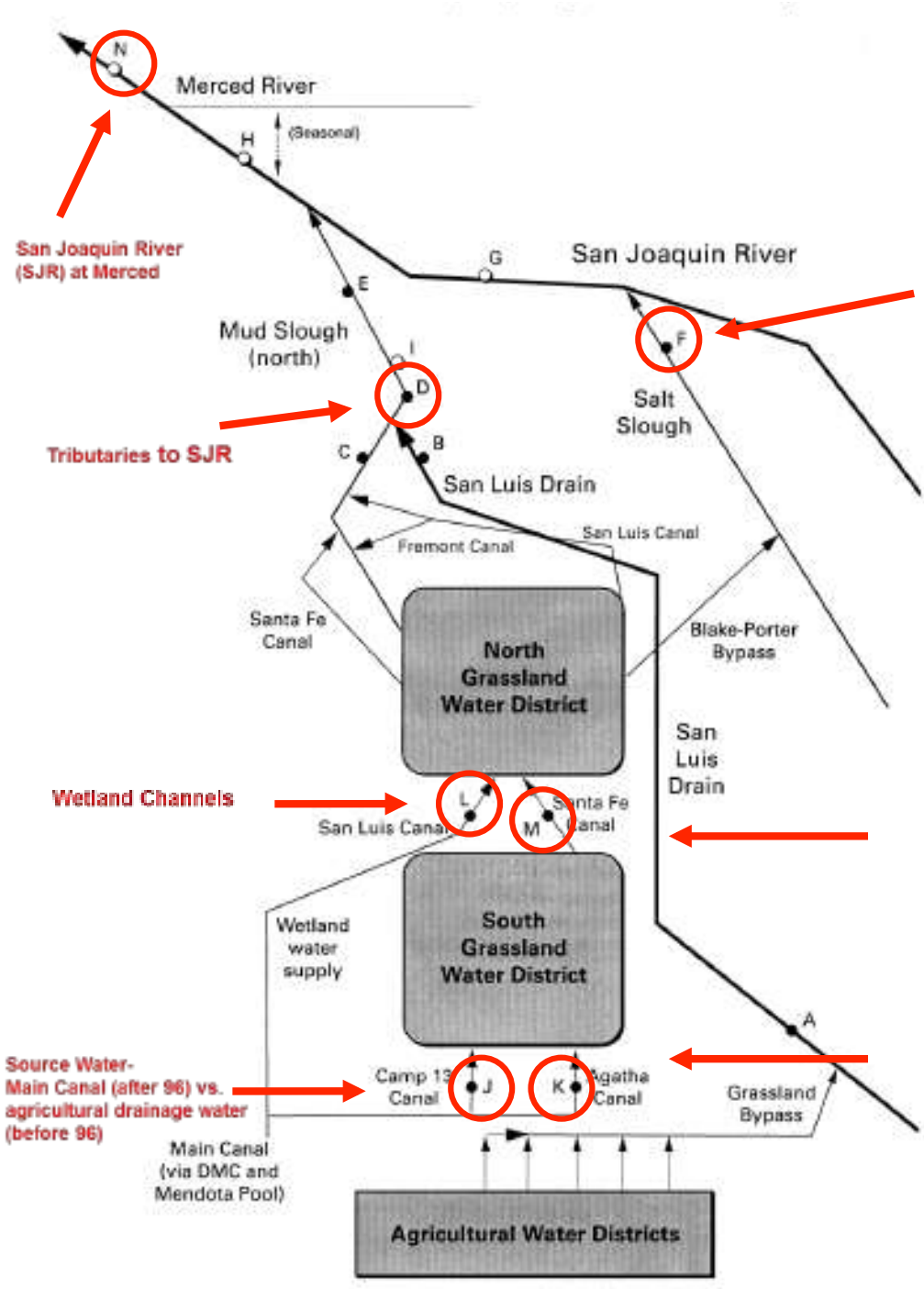


Figure 2. Grasslands subbasin (blue) and the Drainage Project Area (green)

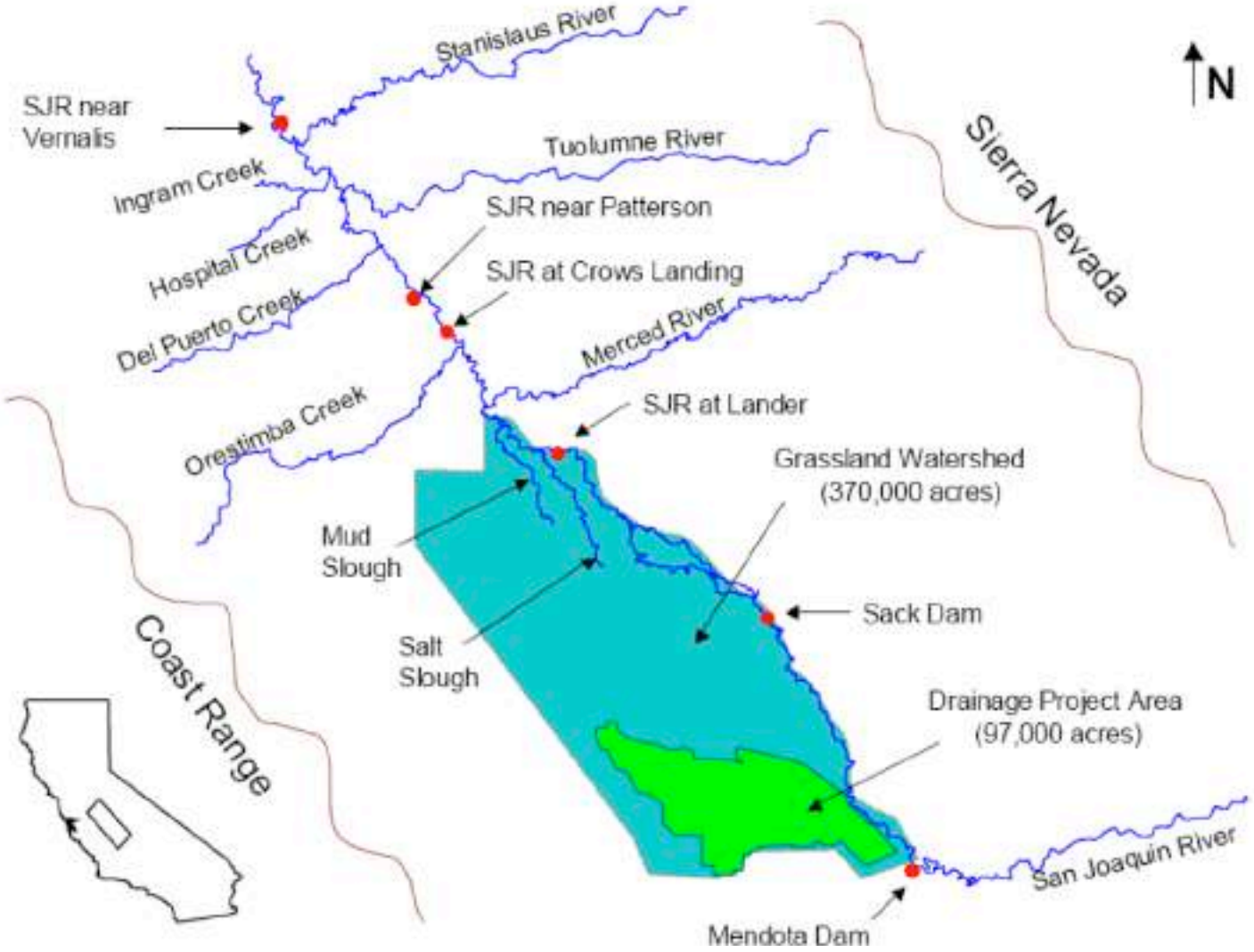


Figure 3. 4-day average selenium concentrations in the San Joaquin River below the confluence with the Merced River (Site N)
Red line indicates the water quality objective of 5 µg/L, 4-day average.

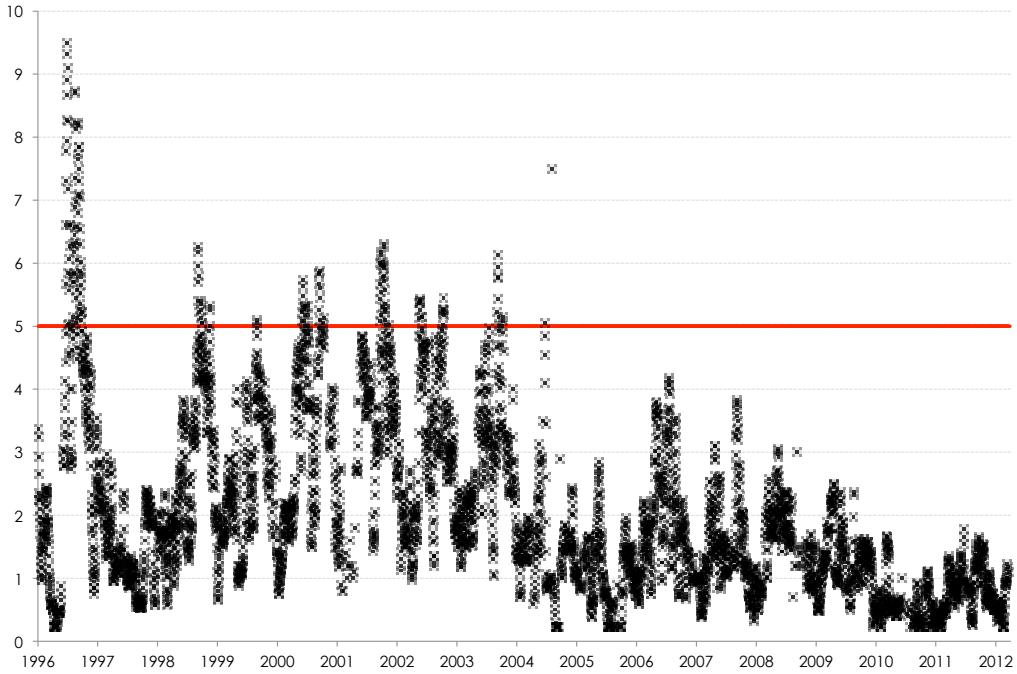


Figure 4. Acreage of land cultivated with salt-tolerant crops in the SJRWQIP
In 2001, an area of 6,200 acres has been dedicated to the San Joaquin River Water Quality Improvement Project for drainage collection systems, reuse and concentration of drainage to minimize discharge of water enriched in selenium and salt, and planting of salt-tolerant crops. *Note: 2001 through 2003 are estimated from incomplete records.*

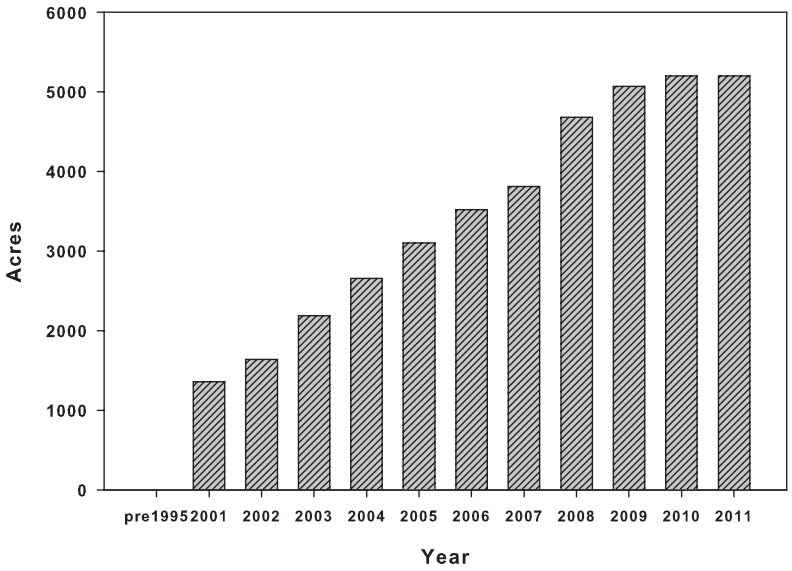


Figure 5. Annual selenium loads (lbs/year) from subsurface agricultural drainage to the Grassland wetlands and from the SLD to Mud Slough

Blue Line: annual load limitations (reference condition) depending on Water Year classification (load numbers are higher during wet years). Green bar: implementation of GBP. Water Year 1986 to 1995 data from CVRWQCB 2000b.

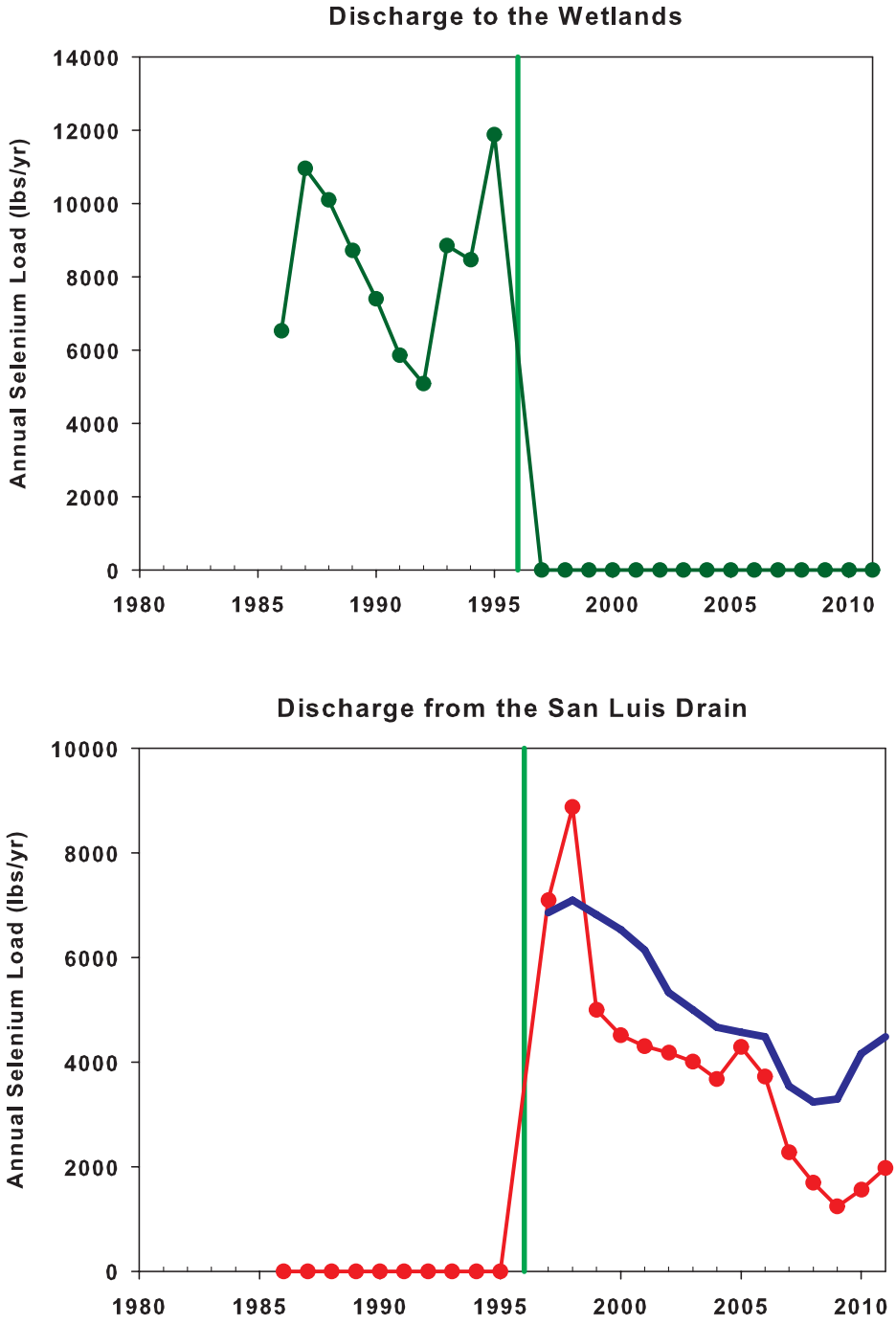


Figure 6. Mean monthly selenium concentrations (µg/L) at Grassland sampling stations (see **Figure 1**): a) Mud Slough (D), b) Salt Slough (F), c) San Luis Canal (L2), d) Santa De Canal (M2), e) Camp 13 (J), and f) Agatha Canal (K). The green bar represents the implementation of the Grassland Bypass Project. The red line represents the 2 µg/L reference condition, which is the no effect threshold for fish and bird toxicity and is used as the mean monthly water quality objective.

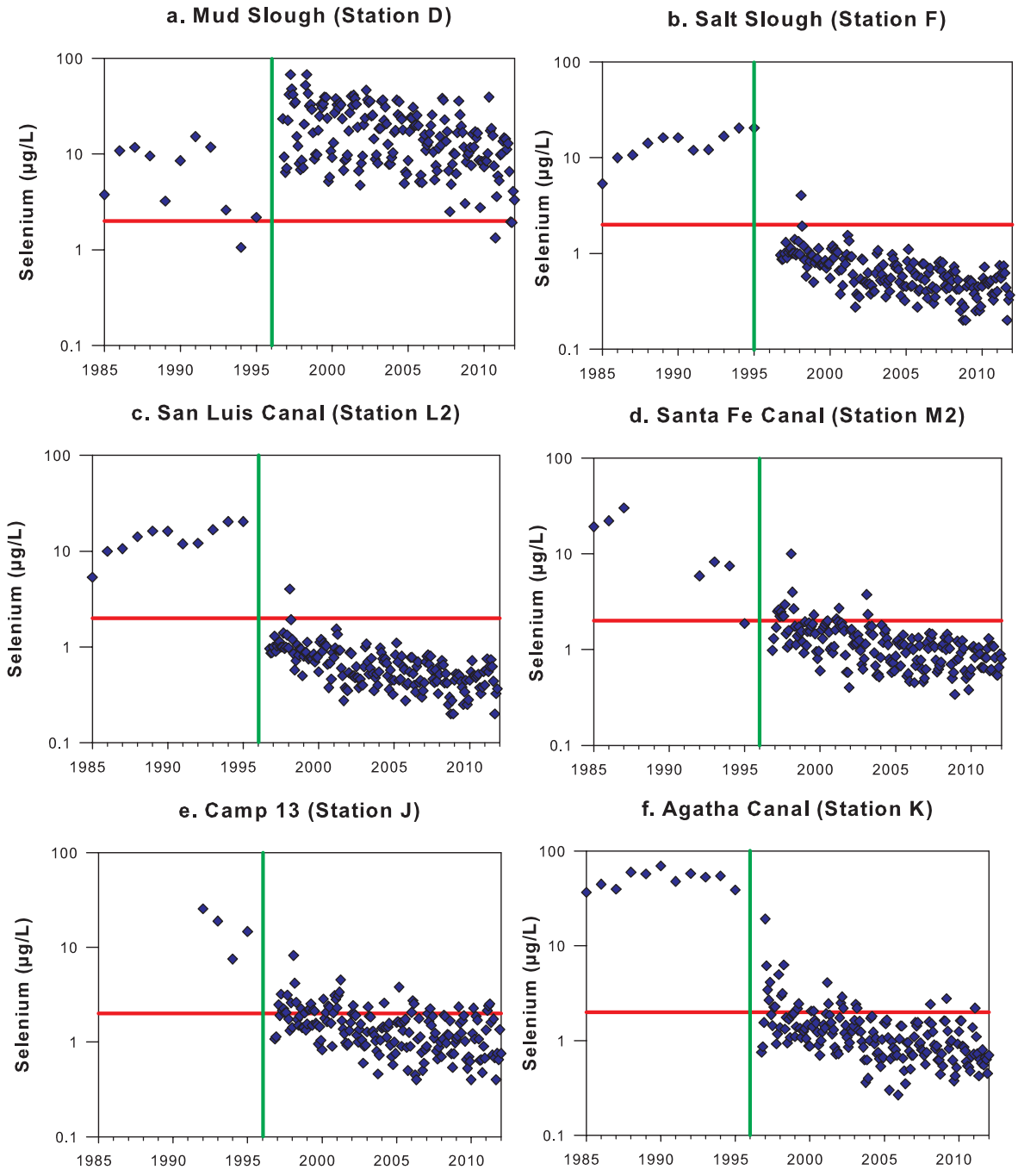


Figure 7. Sampling site locations for data used in the bioaccumulation indicator

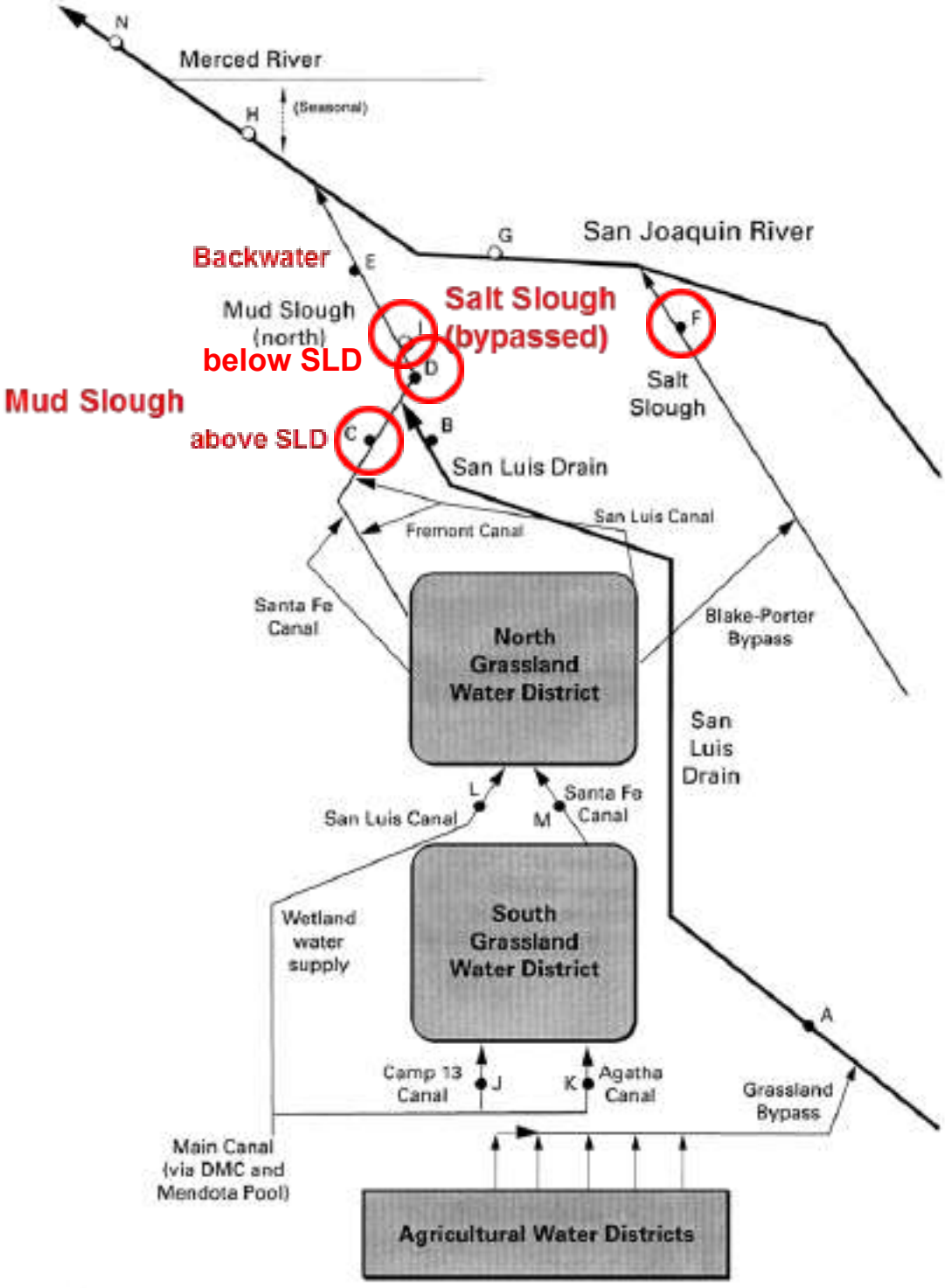


Figure 8. Bioaccumulation Indicator—Mean annual whole body concentrations (mg/kg dry weight) of selenium in invertebrates, small fish, and medium-size fish at four Grassland sampling sites.
Red line indicates thresholds for invertebrates and fish.

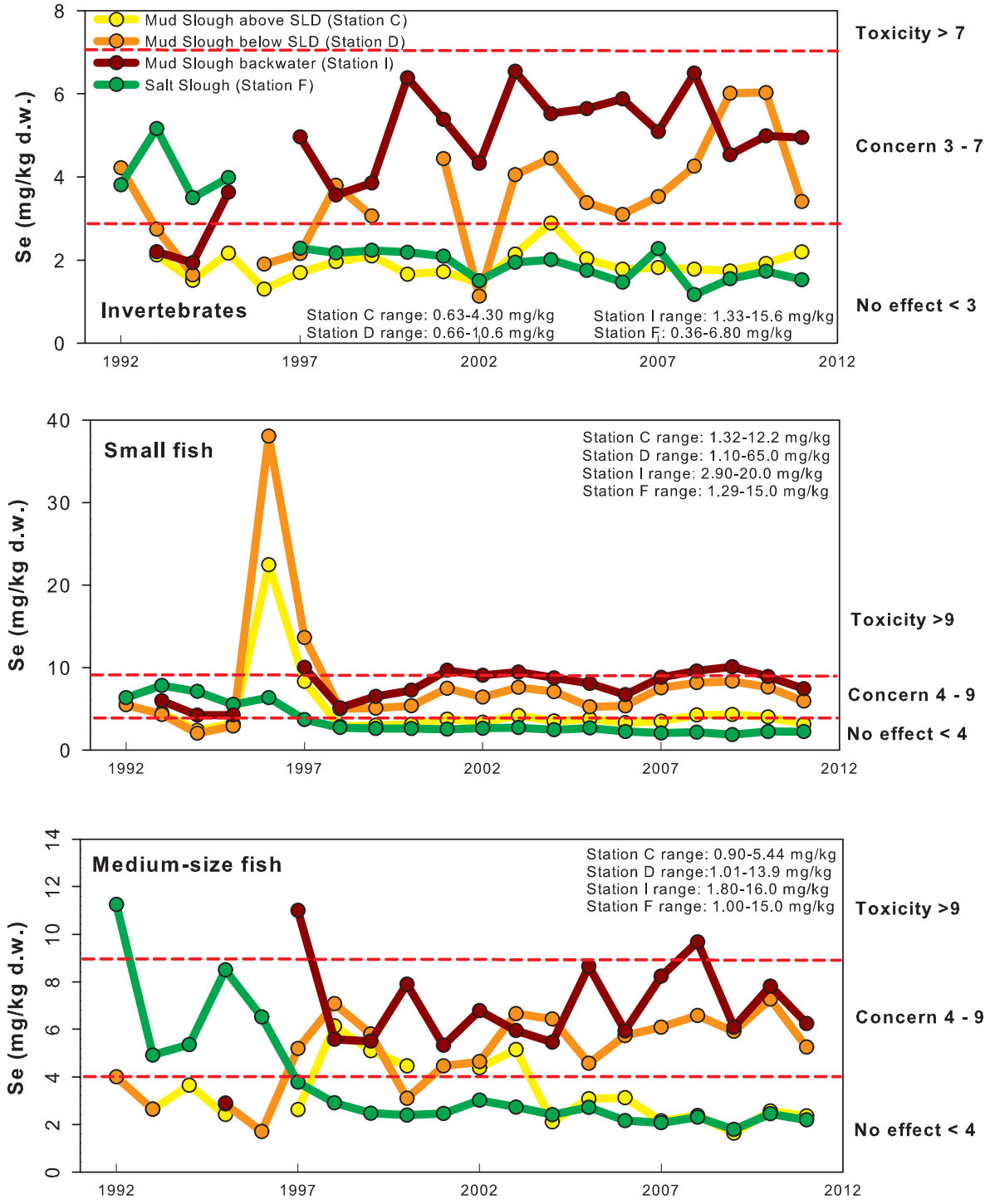


Figure 9. Sampling site locations for toxicity testing

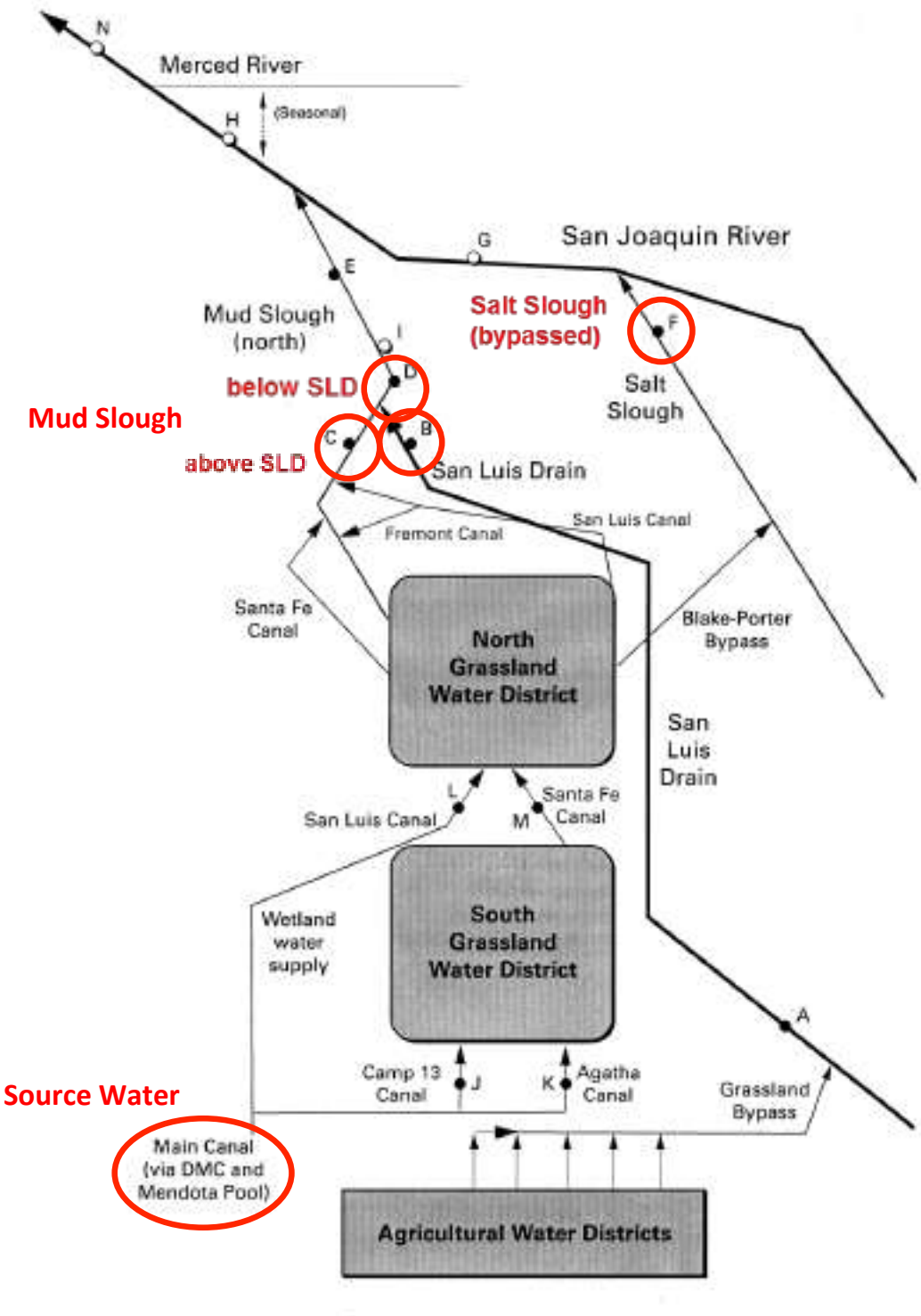
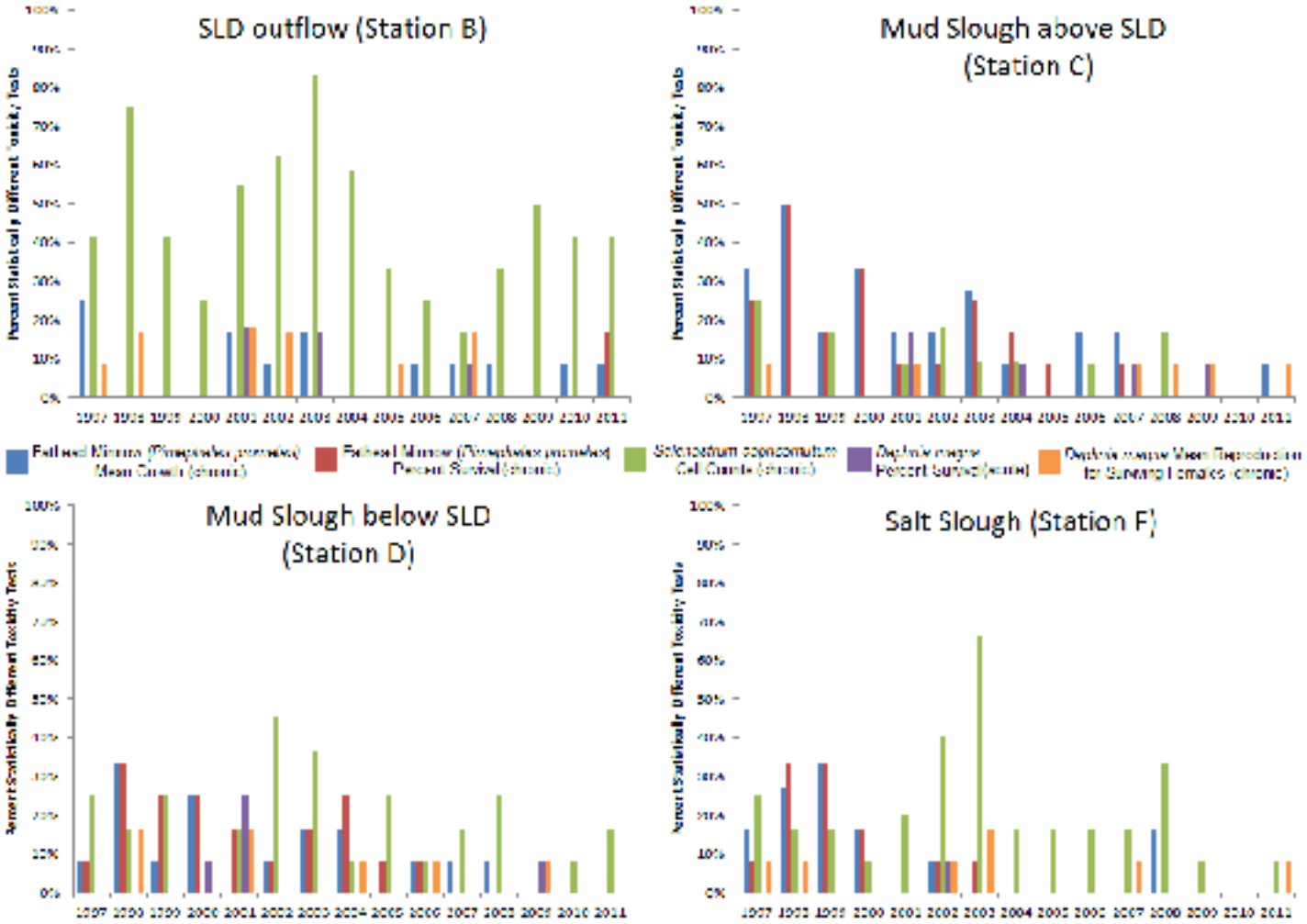


Figure 10. Percentage of statistically different toxicity tests compared to control samples from the Delta Mendota Canal for four Grassland sampling stations

SLD outflow (Station B), Mud Slough above SLD (Station C), Mud Slough below SLD (Station D), and Salt Slough (Station F).



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