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(Grasslands Bypass Project)
to Carry Subsurface Irrigation Drainwater

by

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ABSTRACT

Historically, farmers in the Grasslands area of the western San Joaquin Valley have discharged subsurface agricultural drainwater through wetland channels in the San Luis National Wildlife Refuge Complex (Refuges) to the San Joaquin River. This drainage contains elevated concentrations selenium, salt, boron and other trace elements. To convey this drainwater more directly to the San Joaquin River, bypassing wetland channels, a portion of the San Luis Drain (Drain) was reopened in September 1996 as the Grasslands Bypass Project (Project). The drain has been modified to allow discharge through Mud Slough, a natural waterway which traverses through Kesterson National Wildlife Refuge. An interagency group is cooperatively monitoring and evaluating the effects of the Project to insure that the Project does not result in a net degradation of the ecosystem, and to determine whether the Project should be continued beyond the first two years of operation. The responsibility of the U. S. Fish and Wildlife Service (Service) in this program is to collect samples of potentially affected fish and wildlife for analysis of levels of selenium and boron and provide an interpretation of environmental risk of the project within the Refuge and beyond. Analyses completed to date indicate that selenium concentrations have begun to decline in the fish and invertebrates of Salt Slough, the principal wetlands channel from which drainwater has been removed by the Project. After the Drain began discharging drainwater into Mud Slough, selenium concentrations in the most common fish (mosquitofish and inland silversides) both upstream and downstream of the discharge point rose substantially during the first six months of operation of the Project. These concentrations have more recently declined somewhat, but are still above pre-project levels. Continued biological monitoring is critical to determine whether trends continue downward sufficiently to justify continuation of this Project.

INTRODUCTION

In 1985 the San Luis Drain was closed due to selenium poisoning of waterbirds at a reservoir in the Kesterson National Wildlife Refuge at the terminus of the Drain. The Drain, constructed by the U. S. Bureau of Reclamation (USBR), had been conceived as the solution to valley-wide problems of disposal of agricultural drainwater. However, due to environmental concerns and budget constraints, the Drain had never been completed as originally planned. The constructed portion of the Drain had been used only to convey subsurface agricultural drainwater from the Westland Water District in the western San Joaquin Valley. Farms in the adjacent Grasslands area never used the Drain, but discharged toxic subsurface drainwater through wetland channels in the San Luis National Wildlife Refuge Complex (Refuges) to the San Joaquin River (Figure 1). This drainwater contains extraordinarily elevated concentrations of selenium, boron, chromium, molybdenum, and extremely high concentrations of various salts that disrupt the normal ionic balance of the aquatic system. State health advisories for consumption of fish and waterfowl have been put into effect for the Grasslands area, and warnings not to eat fish have been posted at the Refuges. Discharge from Grasslands area farmerss was unaffected by the closure of the Drain, and drainage continued to contaminate Refuge water delivery channels after the closure of Kesterson Reservoir.

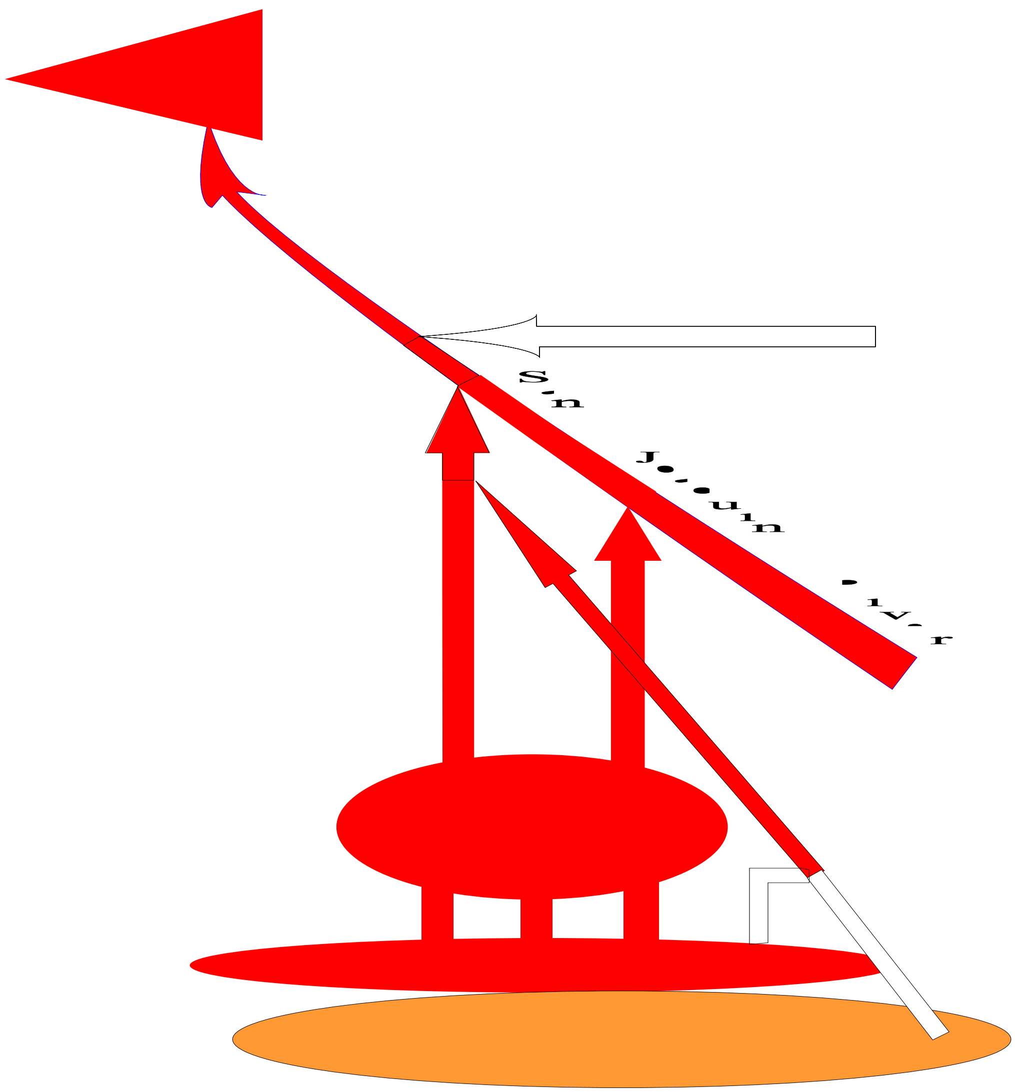

Figure 1 Schematic of Grasslands Bypass Project drainwater routes and affected waterways.

To address this problem, a proposal to reopen the San Luis Drain 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, 1995a, 1995b; USBR et al., 1995). This project is identified in the Final Report of the San Joaquin Valley Drainage Program (1990) as one of the key action items to manage irrigation drainage in the Grasslands watershed. One of the original authors of the plan was Gary Zahm, Manager of the Refuges. The U.S. Bureau of Reclamation has signed a two-year Use Agreement with the San Luis Delta-Mendota Water Authority (SLD-MWA) with renewal for three more years dependent upon meeting certain conditions and the review of an inter-agency Oversight Committee (USBR, 1995b). A Finding of No Significant Impact (FONSI) was also approved (USBR, 1995a). The Grasslands Bypass Project, as it is called, is intended to remove drainwater from more than 90 miles of channels including Salt Slough and allow the Refuges full use of water rights to create and restore wetlands on the Refuges. This action will likely continue, and even increase, the degradation of a six-mile portion of Mud Slough and the San Joaquin River until phased-in load reduction goals can be achieved by water districts. The Refuges have 19,900 acre-feet of water rights to Salt Slough that has been precluded from use due to contamination by sub-surface drainage flows. Salt Slough is the conveyance channel from which the Refuges exercise appropriative water rights. Monitoring is essential to avoid using water for wetland management that does not meet Service water quality requirements. A key section of the FONSI identifies an interagency monitoring program as critical to the success of the project.

METHODS

The study reported here is the Service s portion of a larger interagency monitoring program that is essential to the Use Agreement (USBR, 1995a) and FONSI (USBR, 1995b) under which the Grasslands Bypass Project is operating. The methods used in this study are described in a multi-agency monitoring plan (USBR et al., 1996) and follow the standard operating procedures of the Service s Division of Environmental Contaminants (USFWS, 1995). The role of the Service in this interagency program is to monitor biota on the Refuges for effects on wildlife. The responsibilities of other agencies and entities in the monitoring program include the following: drainage districts monitor water quality from drainage systems and contract bioassay tests; the USBR monitors sediment data management, and oversees the project; the Regional Board monitors water quality throughout the Grasslands Basin; the U.S. Geological Survey maintains several gaging stations related to the project which record flow and basic water quality parameters; the California Department of Fish and Game monitors game fish tissue for human health concerns; and the Service.

To obtain baseline data for this study, the Service began sampling in 1992, shortly after this Project was first proposed in 1991 by the USBR. Service sampling efforts before the reopening of the drain were based on early drafts of the monitoring plan. Certain aspects of the sampling protocol have been adaptively adjusted in close coordination with other cooperating agencies of the interagency monitoring group by way of monthly meetings of the Data Collection and Reporting Team.

Contaminants of concern

The primary contaminant of concern in this study is selenium because of the propensity of this element to bioaccumulate in aquatic organisms and because of the well-known history of poisoning and terratogenesis caused by selenium in drain water in this area. Nearly a dozen inorganic constituents in drainage water, however, are of potential toxicological interest, especially boron.

To provide benchmarks for interpreting selenium concentrations in various biologically relevant matrixes sampled in this study, a set of ecological risk guidelines was developed (Table 1) based on a large number of laboratory studies and confirmatory field studies most of which are summarized in Skorupa, et al. (1996) and Lemly (1993). For water, sediment, and various biotic compartments, these guidelines identify ranges of selenium concentrations associated with no known risk, uncertain risk (grey zone), and known toxicity (red zone).

Table 1. Recommended Ecological Risk Guidelines Based Upon Selenium Residues

Matrix	Units	No Effect	Level of Concern (grey zone)	Toxicity Threshold (red zone)
Fish (whole body)	mg/kg (dry weight)	< 4	4-12	> 12
Vegetation (as diet)	mg/kg (dry weight)	< 2	3-7	7
Animal food chain (invertebrates)	mg/kg (dry weight)	< 3	3-7*	> 7
Sediment	mg/kg (dry weight)	< 2	2-4	> 4
Water	g/L	< 2 (prefer <1)	2-5	> 5
Avian Egg	mg/kg (dry weight)	< 3	3-8 (pop. hatchability)	> 8

Notes

These guidelines are intended to be population based. Thus, trends in means over time should be evaluated.

A tiered approach is suggested with water being the least meaningful measure and whole body fish being the most meaningful in assessment of ecological risk in a flowing system.

The red zone effect is reproductive impairment in fish and birds.

The whole body (WB) fish guideline is for warm water fish.

The animal food chain guideline refers to hazards to birds. If food chain residues exceed 6 mg/kg then avian eggs should be monitored.

Vegetation as diet is based on poultry literature.

Sampling sites

Baseline samples were collected from two sites on Salt Slough, four sites on Mud Slough, two sites in the San Luis Drain, and from one reference site at East Big Lake, which receives little selenium contaminated drainwater. In 1996 and 1997, in accordance with the Service s commitments under the interagency monitoring plan (USBR, et al., 1996) sampling was focused on five of those baseline sampling locations. Three of these sites are on Mud Slough: site C) an upstream reference location a quarter mile above the discharge of the San Luis Drain; site D) a point downstream of the San Luis Drain connection at the USGS gage station; and site I) a backwater area adjacent to Mud Slough approximately 1 mile downstream from site D. To assess the mitigative effects of removal of drainwater from Salt Slough one sample point, site F, is located on Salt Slough just upstream of the USGS gaging station on the refuges. Service biota sample sites are shown in Figure 2.

Figure 2 U. S. Fish and Wildlife Service sampling locations for the Grasslands Bypass Project.

Sampling times

Experience gained in the early years of baseline sampling for this Project 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. These sampling times are spread out in a roughly quarterly sampling regime. They are in November, March, June, and August. The history of actual sample times for this project is listed in Table 2. For each sampling, Table 2 also lists the catalog number of the samples submitted to the Patuxent Analytical Control Facility for analysis.

Table 2. Grasslands Bypass Project sampling history

Year	Month	Catalog
1992		
	March	1080015, 1080018
	May	1080015, 1080018
	June	1080015, 1080018
	July	1080015, 1080018
	October	1080015, 1080018
1993		
	March	1080043, 1080056
	July	1080043, 1080056
	November	1080043, 1080056
1994		
	February	1080072, 1080085
	June	1080072, 1080085
	September	1080072, 1080085
1995*		
	May	1080104, 1080105
	August	1080104, 1080105
1996		
	March	1080116, 1080120 (de-funded)
	May (eggs only)	1080121 (results pending)
	June	1080115 (de-funded)
	August	1080118 (de-funded)
****** San Luis Drain reopened September 25, 1996 ****************		
	November	1080125
1997		
	March	1080131
	May (eggs only)	1080138 (results pending)
	June	1080136
	September	1080141, 1080142, 1080143 (results pending)

*Sampling limited by severe flooding early in the year and by Regional Office restrictions

Matrices sampled and parameters measured

Samples of biota, water, and sediment were collected concurrently at each site and analyzed for selenium and boron. At each site, standard water quality parameters including temperature, dissolved oxygen, pH, and electrical conductance (as specific conductance) were also measured with a Sonde hydrolab.

Biota

Aquatic specimens were collected with hand nets and seine nets and handled following procedures in Saiki (1984) and USFWS (1995). Mosquitofish (*Gambusia affinis*), inland silversides (*Menisia beryllina*), red shiners (*Notropis lutrensis*), fathead minnows (*Pimephales promelas*), and green sunfish (*Lepomis cyanellus*) were the principal species of fish collected. Water boatmen (family: *Corixidae*), backswimmers (Family: *Notonectidae*), and red crayfish were the principle invertebrates collected. Separation of biological samples from unwanted material also collected in the nets was accomplished by using stainless steel sieves and glass (or enamel) pans pre-rinsed with deionized 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 collected also. Fish were submitted for whole body analysis. The seed heads of wetland plants that provide food for waterfowl were collected once a year in the late summer. Waterfowl and/or shorebird eggs, depending on availability, were collected from areas adjacent to Mud Slough and the Drain in the spring (minimum 5 eggs per species). In addition, in 1992 snowy egret and black-crowned night heron eggs were collected at East Big Lake. All biota samples were kept on ice while in the field then kept frozen to -20 ºC during storage and shipment. Equipment was cleaned between sites as stated above. All tissue samples were composite samples. Tissue samples were freeze dried and homogenized. For all samples, after Nitric-perchloric digestion, total selenium was determined by hydride generation A.A.. Dry weight (mg/kg) detection limits ranged from 0.2 to 0.6 in tissue, 0.05 to 1.0 in sediment, and was 0.5 ug/L in water.

Water

The Regional Board, Water Authority, and USGS are responsible for monitoring water on a daily and weekly basis for the interagency monitoring program (USBR, et al., 1996). In addition, for comparison and correlation with biota samples, we collected unfiltered grab samples at the times and locations of biota collection. A hand-held depth integrating sampler was used along a transect across the slough channels to collect a composited sample. A transect across the backwater area at site I was also done. Water samples are handled according to Keith (1988) and USFWS (1995). Samples were placed in plastic, 1 liter jars and acidified with nitric acid to less than pH 2. Water samples were kept on ice in the field and then maintained at 4 C to 6 C during storage. Equipment was washed in soap and water and rinsed with dilute hydrochloric acid and deionized water between sites. Samples were analyzed for total recoverable selenium and boron.

In selenium contaminated environments, total recoverable selenium has more toxicological significance than dissolved selenium in the interpretation of bioaccumulation data (Skorupa and Ohlendorf, 1991; Skorupa, et al., 1996).

Sediment

In 1992, sediment was collected from the slough sites, East Big Lake and the San Luis Drain but in 1993 sediment collection efforts for background data at the slough sites were reduced. Under the interagency monitoring program (USBR, et al., 1996), responsibility for sediment monitoring was assumed by the Bureau of Reclamation. However, concomitant with biota sampling, we continued to collect composite sediment samples in Salt Slough and in the potentially depositional backwater area of Mud Slough (Site I) to provide confirmatory data with Bureau sampling. A minimum of three samples along a transect across the channel was composited in a cleaned plastic or stainless steel bucket (USFWS, 1995). A subsample was placed in a plastic bag (Whirl-Pak) and placed on ice in the field. Samples were stored frozen and shipped on dry ice to the contract laboratory. Equipment was washed in soap and water and rinsed with dilute hydrochloric acid and deionized water between sites.

RESULTS

After the reopening of the Drain in September 1996 selenium concentrations increased dramatically in the two most common species of fish in Mud Slough, mosquitofish and inland silversides. In November, one month after discharge of drainwater began, extremely elevated levels of selenium were found in mosquitofish in Mud Slough both upstream (mean = 33 ppm) and downstream (mean = 59 ppm) from the discharge point in the slough (Figures 3 and 4). These concentrations were much higher than those found in mosquitofish sampled in the five years prior to the reopening of the Drain (~5 ppm) and were several times higher than the toxicity threshold (12 ppm) for fish (Table 1). By March 1997, selenium concentrations in Mud Slough mosquitofish had declined but were still well above the toxicity threshold both upstream (mean = 17.5) and downstream (mean = 33.6) from the drainwater outfall. By June 1997 selenium levels in Mud Slough mosquitofish had further declined to below the toxicity threshold but within the region of concern and well above historic levels for that season.

Figure 3 Selenium in fish in Mud Slough below the San Luis Drain discharge (Site D).

Selenium levels in inland silversides responded more slowly to the increase in ambient selenium caused by the discharge of drainwater into Mud Slough (Figure 4). One month after the reopening of the Drain, selenium in inland silversides downstream from the drainwater outfall had increased to levels (mean = 17.3 ppm) well above historic levels and above the toxicity threshold. Selenium in inland silversides rose further in March 1997 (upstream mean = 22.4 ppm, downstream mean = 33.7 ppm) when selenium in mosquitofish was dropping at the same locations in Mud Slough. By June 1997, selenium concentrations in inland silversides in Mud Slough had begun dropping again but were still well above pre-project levels; downstream of the drain outfall, concentrations (mean = 15.5 ppm) remained well above the toxicity threshold.

Selenium concentrations in red shiners responded even more slowly than in inland silversides to the influx of drainwater in Mud Slough (Figure 3). In March 1997 concentrations in red shiners downstream from the discharge (mean = 5.4 ppm) were about the same as pre-project same-season concentrations (mean = 5.8 ppm). However, by June 1997, selenium in red shiners in that location (mean = 7.2 ppm) was significantly elevated ($p < 0.0001$, Student s *t*-test) compared with baseline June levels (mean = 3.4 ppm).

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

Levels of selenium in both mosquitofish and inland silversides upstream of the discharge tracked downstream trends at about half downstream concentrations (Figures 3 and 4). This suggests that some portion of the population of these fish may have moved upstream from the drainwater discharge point after having fed and accumulated selenium in drainwater. Conversely, the full impact of drainwater selenium on individual fish downstream of the Drain discharge may be masked by relatively clean individuals migrating downstream and being included in our composite samples.

After reopening of the Drain, concentrations of selenium in mosquitofish in the backwater area of Mud Slough (Site I) downstream of the Drain discharge rose well above baseline levels (pre-project mean = 6.85 ppm) to nearly the toxicity threshold concentration (Figure 5; mean = 11.7 ppm; toxicity threshold = 12 ppm). Because the backwater is dry for most of the year, aquatic samples can reliably be collected only during the March sampling.

Figure 5 Selenium in fish in the Mud Slough backwater below the Drain discharge (Site I)

In Salt Slough, a principal waterway from which drainwater was to be removed by the Project, reductions in concentrations of selenium in fish have been slight and slow to occur (Figure 6). The only significant reduction to be found in our data set was exhibited by red shiners in June 1997 (mean = 3.5 ppm; baseline June mean = 5.5; $p = 0.01$, Student s *t*-test). Several months to a year may be required for fish populations to depurate accumulated selenium after selenium in their environment is reduced. In addition, residual selenium deposited in slough sediments may continue to be re-mobilized into the food chain long after drainwater has been removed from the slough. A further complication in interpretation has been caused by the unilateral decision of drainers to divert drainwater back into wetland channels during a storm event in late January 1997. This has recontaminated channels, such as Salt Slough, that were to be cleaned up the operation of the project.

Figure 6 Selenium in fish in Salt Slough (Site F).

Concentrations of selenium in aquatic invertebrates did not exceed the toxicity threshold for invertebrates at any of the sampled locations (Figures 7, 8, 9, and 10). Below the drain discharge in Mud Slough selenium concentrations in invertebrates exhibit seasonal variation, with maximum concentration in February and March (Figure 7). However, as of March of 1997 there was no clear effect of discharge of agricultural drainwater at this location. Not enough invertebrates could be collected there in June of 1997 to provide an adequate sample of any invertebrate species.

Figure 7 Selenium in invertebrates in Mud Slough below the San Luis Drain discharge (Site D)

In Mud Slough above the Drain discharge, selenium concentrations in waterboatmen in March 1997 (mean = 1.94 ppm) were appreciably above the pre-project baseline concentration for the same season (mean = 0.85 ppm). Concentrations in waterboatmen rose further in June 1997 to levels (mean = 3.35 ppm) well above the June baseline (mean = 1.73 ppm) and above the threshold of concern (3 ppm).

Figure 8 Selenium in invertebrates in Mud Slough above the San Luis Drain discharge (Site C)

In the backwater of Mud Slough below the Drain discharge, selenium concentrations in waterboatmen in March 1997 after reopening of the Drain (mean = 3.5 ppm) exceeded the threshold of concern for invertebrates (3 ppm) and were well above the baseline March concentrations (mean = 2.2 ppm; Figure 8).

Figure 9 Selenium in invertebrates in the Mud Slough backwater below the Drain discharge (Site I)

In Salt Slough, which was expected to benefit from removal of drainwater, selenium concentrations in waterboatmen and crayfish in March 1997 after opening of the bypass were about half pre-project levels for the same season (Figure 10).

Figure 10 Selenium in invertebrates in Salt Slough (Site F).

CONCLUSIONS

Within a month after the reopening of the San Luis Drain to carry Grasslands area agricultural drainwater, the worst affected Refuge ecosystem (Mud Slough) exhibited bioaccumulation of selenium to well above hazardous concentrations. In the last six to nine months, selenium concentrations in the biota have begun to trend downward, but remain sufficiently elevated to be of ecological concern. While drainwater was formerly discharged to Mud Slough it is now the predominant source of water and this dominance persists year round. In the portions of the Refuges that were to benefit from the Project, principally Salt Slough, reductions in selenium have thus far been slight to moderate but statistically and toxicologically significant. It remains to be seen whether the overall effect of the Project on the wetland ecosystems in the area will prove to be significantly negative or positive. Continued monitoring of the biota is essential to a sound evaluation of the project impact. On this assessment rests the fate of the Grasslands Bypass Project, a project which has combined all non-point sub-surface drainage sources into one monitorable and manageable source. Within the year this project will be regulated by a waste discharge requirement under state law. It tentatively appears that the first year result of the project on selenium loads was to reduce the annual selenium load from 10,000 lbs in 1996 to 7,300 lbs in 1997.

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REFERENCES

Baumann, P.C. and T.W. May. 1984. Selenium residues in fish from inland waters of the United States. In Workshop Proceedings: The effects of trace elements on aquatic ecosystems, pp.7-1 to 7-16. Compiled by the Carolina Power and Light Co. For the Electric Power Research Institute, Palo Alto, CA. 1984.

Clark, S. and F. Paveglio. 1989. Water quality in the Camp 13 ditch/Agatha Canal water exchange system and other primary canals in the west Grasslands, Merced County, California, September 6 - October 18, 1988. San Luis National Wildlife Refuge report in cooperation with the San Joaquin Valley Drainage Program. April 12, 1989.

Gillespie, R.B. and P.C. Baumann. 1986. Effects of high tissue concentrations of selenium on reproduction by bluegills. Trans. Am. Fish. Soc., 115:208-213.

Hermanutz, R.O., K.N. Allen, T.H. Roush, and S.F. Hedtke. 1992. Effects of elevated selenium concentrations on bluegills (*Lepomis macrochirus*) in outdoor experimental streams. Environ. Toxicol. Chem., 11:217-224.

Keith, Lawrence H. 1988. Principles of environmental sampling. American Chemical Society, ACS professional reference book, 1988.

Lemly, A.D. 1993. Guidelines for evaluating selenium data from aquatic monitoring and assessment studies. Environ. Monitor. Assess., 28:83-100.

Maier, K.J. and A.W. Knight. 1994. Ecotoxicology of selenium in freshwater systems. Rev. Environ. Contam. Toxicol., 134:31-48.

Moore, S.B., J. Winckel, S.J. Detwiler, S.A. Klasing, P.A. Gaul, N.R. Kanim, B.E. Kesser, A.B. DeBevac, K. Beardsley, and L.K. Puckett. 1990. Fish and Wildlife Resources and Agricultural Drainage in the San Joaquin Valley, California. San Joaquin Valley Drainage Program, Sacramento, CA. October 1990.

PACF. 1990. Patuxent Analytical Control Facility Reference Manual. U.S. Fish and Wildlife Service, Laurel, MD.

Paveglio, F. and S. Clark. 1988. Water quality in the Camp 13 ditch/Agatha Canal water exchange system and other primary canals in the west Grasslands, Merced County, California, September 16 - October 22, 1987. San Luis National Wildlife Refuge report in cooperation with the San Joaquin Valley Drainage Program. June, 1989.

Saiki, Michael K. 1984. Environmental conditions and fish fauna in low elevation rivers on the irrigated San Joaquin Valley floor, California. California Fish and Game, 70(3): 145-157. 1984.

San Joaquin Valley Drainage Program. 1990. A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley. Final Report. September, 1990. 183 pp.

SWRCB (State Water Resources Control Board). 1987. Regulation of agricultural drainage to the San Joaquin River. Final Report. SWRCB Order No. W.Q. 85-1, Technical Committee Report. August 1987.

Skorupa, Joseph P., S.P. Morman, and J.S. Sefchick-Edwards. 1996. Guidelines for interpreting selenium exposures of biota associated with nonmarine aquatic habitats. Prepared for the Department of Interior, National Irrigation Water Quality Program by the Sacramento Field Office of the U.S. Fish and Wildlife Service. March 1996. 74 pp.

Skorupa, Joseph P. and H.M. Ohlendorf. 1991. Contaminants in drainage water and avian risk thresholds. In The Economics and Management of Water and Drainage in Agriculture. Arial Dinar and David Zilberman Editors. Kluwer Academic Publishers, 1991.

USBR (U.S. Bureau of Reclamation). 1995a. Finding of No Significant Impact and Supplemental Environmental Assessment. Grasslands Bypass Channel Project, interim use of a portion of the San Luis Drain for conveyance of drainage water through the Grasslands Water District and adjacent Grassland areas. Mid-Pacific Region, Sacramento California. November 1995.

USBR (U.S. Bureau of Reclamation). 1995b. Agreement for use of the San Luis Drain. Agreement No. 6-07-20-W1319 between the United States Department of Interior Bureau of Reclamation, Central Valley Project, California and the San Luis & Delta-Mendota Water Authority. November 3, 1995.

USBR (U.S. Bureau of Reclamation), U.S. Fish and Wildlife Service, San Luis & Delta-Mendota Water Authority, and U.S. Environmental Protection Agency. 1995. Consensus letter to Karl Longley, Chairman, Central Valley Regional Water Quality Control Board. Subject: Basin Plan Amendment for the San Joaquin River. November 3, 1995.

USBR (U.S. Bureau of Reclamation), U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S. Geological Survey, Central Valley Regional Water Quality Control Board, California Department of Fish and Game, and San Luis & Delta-Mendota Water Authority. 1996. Compliance monitoring program for use and operation of the Grassland Bypass Project. September 1996.

USFWS (U.S. Fish and Wildlife Service). 1995. Standard Operation Procedures for Environmental Contaminant Operations, Vols. I - IX. Quality Assurance and Control Program, U.S. Fish and Wildlife Service, Division of Environmental Contaminants, Quality Assurance Task Force. Washington D.C. February 1995.

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