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June 22, 2015

VIA U.S. POST AND EMAIL: margaret.wong@waterboards.ca.gov

Attn: Ms. Margaret Wong
Central Valley Regional Water Quality Control Board
11020 Sun Center Drive, Suite 200
Rancho Cordova, CA 95670-6114

Re: Comments of the Pacific Coast Federation of Fishermen's Associations Requesting Denial of Proposed Waste Discharge Requirements for Surface Water Discharges from the Grassland Bypass Project

Dear Ms. Wong:

On 8 May 2015, the California Regional Water Quality Control Board, Central Valley Region released proposed waste discharge requirements and a monitoring and reporting program for surface water discharges from the Grassland Bypass Project ("GBP"). The proposed Waste Discharge Requirement ("WDR") and monitoring and reporting program are proposed to be issued to the San Luis & Delta-Mendota Water Authority ("SLDMWA") and the U.S. Department of the Interior, Bureau of Reclamation ("Reclamation"). The Regional Board's notice states that written comments on the proposed GBP Order are due by 22 June 2015.

On behalf of the Pacific Coast Federation of Fishermen's Associations ("PCFFA"), we respectfully **oppose** the proposed WDR. This 2015 Tentative WDR conflicts with the Environmental Impact Statement/ Environmental Impact Report ("EIS/EIR") for the GBP. Further, it is internally inconsistent and in conflict with the Third Use Agreement. Finally, the WDR's monitoring requirements and other measures aimed at protecting the area's biological resources are wholly inadequate. For these reasons and others as discussed below, we ask you to **disapprove** the 2015 Tentative WDR for the GBP. PCFFA opposes the use of the San Joaquin River and its tributaries as a de-facto drain for agricultural wastewater from the SLDMWA's Westside districts causing downstream users and the Delta Estuary to bear the crippling burden of the pollution carried in these flows. The Tentative WDR will not protect beneficial uses, will continue to degrade water quality, and does not protect the public trust values ensured under the California Constitution.

It is essential that aquatic species and water quality in the San Joaquin River and Bay-Delta be protected by adequate pollutant load limits and mitigation measures. Reducing the discharge of selenium and salt into the San Joaquin River and Delta is a vital component of this long-overdue protection.

The Tentative GBP WDR contains language allowing the discharge of agricultural drainage water to Mud Slough (north), and discharges of selenium from the San Luis Drain or Grassland Bypass, after December 31, 2019. Tentative WDR Prohibition 3, Table 2. This is unacceptable.

The August 2009 Environmental Impact Statement and Environmental Impact Report ("EIR/EIS") only analyzed operation of the GBP through December 31, 2019, and requires *cessation* of all discharges from the San Luis Drain after that date. Therefore, this EIR/EIS cannot be used to provide the necessary CEQA and NEPA compliance for agricultural drainage discharges to the San Joaquin River *after* December 2019.

Background

PCFFA is a non-profit, tax-exempt corporation which represents a coalition of 16 fishermen's organizations in California, Oregon, and Washington with a combined membership of more than 750 fishing men and women, the largest such association on the West Coast. Individual members fish primarily with non-trawl gear under limited entry and open access regimes, targeting rockfish, sablefish, and other groundfish, as well as a variety of non-groundfish species including salmon. Each member depends on the ocean's fisheries – including many species of anadromous fish that use the San Joaquin River and Bay-Delta as juveniles when migrating out to sea and again as adults when returning to spawn – for his or her livelihood.

Nineteen years ago, the Regional Board implemented a selenium control program which required compliance with a protective standard (5 μg/L) by October 1, 2010 for Mud Slough (north) and the San Joaquin River above the Merced River. The Basin Plan was then amended and substantially weakened by delaying the selenium objective in these waterbodies by another nine years, three months. This extension needlessly facilitated additional discharge of selenium-contaminated water, preventing compliance with key provisions of the Basin Plan and the Clean Water Act,[1] as well as state policy for water quality control. *See* Wat. Code section 13146. Now the Tentative GBP WDR seeks to allow continued discharge of selenium after the new 2019 cutoff date. For the following reasons, the Regional Board should reject this proposed WDR because it

[1] National Pollution Discharge Elimination Permits are required under the Clean Water Act for the reuse area, lands that discharge into the GBP but are not part of the Project, and for groundwater pumping into the Delta Mendota Canal. Yet the WDR fails to address this Clean Water Act requirement.

conflicts with federal and state laws and policies. PCFFA requests that the Regional Board instead issue a cease and desist order to halt this pollution immediately.

1. **The Proposed Relaxation of Selenium Load Targets Between 2015-2019 Conflicts with the 2010-2019 GBP EIS/EIR**

The proposed WDR dramatically weakens the selenium loading targets established in the 2010-2019 GBP EIS/EIR. The EIS/EIR's analysis of environmental impacts was predicated upon the lower, stricter targets currently in effect. And the Biological Opinion ("BiOp") prepared by the U.S. Fish and Wildlife Service ("FWS") expressly relies upon the fact that beginning "[i]n 2015, more restricted load limits" for "selenium and salt" "will apply in all water use types, reducing allowable contaminant loadings to Mud Slough (North) and the San Joaquin River." 2009 FWS BiOp at 17. The BiOp also states that its conclusions are premised upon the requirement that "[a]ll conservation measures . . . be fully adhered to." *Id.* at 146. Yet the Board inexplicably claims that this loosening of environmental protections "is covered by the [2010-2019 GBP EIS/EIR]." Attachment A to Tentative WDR, Information Sheet, at 41-42. The proposed WDR eviscerates environmental standards and poses significant environmental impacts. At a minimum, additional public review and revision is required before it can be adopted.

The 2010-2019 GBP EIS/EIR mandates that selenium load values begin a "glide path" from "load values equal to TMML load values" down "to very low loads" starting in January 2015. EIS/EIR at 2-10 to 2-11. Accordingly, the 2010 Use Permit includes "selenium load value charts" for all water year types that beginning in 2015 show a dramatic reduction in selenium loads. Appendix C to 2010 Agreement for Continued Use of the San Luis Drain. By contrast, the proposed WDR is substantially weaker: it calls for discharge limits to "apply no later than 31 December *2019*" that are identical to the original discharge limits applicable in *2014*. *Compare* Tentative WDR at 4 (Table 2) *with* Appendix C to 2010 Agreement for Continued Use of the San Luis Drain (table contains identical values for 2014 with much *lower* targets for 2019).

The environmental analysis in the 2010-2019 GBP EIS/EIR cannot be used to support the Tentative 2015 WDR's proposed *increase* in allowable selenium loads. Indeed, the EIS/EIR concluded that even with the "increasingly stringent Se[lenium] load targets" that were proposed in 2010 and are currently in effect that there would be "potentially significantly adverse" environmental impacts from allowing continued operation of the San Luis Drain because selenium bioaccumulates and "further deposition of" it would result. 2010-2019 GBP EIS/EIR at 6-40 to 6-44. These "increasingly stringent . . . load targets" that the EIS/EIR relies upon to "mitigate" these impacts to a "less-than-significant" level are the load targets that the WDR would eviscerate. *Id.* The proposed weakening of environmental protections called for in the WDR invalidates the

2010-2019 GBP EIS/EIR's impact analysis and cannot be approved without additional environmental analysis and public review. Additionally, reinitiation of consultation with FWS and NMFS is required to ensure that these newly increased permissible selenium load levels do not result in the take of any special-status species.

2. **<u>The 2015 Tentative WDR Is Not Consistent with the Basin Plan.</u>**

The 2015 Tentative WDR lacks boron and molybdenum water quality objectives. It should require compliance with boron and molybdenum water quality objectives contained in the Water Quality Control Plan, Fourth Edition, for the Sacramento River and San Joaquin River Basins ("Basin Plan"). In addition, the WDR should contain water quality objectives for salt, mercury, and arsenic.[2]

Under the Basin Plan, compliance with the two mitigation measures in the Third Use Agreement is required. If compliance is not achieved, under the Basin Plan any further delay in achieving the absolute prohibition of discharge from the GBP is forbidden. According to the Basin Plan:

> The discharge of agricultural subsurface drainage water to the San Joaquin River from Sack Dam to Mud Slough (north) is prohibited after 1 October 2010, unless water quality objectives for selenium are being met. The discharge of agricultural subsurface drainage water to Mud Slough (north) and the San Joaquin River from the Mud Slough confluence to the Merced River is prohibited after 31 December 2019 unless water quality objectives for selenium are being met. The prohibition becomes effective immediately upon Board determination that timely and adequate mitigation, as outlined in the 2010-2019 Agreement for Continued Use of the San Luis Drain has not been provided.

Final Staff Report for the selenium Basin Plan amendment. The Third Use Agreement, Appendix L (*see* Attachment A), contains specific acreages of year round water supply and wetland habitat requirements. The Tentative WDR violates these requirements, and so violates the Basin Plan because it specifically refers to the mitigation measures in the Use Agreement.

3. **<u>Approving Continued Discharges After 2019 Violates CEQA.</u>**

The continued operation of the GBP, including the continued discharge of selenium from the GBP, is a project requiring full compliance with and environmental review under the California Environmental Quality Act ("CEQA"), Public Resources

[2] Salt, in particular, must have a separate water quality objective. There has been a significant variation in specific conductance since the first years of the GBP. Water quality objectives should be based on those set forth in the Third Use Agreement.

Code section 21000 *et seq*. But as the Regional Board itself admits in the 2015 Tentative WDR, CEQA review has only been completed for a "limited" continuance of GBP operation "for the period 1 October 2010 through 31 December 2019." 2015 Tentative WDR, p. 7.

The EIS/EIR simply *does not* analyze the impacts of continued GBP operation past 2019. EIS/EIR at ES-2 (defining the "Proposed Action" as "the proposed continuation of the Grasslands Bypass Project, 2010-2019"). Yet, the proposed WDR would allow for continued "discharge of agricultural subsurface drainage water to Mud Slough (north)" after December 31, 2019, so long as the "water quality objectives for selenium are being met." 2015 Tentative WDR, p. 12. The WDR further specifies that the "discharge of selenium from the San Luis Drain" may continue after December 31, 2019 if it is within "the monthly loads in Table 2." *Id.* Allowing the GBP to continue discharging selenium in 2020 and beyond violates CEQA because *no CEQA review whatsoever* has been done for GBP operation past 2019. Before approving any selenium discharges after 2019, the Regional Board – which has been a responsible agency for previous CEQA reviews of the GBP – must "consider[] the EIR . . . prepared by the lead agency" and find it deficient, and therefore *reject* the proposed WDR. Title 14 Cal. Code Regs. ("CEQA Guidelines") §15096(a).

4. **<u>The WDR's Selenium Loads Are Not Sufficient to Achieve a 5 pbb Objective.</u>**

The water quality standards contained in the WDR — including as high as 15 parts per billion ("ppb") at Crows Landing – are insufficient to achieve the mandatory objectives that apply to the GBP, such as the 5 ppb objective, and therefore unacceptable. Spikes in selenium remain in the biological system long after water column levels have been reduced. Thus, biological accumulation and its associated risks rise exponentially when water quality standards are not sufficient to achieve objectives.

Load limits for selenium specified in the draft WDR will not meet the 2019 water quality objective for selenium of 5 ug/L over a 4-day average for Mud Slough (north) and the San Joaquin River between Sack Dam and the Merced River. These objectives were part of the Basin Plan and must be met.

5. **<u>Not All the Mitigations from the Third Use Agreement Have Been Achieved</u>**.

The 2010 Use Agreement includes three items of "Mitigation for the Continued Use of Mud Slough," including habitat mitigation and mitigation fees. Appendix L to 2010 Agreement for Continued Use of the San Luis Drain. Page IV.26.00 of the Basin Plan states that the "discharge of agricultural subsurface drainage water to Mud Slough (north) and the San Joaquin River from the Mud Slough confluence to the Merced River is prohibited . . . immediately upon Board determination that . . . mitigation, as outlined in the 2010-2019 Agreement for Continued Use of the San Luis Drain has not been provided." The Board cannot permit continued discharges without first ensuring that the mitigation required in the Use Agreement has been achieved.

6. **Selenium Is Not Controlled for Discharges to Groundwater According to the WDR for Growers.**

The WDR for the Grassland Farmers – the groundwater WDR – does not address selenium. Selenium must be controlled in the WDR for this source.

7. **The WDR's Selenium Standards Are Not Protective of Aquatic Species.**

The WDR's discussion of the issuance of the U.S. Environmental Protection Agency's ("USEPA's") National Toxics Rule neglects to evaluate the delayed revised selenium criteria for California and Bay-Delta, as well as recent scientific findings (*see* Presser/Luoma, Attachment B) that report that existing water quality criteria are inadequate. Larval stages for aquatic species are particularly vulnerable, and existing water quality criteria fail to protect these vital stages of development. This study, Presser & Luoma, *A Methodology for Ecosystem-Scale Modeling of Selenium*, US Geological Survey (2010) (Attachment B) is essential new information that has become available since the completion of the EIS/EIR in 2009 that must be considered before a new WDR is issued. As previous comments have shown, here incorporated by reference, selenium is a particularly pernicious and long-lasting pollutant and rigorous standards for its reduction are required in order to protect aquatic species. *See* Attachment C (2011 Comments of PCFFA, Sierra Club, Friends of the River, and Planning and Conservation League, with attachments), D (PCFFA *et al.* opposition to reduced selenium monitoring), F (PCFFA *et al.* 2013 comment letter on GBP monitoring).

8. **Sediment Disposal Issues Should be Resolved by 2019 According to the 2010 Third Use Agreement.**

Sediment disposal issues must be resolved by 2019 according to the Third Use Agreement. Yet requirements in the WDR fail to include sediment disposal commitments or otherwise address the sediment disposal requirements from the GBP EIS/EIR. The WDR must include sufficient compliance with the sediment management mitigation from the GBP EIS/EIR.

9. **Unincorporated Agricultural Lands Continue to Discharge to Wetland Channels that Contribute to the GBP and Should be Included in the GBP.**

Lands that discharge into the GBP but are not part of the Project must be included in the WDR. In order to effectively implement this Tentative WDR, the Board must investigate what efforts have been made to halt these unauthorized or illegal discharges. Further, the Board must quantify and take into account these unauthorized or illegal discharges when it calculates monthly and annual loads. None of this information is available, let alone addressed, in the WDR.

10. **The WDR's Monitoring and Reporting Program Is Inadequate.**

The WDR's monitoring and reporting program is inadequate to detect discharges of selenium and to accurately record monthly and yearly load limits. (*See* PCFFA's previous letters for specific monitoring deficiencies as well as the USEPA's 2009 letter.) Monitoring in existing wetland channels and the San Joaquin River should not be reduced. The Clean Water Act mandates a 4-day average water quality standard measurement protocol which Sites H and G fail to provide. These sites must include both biological and water quality monitoring standards for selenium and other pollutants to meet this mandate.

Monitoring cannot be reduced until the Project has demonstrated complete, long-term success. No such success has been demonstrated. Wildlife monitoring required in the WDR must include tissue samples as well as tracking and monitoring of nesting birds so that eggs are found and tested. These are the kinds of steps that might lead to a more comprehensive monitoring design that could inform the public and decision makers as to biological exposure and the effects of such exposure. Such comprehensive monitoring would also aid in the public and decision makers' understanding of the regional transport and location of the selenium discharged from the Grassland area. Where bioaccumulation has such devastating consequences, as demonstrated by PCFFA's previous comments (Attachments C-F), a comprehensive monitoring program is essential to compliance with state and federal environmental laws and regulations.

Reduced or ineffective monitoring allows for huge increases in the amount of pollution allowed under the WDR. For instance, in 2000 the move from a four day average load calculation to a monthly mean load calculation allowed for a 21-40% increase in monthly loads. The Surface Water Quality Management Plan should include daily sampling and no more than 4 day averaging, not 30 days and weekly or less frequent sampling, in order to comply with the Clean Water Act. The proposal to discontinue weekly monitoring for sites J, K2, L2, and M2 (see Attachment A of the Tentative WDR) is unacceptable. The wetland channels where that monitoring is done are even more polluted than the San Joaquin River. Finally, records should be kept for 20 years in order to maintain long term continuity, not five years as suggested by the WDR. Such reduced and ineffective monitoring also obscures the harms or benefits of a project from the public and from decision makers, creating confusion as to its continued environmental impacts (or benefits).

11. **Conclusion**

The 2015 Tentative WDR is woefully deficient for the reasons stated above. PCFFA urges the Regional Board to work with the EPA, USFWS, CDFW, NMFS and the Delta Stewardship Council to establish a clear and legally binding strategy for ending the use of the San Joaquin River as a drain for toxic agricultural wastewater. After a quarter century of promising – but failing – to comply with water quality standards, any further loosening of regulatory requirements such as is proposed in the 2015 Tentative WDR is a public resource tragedy. It is nothing more than an open-ended license to pollute.

Very truly yours,

Stephan C. Volker
Attorney for the Pacific Coast Federation of
Fishermen's Associations

SCV:taf

Attachments: A-F as stated

AGREEMENT FOR CONTINUED USE
OF THE
SAN LUIS DRAIN

APPENDIX "L" Mitigation for the Continued Use of Mud Slough

1. Baseline Mitigation Habitat

Baseline mitigation will be developed and maintained so long as the Use Agreement remains in effect. The Draining Parties will provide Baseline mitigation in the form of alternate wetland habitat as outlined below. This habitat will be located on USFWS lands and CDFG lands. The proposals were developed by working with USFWS & CDFG staff to determine the habitat needs within their respective wetland complexes. Ownership of all capital improvements on agency land will remain with the agencies after the term of the Use Agreement.

- <u>CDFG Mitigation Proposal:</u> Supply year-round water to a series of ponds between Mud Slough and the San Joaquin River. Water will be delivered through an existing pipeline and turned out into natural swales to create wetland habitat. The water surface area of the ponds will be approximately 95.3 acres. (Mud Slough affected area in China Island = 76.8 acres.) As a result of the applied water vegetation will emerge in and around the ponds. Water will likely be developed locally from wells.

- <u>USFWS Mitigation Proposal:</u> Create year around wetlands on USFWS lands. This proposal will establish 31.6 acres of year around wetland marsh habitat. It may create wetland Slough habitat in a drainage ditch next to the Schwab Unit (BG001). This could create a broad yet linear habitat that could provide slough mitigation habitat. The final site has not been selected. (Mud Slough affected area within San Luis Unit = 24 acres) Water will likely be developed locally from wells.

The Baseline Mitigation projects are designed to expand permanent wetlands in the area of Mud Slough to provide benefits to species such as waterfowl, shorebirds, and terrestrial wildlife. The habitat may be suitable for use by special status species including, Giant Garter Snakes, San Joaquin Valley Kit Fox and Tricolored Blackbirds.

2. Supplemental Mitigation Habitat

Supplemental mitigation will be implemented beginning in Year Six (2015) of the Use Agreement by the establishment of a "Mitigation Project Fund" held by the San Luis Delta Mendota Water Authority. Beginning in that year, the Grassland Area Farmers will be required to pay a fee per pound of Attributable selenium discharge. The fee per pound will vary depending upon the water year type and year. (See Supplemental Mitigation Fee Chart, below) The fee will be charged on the Attributable selenium pounds discharged from the first pound up to the selenium load value for that year. Loads discharged above the Load Values will incur Incentive Fees but not Supplemental Mitigation Fees.

The Supplemental Mitigation Project Fund will be administered by the San Luis Delta Mendota Water Authority (SLDMWA) and held in a separate account of the SLDMWA with transparent detailed accounting provided to the Oversight Committee and available to the public. After considering recommendations from the Mitigation Sub-Committee, the Oversight Committee will select projects to be funded from the Supplemental Mitigation Project Fund and shall authorize and direct the SLDMWA to release funds for the selected project(s).

The Mitigation Sub-Committee shall identify a list of projects to be provided to the Oversight Committee that may be funded by the Mitigation Project Fund. The Supplemental Mitigation Sub-Committee shall include a representative from each of the following, each of which shall have 1 vote: (1) The Grassland region California Department of Fish & Game wildlife areas; (2) The Grassland region United States Fish & Wildlife Service refuges; and (3) A nonprofit organization with a background in restoration efforts in the Grassland Region. The three Sub-Committee Members shall select one of their members to serve as Chairman, who is authorized to call meetings and is responsible to keep the Oversight Committee informed of all Sub-Committee meetings and actions. Two of 3 members are required for a quorum, and the vote of 2 of 3 members (regardless of the number of members present) is required to include a project on the list of projects to be provided to the Oversight Committee. The Mitigation Sub-Committee shall hold open public meetings and shall allow interested parties to have input into the selection process. The Supplemental Mitigation Project Fund shall be spent on projects that enhance fish, wildlife or ecological values in the Grasslands region. The Oversight Committee shall determine which projects are implemented.

Below are examples of the types of projects that the Oversight Committee may choose to implement with the Supplemental Mitigation Project Fund. This list is intended to give examples of potential projects but not to limit the use of the funds on other projects:

- Refuge water supply augmentation
- Increased water flows in Mud Slough after drain flows cease.
- Habitat restoration projects
- Species specific habitat establishment

3. Supplemental Mitigation Fee Charts

MAXIMUM ANNUAL SUPPLEMENTAL MITIGATION FEE

	Annual Maximum Supp. Mitigation Fee Year 6	Annual Maximum Supp. Mitigation Fee Year 7	Annual Maximum Supp. Mitigation Fee Year 8	Annual Maximum Supp. Mitigation Fee Year 9	Annual Maximum Supp. Mitigation Fee Year 10	Total Possible Supp. Mitigation Fee Generated in 5 Years
Maximum Fee	$ 112,500	$ 112,500	$ 150,000	$ 187,500	$ 187,500	$ 750,000
Above fees are calculated assuming the discharge of the total annual Load Value for that year.						

SUPPLEMENTAL MITIGATION FEE PER POUND OF SELENIUM

SUPPLEMENTAL MITIGATION FEE PER POUND					
	$ per Lb of Discharge Year 6	$ per Lb of Discharge Year 7	$ per Lb of Discharge Year 8	$ per Lb of Discharge Year 9	$ per Lb of Discharge Year 10
Critical Year Type	$ 133.29	$ 183.52	$ 393.70	$ 1,250.00	$ 1,250.00
Below Normal Year Type	$ 57.78	$ 80.47	$ 176.68	$ 625.00	$ 625.00
Above Normal Year Type	$ 34.79	$ 48.79	$ 108.85	$ 416.67	$ 416.67
Wet Year Type	$ 32.05	$ 44.29	$ 95.54	$ 312.50	$ 312.50
The above Supplemental Mitigation Fees are paid on Attributable Selenium Discharge from first pound up to the Annual Load Value. Selenium Loads discharged above Load Values result in Incentive Fees but not Supplemental Mitigation Fees.					

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A Methodology for Ecosystem-Scale Modeling of Selenium

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(Submitted 18 August 2009; Returned for Revision 12 February 2010; Accepted 26 May 2010)

Original Research

ABSTRACT

The main route of exposure for selenium (Se) is dietary, yet regulations lack biologically based protocols for evaluations of risk. We propose here an ecosystem-scale model that conceptualizes and quantifies the variables that determine how Se is processed from water through diet to predators. This approach uses biogeochemical and physiological factors from laboratory and field studies and considers loading, speciation, transformation to particulate material, bioavailability, bioaccumulation in invertebrates, and trophic transfer to predators. Validation of the model is through data sets from 29 historic and recent field case studies of Se-exposed sites. The model links Se concentrations across media (water, particulate, tissue of different food web species). It can be used to forecast toxicity under different management or regulatory proposals or as a methodology for translating a fish-tissue (or other predator tissue) Se concentration guideline to a dissolved Se concentration. The model illustrates some critical aspects of implementing a tissue criterion: 1) the choice of fish species determines the food web through which Se should be modeled, 2) the choice of food web is critical because the particulate material to prey kinetics of bioaccumulation differs widely among invertebrates, 3) the characterization of the type and phase of particulate material is important to quantifying Se exposure to prey through the base of the food web, and 4) the metric describing partitioning between particulate material and dissolved Se concentrations allows determination of a site-specific dissolved Se concentration that would be responsible for that fish body burden in the specific environment. The linked approach illustrates that environmentally safe dissolved Se concentrations will differ among ecosystems depending on the ecological pathways and biogeochemical conditions in that system. Uncertainties and model sensitivities can be directly illustrated by varying exposure scenarios based on site-specific knowledge. The model can also be used to facilitate site-specific regulation and to present generic comparisons to illustrate limitations imposed by ecosystem setting and inhabitants. Used optimally, the model provides a tool for framing a site-specific ecological problem or occurrence of Se exposure, quantify exposure within that ecosystem, and narrow uncertainties about how to protect it by understanding the specifics of the underlying system ecology, biogeochemistry, and hydrology. Integr Environ Assess Manag 2010;6:685–710. © 2010 SETAC

Keywords: Selenium Food web Bioaccumulation Site-specific ecological exposure Ecosystem-scale

INTRODUCTION

Effects from Se toxicity have proven dramatic because of extirpations (i.e., local extinctions) of fish populations and occurrences of deformities of aquatic birds in impacted habitats (Skorupa 1998; Chapman et al. 2010). The large geologic extent of Se sources is connected to the environment by anthropogenic activities that include power generation, oil refining, mining, and irrigation drainage (Presser, Piper, et al. 2004). Toxicity arises when dissolved Se is transformed to organic Se after uptake by bacteria, algae, fungi, and plants (i.e., synthesis of Se-containing amino acids de novo) and then passed through food webs. Biochemical pathways, unable to distinguish Se from S, substitute excess Se into proteins and alter their structure and function (Stadtman 1974). The impact of these reactions is recorded most importantly during hatching of eggs or development of young life stages. Thus, the reproductive consequences of maternal transfer are the most direct and sensitive predictors of the effects of Se (Heinz 1996).

Each step in this sequence of processes is relatively well known, but the existing protocols for quantifying the linkage between Se concentrations in the environment and effects on animals have orders of magnitude of uncertainties. Conventional methodologies relate dissolved or water-column Se concentrations and tissue Se concentrations through simple ratios (i.e., bioconcentration factor, BCF; bioaccumulation factor, BAF), regressions, or probability distribution functions (DuBowy 1989; Peterson and Nebeker 1992; McGeer et al. 2003; Toll et al. 2005; Brix et al. 2005; DeForest et al. 2007). None of these approaches adequately accounts for each of the important processes that connect Se concentrations in water to the bioavailability, bioaccumulation, and toxicity of Se.

In this paper, we present an ecosystem-scale methodology that reduces uncertainty by systematically quantifying each of the influential processes that links source inputs of Se to toxicity. In particular, we emphasize a methodology for relating dissolved Se to bioaccumulated Se. The methodology allows us to 1) model Se exposure with greater certainty than previously achieved through traditional approaches that skip steps, 2) explain or predict Se toxicity (or lack of toxicity) in site-specific circumstances, and 3) translate proposed Se guidelines among media under different management or regulatory scenarios.

Important components of the methodology are 1) empirically determined environmental partitioning factors between water and particulate material that quantify the effects of dissolved speciation and phase transformation, 2) concentrations of Se in living and nonliving particulates at the base

All Supplemental Data may be found in the online version of this article.

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of the food web that determine Se bioavailability to invertebrates, 3) Se biodynamic food web transfer factors that quantify the physiological potential for bioaccumulation from particulate matter to consumer organisms and prey to their predators, and 4) critical tissue values that relate bioaccumulated Se concentrations to toxicity in predators. We compile data from 1) laboratory experiments that measured physiological biodynamic parameters for the dietary pathways of invertebrates and fish, and 2) field studies that simultaneously collected particulate, prey, and predator Se concentrations to develop species-specific trophic transfer factors. Additionally, we compiled data from field studies that simultaneously collected dissolved and particulate Se concentrations to evaluate partitioning into the base of the food web. Alternative approaches for modeling of aquatic birds are illustrated because biodynamic data for wildlife are limited. We show that enough data exist, or can be derived site specifically, to address food web transfer in many types of ecosystems. Finally, we test the predictions derived from the ecosystem-scale methodology against observations from nature and compare the outcomes of alternative exposure choices to assess implications for ecosystem management and protection.

Regulatory aspects

Persistent toxicants such as Hg and xenobiotic organic substances are among the most hazardous of contaminants because they efficiently bioaccumulate or biomagnify in food webs and put fish, wildlife, and humans at risk (Thomann 1989; Gobas 1993). Early in the history of pollution by these types of chemicals, a measure of bioaccumulative potential (or trophic transfer potential) was deemed necessary ''because acute toxicity is low (water pathway) and, once chronic effects appear, corrective actions such as terminating the addition of chemical to an ecosystem may not take hold soon enough to alleviate the situation before irreparable damage has been done'' (Neely et al. 1974). Selenium shares many attributes with bioaccumulative chemicals when toxicity is determined from diet, not dissolved exposure (Sappington 2002). Classification of Se as a hazard equivalent to other bioaccumulative chemicals has been contentious (Luoma and Presser 2009).

Regulating agencies such as the US Environmental Protection Agency (USEPA) have recognized that development of water quality Se criteria for the protection of aquatic life and wildlife require consideration of exposures other than solely dissolved Se to understand and assess environmental protection with certainty (USEPA 1998; US Fish and Wildlife Service [USFWS] and National Marine Fisheries Service [NMFS] 1998, amended 2000; Reiley et al. 2003). As of 2010, the USEPA has under consideration a national fish-tissue criterion and other state-, region-, or site-specific approaches for managing Se contamination (USEPA 1997, amended 2000, 2004). In general, this type of criterion would help fill the need to connect effects from a dietary exposure pathway into a regulatory framework. However, such regulations do not yet reflect the current state of knowledge concerning the transfer of Se through ecosystems (Sappington 2002; Reiley et al. 2003), nor do they formalize the knowledge necessary to understand the basis of protective criteria for Se. Furthermore, implementation of a fish-tissue criterion would require translation to a dissolved Se concentration to satisfy other regulatory requirements, such as permit and load limits. An important purpose of this paper is to demonstrate how a step-by-step ecosystem-scale methodology can address these problems and facilitate translation across steps to harmonize regulation.

Overview of modeling approach

A conceptual model (Figure 1) illustrates the linked factors (Table 1) that determine the effects of Se in ecosystems. Figure 1 also shows the data needed (e.g., Se speciation) for optimally modeling or fully understanding these linkages. The first 8 variables (source loads to health effects; Table 1) are considered systematically in developing and implementing an ecosystem-scale methodology. Predator life cycle (constraining the model in time and space) and demographics are listed as components of a comprehensive site-specific assessment but are not covered in detail in this paper. Emphasis in this paper is on protection of fish and birds, but similar modeling techniques could be used to evaluate amphibians and mammals.

The organizing principle for the methodology is the progressive solution of a set of simple equations or models, each of which quantifies a process important in Se exposure (Figure 2). Environmental partitioning between dissolved and particulate phases (K_d) is used here to characterize operationally the uptake and transformation (commonly termed bioconcentration) of dissolved Se into the base of the food web (Figure 2). K_d is environment specific (i.e., dependent on site hydrology, dissolved speciation, and type of particulate material) and is the ratio of the particulate material Se concentration (in dry weight, dw) to the dissolved Se concentration observed at any instant. The base of the food web, as sampled in the environment and characterized by K_d, can include phytoplankton, periphyton, detritus, inorganic suspended material, biofilm, sediment, or attached vascular plants. For simplicity, in our discussion we define this mixture of living and nonliving entities as particulate material. Dissolved or total Se can be specified in the derivation of K_d for modeling to accommodate use of existing data sets, but this substitution is a possible source of variability. Consideration of the amount of suspended particulate material and its contribution to the total Se measurement gives an indication of the difference incurred by this substitution. In our discussions, we refer to a generalized water-column Se concentration, but the preferred parameter to measure and model would be dissolved Se.

Kinetic bioaccumulation models (i.e., biodynamic models; Luoma and Fisher 1997; Luoma and Rainbow 2005) account for the now well-established principle that Se bioaccumulates in food webs principally through dietary exposure. Tissue Se attributable to dissolved exposure makes up less than 5% of overall tissue Se in almost all circumstances (Fowler and Benayoun 1976; Luoma et al. 1992; Roditi and Fisher 1999; Wang and Fisher 1999; Wang 2002; Schlekat et al. 2004; Lee et al. 2006). Biodynamic modeling (Figure 2) further shows that the extent of Se bioaccumulation (the concentration achieved by the organism) is driven by physiological processes that are specific to each species (Reinfelder et al. 1998; Baines et al. 2002; Wang 2002; Stewart et al. 2004). Experimental protocols for measuring parameters such as assimilation efficiency (AE), ingestion rate (IR), and the rate constant that describes Se excretion or loss from the animal (k_e) are

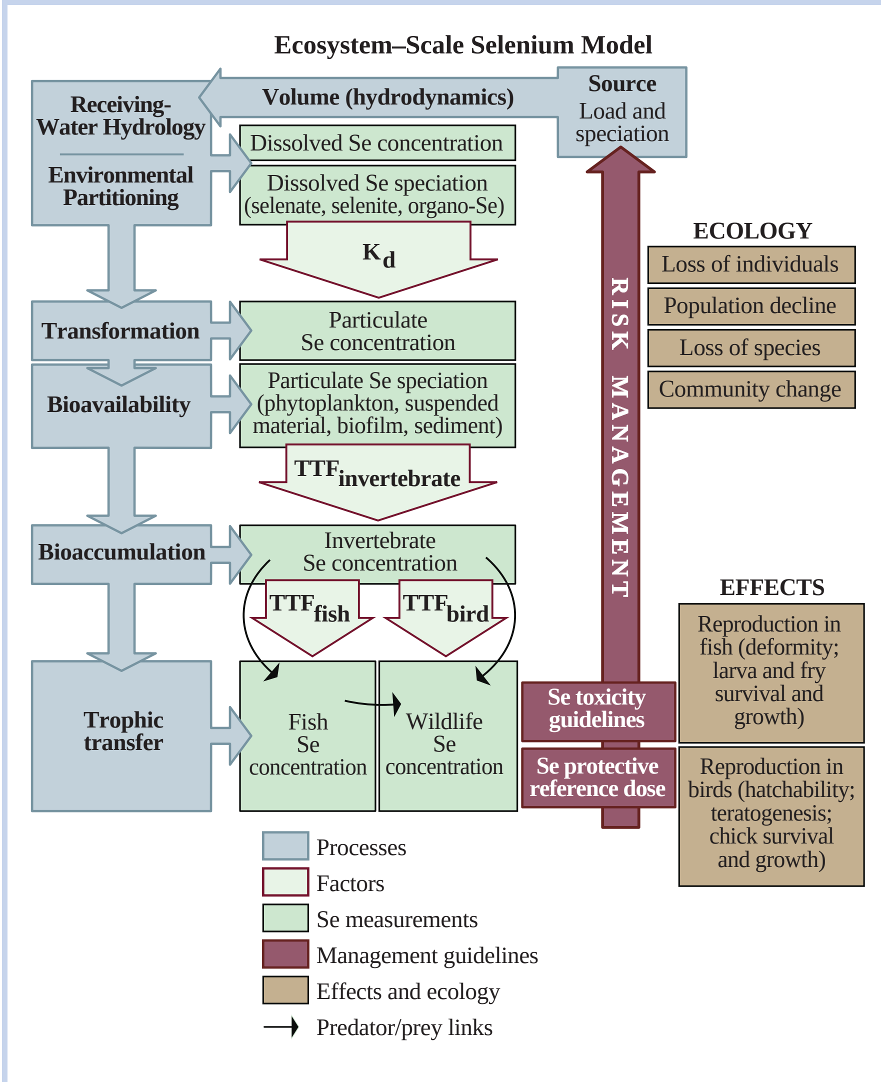

Figure 1. Ecosystem-scale Se model. The model conceptualizes processes and parameters important for quantifying and understanding the effects of Se in the environment. The model can be applied to forecast exposure and to evaluate the implications of management or regulatory choices. K_d = empirically determined environmental partitioning factor between water and particulate material; TTF = biodynamic food web transfer factor between an animal and its food.

now well developed (Wang et al. 1996; Luoma and Rainbow 2005).

Biodynamic models have the further advantage of providing a basis for deriving a simplified measure of the linkage between trophic levels: trophic transfer factors (TTFs; Figure 2; Reinfelder et al. 1998). TTFs are species-specific and link particulate, invertebrate, and predator Se concentrations (e.g., TTF_{clam} or $TTF_{sturgeon}$). They can be derived from laboratory experiments or from field data. $TTF_{invertebrate}$ and $TTF_{predator}$ differ from traditional BAFs in that they are the ratio of the Se concentration in each animal to the Se concentration in its food (Figure 2), whereas BAFs almost always are implemented as the Se concentration in an animal to the Se concentration in the water of its environment. Biodynamic model calculations and ratios derived here employ dw for media (particulate material and tissue). Variability or uncertainty in processes such as AEs or IRs can be directly accounted for in sensitivity analysis as shown for Se by Wang et al. (1996). This is accomplished by considering the range in the experimental observations for the specific animal in the model. Field-derived factors require some knowledge of feeding habits and depend upon available data for that species. Laboratory and field factors for a species can be compared and refined to improve levels of certainty in modeling. Hence, both physiological TTFs derived from kinetic experiments for a species and ecological TTFs derived either from data for a species across different field sites (global) or from one site (site-specific) are of value in modeling and understanding an ecosystem.

By modeling different exposure scenarios, it is possible to differentiate consumer species and food webs in terms of bioaccumulative potential, an important step in reducing uncertainties in predicting ecological risks (Stewart et al. 2004). To translate exposure into toxicity, we employ results from dietary toxicity studies in predators that correlate the two. There has been considerable discussion about choices of protective levels for fish and wildlife (Skorupa 1998; DeForest et al. 1999; Hamilton 2004; Lemly 2002; Adams et al. 2003; Ohlendorf 2003). Nevertheless, tissue guidelines are being proposed to be nationally promulgated by USEPA,

Table 1. Variables considered for ecosystem-scale modeling of Se

Variable	Ecosystem-scale modeling
Source load	Coal fly ash disposal, agriculture drainage, oil refinery effluent, phosphate and coal mining waste leachate, mining discharge
Dissolved speciation	Selenate, selenite, organo-Se
Receiving-water partitioning and/ or transformation environment	Wetland and/or marsh, pond, backwater and/or oxbow, stream, river, estuary, ocean, freshwater or saltwater
Particulate speciation	Elemental Se, adsorbed selenite and/or selenate, organo-Se
Bioavailability	Sediment, detritus, phytoplankton, periphyton, biofilm
Invertebrate specific bioaccumulation	Species-specific physiological parameters (ingestion rate, assimilation efficiency, efflux rate, growth), field derived factors
Trophic transfer to fish or aquatic birds[a]	Species-specific physiological parameters (ingestion rate, assimilation efficiency, efflux rate, growth), field derived factors, dose–response curves
Health effect endpoints	Reproduction, teratogenesis, decreased growth, decreased survival (especially in winter), disease (immunosuppression), sublethal (chronic effects)
Predator life cycle	Species-specific energetics (body weight and ingestion rate), life stage (breeding, larval, adult), distribution (resident, mobile, migratory), timing (route, duration), feeding behavior (prey availability and preference, foraging pattern, background intake)
Demographics	Loss of individuals (threatened or endangered species), population reduction, community change, loss of species

[a]Modeling can be extended to terrestrial birds, amphibians, and mammals.

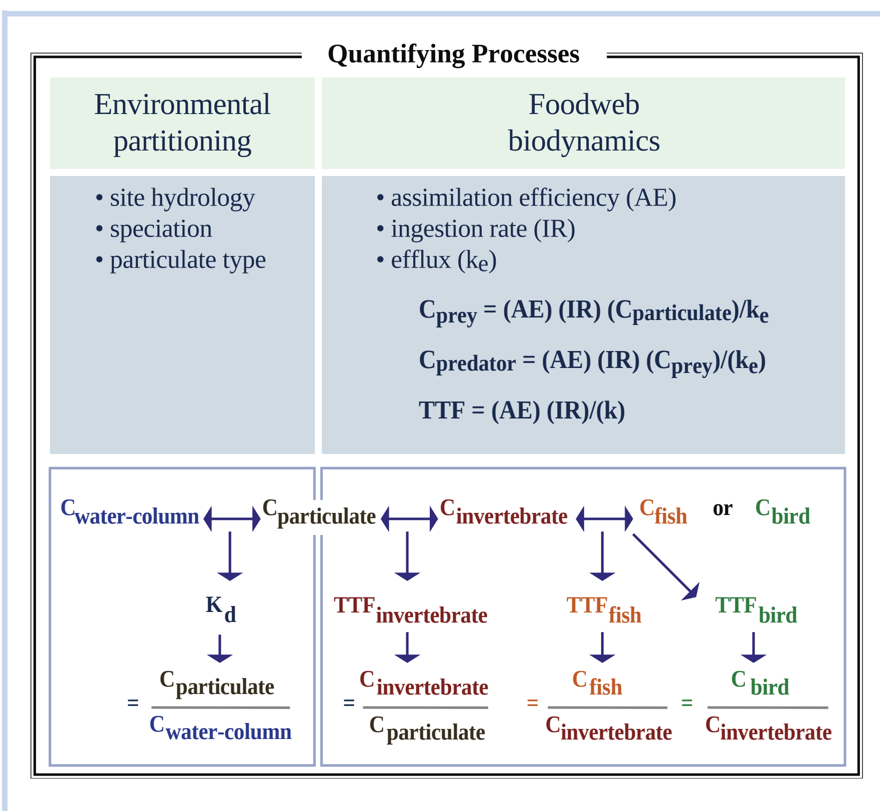

Figure 2. Critical factors for linked steps in ecosystem-scale Se modeling. Environmental partitioning and biodynamic physiological parameters quantify dietary pathways in nature. For modeling, the physiological parameters are combined into a TTF, which characterizes the bioaccumulation potential for each specific particulate–invertebrate pair or prey–predator pair.

recommended by USFWS as part of Endangered Species Act consultation, or stipulated for watershed or regional regulation based on a review of existing toxicity literature (USFWS and NMFS 1998, amended 2000; USEPA 2004). Steps in wildlife criteria development (e.g., ingestion models that use rate of consumption, body weight, and reference dose to calculate a dietary limitation or wildlife criterion) are also delineated here to illustrate that our approach is compatible with a more traditional regulatory approach to the protection of wildlife.

Another use of the model is in understanding the environmental concentrations and conditions that would result in a predetermined Se concentration in the tissues of a predator. Assuming that the tissue guideline is generic for all fish or birds (for example), the choice of the predator species in which to assess that concentration is still important because it determines the $TTF_{invertebrate}$. That specific predator's feeding habits drive the choice of invertebrate, for which a species-specific TTF is used to calculate particulate Se concentrations. A K_d feasible for that ecosystem (or a range of K_ds) is then used to determine the allowable water-column Se concentration, which is ultimately the concentration in that specific type of environment and food web that would result in the specified Se concentration in the predator (i.e., the applied criterion). Thus the allowable water-column concentration can differ among environments, an outcome that reflects the realities of nature. This biologically explicit approach also forces consideration of the desired uses and benefits in a watershed (i.e., which species of birds and fish are the most threatened by Se and/or are the most important to protect).

In the absence of detailed knowledge of the watershed, choices can be made based on rudimentary knowledge about prey and predator pairs; however, the more rudimentary the choices, the greater the uncertainty. Thus, implicitly, the modeling approach creates incentives to understand ecosystems better for which enough is at stake to invest in data collection. Explicitly, it points toward critical choices for data collection. As the knowledge necessary for a full conceptual ecosystem-scale model for Se is developed at a selected site, uncertainties about effects of Se are progressively narrowed. A strength of this approach is that Se bioaccumulation and trophic transfer predicted by the methodology (Figure 1) can be used to validate or estimate uncertainties through comparison of predicted invertebrate, fish, and bird Se concentrations with independent observations of those concentrations from field studies.

MODEL COMPONENTS

Sources of selenium

Knowledge of a dissolved Se concentration in a water body is a crucial first step in understanding the potential for adverse ecological effects. Documenting how different sources and processes contribute to that concentration is also essential (Figure 1). Potential sources of Se in the environment have been well described elsewhere (Seiler et al. 2003; Presser, Piper, et al. 2004). In brief, organics-rich marine sedimentary rocks, especially black shales, petroleum source rocks, and phosphorites, are major sources of Se. In terms of Se as a commodity, Se's source is in igneous Cu deposits. The interface of aquatic systems with waste products or overburden from coal, phosphate, and metals mining; oil refining; fossil fuel combustion; and irrigation in arid regions can deliver Se to the environment on a large scale.

Each of the above sources typically can release Se with a different speciation. Selenate is often dominant in agricultural drainage, mountaintop coal mining and/or valley fill leachate, and Cu mining discharge (Presser and Ohlendorf 1987; Naftz et al. 2009; West Virginia Department of Environmental Protection 2009). Selenite is frequently found in oil refinery and fly-ash-disposal effluents (Bowie et al. 1996; Cutter and Cutter 2004). Combinations of selenite and organo-Se are common in pond-treated agricultural drainage (Amweg et al. 2003) and the oceans (Cutter and Bruland 1984). Speciation in phosphate mining overburden leachate in streams depends on season and flow conditions: selenate during maximum flow, selenite and organo-Se during minimum flow (Presser, Hardy, et al. 2004).

Hydrologic environment

How inputs (source loads) of Se interact in a specific hydrologic environment determines receiving-water Se concentrations (Figure 1). Comprehensive hydrodynamic models can be used to represent Se transport and smaller scale effects such as elevated concentrations near sources of inflow or detailed distribution within receiving waters. Models have been used successfully to describe Se concentrations in complex environments by incorporating basic physical and geochemical processes involved in determining how load and volume interact (Meseck and Cutter 2006; Diaz et al. 2008; Naftz et al. 2009). Simpler approaches can be used to estimate regional scale effects. For example, Se concentrations in San Francisco Bay were estimated by quantifying mass inputs, broadly differentiating seasonal flow regimes, and characterizing source signatures to understand the overall response of the ecosystem to several sources of Se contamination (Presser and Luoma 2006). Regional scale estimates agreed with observations from the use of this abbreviated approach.

Modeling of interactions of Se loading and hydrodynamics initiates the ecosystem-scale approach by developing an understanding of dissolved Se concentrations in a given environment (Figure 1). However, complex physical modeling is not sufficient to determine the ultimate effects of Se in an ecosystem (Wrench and Measures 1982), nor is a detailed understanding of physical processes or dissolved Se distributions adequate to unravel questions about Se effects or its regulation compared with understanding and incorporating phase transformation, biological reactions, and the influences of ecology into modeling.

Partitioning and transformation environments: Speciation and bioavailability

Phase transformation reactions from dissolved to particulate Se are of toxicological significance because particulate Se is the primary form by which Se enters food webs (Figure 1) (Cutter and Bruland 1984; Oremland et al. 1989; Luoma et al. 1992). The different biogeochemical transformation reactions also result in different forms of Se in particulate material: organo-Se, elemental Se, or adsorbed Se. The resulting particulate Se speciation, in turn, affects the bioavailability of Se to invertebrates depending on how an invertebrate samples the complex water, sediment, and particulate milieu that composes its environment.

Given this sequence (Figure 1), the first requirement for reducing the uncertainty in tying dissolved Se to effects on predators is quantification of the linkage between dissolved Se and Se concentrations in particulate material at the base of the food web. In a data-rich environment, biogeochemical models might be able to capture at least some of the processes that drive phase transformation (see, e.g., Meseck and Cutter 2006), but even sophisticated models, to some extent, rely in their development on empirical observations of partitioning between dissolved and particulate Se.

With the present state of knowledge, it is feasible to use field observations to quantify the relationship between particulate material and dissolved Se as expressed by

$$K_d = C_{particulate} \div C_{water-column}. \qquad (1)$$

This operationally defined ratio is an instantaneous observation in which $C_{particulate}$ is the particulate material Se concentration in μg/kg dw and $C_{water\text{-}column}$ is the water-column Se concentration in μg/L. Use of a partitioning descriptor can be controversial because K_d formally implies an equilibrium constant. Indeed, thermodynamic equilibrium does not govern Se distributions in the environment (Cutter and Bruland 1984; Oremland et al. 1989), and partitioning coefficients for Se are known to be highly variable (McGeer et al. 2003; Brix et al. 2005), but K_d can be a useful construct if it is recognized that the instantaneous ratio is not intended to differentiate processes or to be predictive beyond the specific circumstance in which it is determined. The sole intention is to describe the particulate to water ratio at the moment when the sample is taken.

Experience shows that repeated observations of this operational K_d can narrow uncertainties about local conditions. However, K_d will vary widely among hydrologic environments (i.e., in parts of a watershed such as wetlands, streams, or estuaries) and potentially among seasons. Consideration of the characteristics of the environment such as speciation, residence time, and/or particle type can also be used to narrow this potential variability, but K_d remains a large source of uncertainty in the model if translation to a water-column Se concentration is required. Initiation of modeling with a particulate Se concentration (see below under *Validation*) eliminates this step and the associated uncertainty and points to the importance of particulate phases in determining Se toxicity. If required, performing calculations with several alternative, but plausible, site-specific choices for K_d can elucidate and constrain the uncertainty around the introduction of K_d.

Speciation. Dissolved Se can exist as selenate, selenite, or organo-Se (+6, SeO_4^{-2}; +4, SeO_3^{-2}, −2, Se-II, respectively). The dissolved species that are present will influence the type of phase transformation reaction that creates particulate Se. Examples of types of reactions include 1) uptake by plants and phytoplankton of selenate, selenite, or dissolved organo-Se and reduction to particulate organo-Se by assimilatory reduction (see, e.g., Sandholm et al. 1973; Riedel et al. 1996; Wang and Dei 1999; Fournier et al. 2006); 2) sequestration of selenate into sediments as particulate elemental Se by dissimilatory biogeochemical reduction (e.g., Oremland et al. 1989); 3) adsorption as coprecipitated selenate or selenite through reactions with particle surfaces; and 4) recycling of particulate phases back into water as detritus after organisms die and decay (see, e.g., Reinfelder and Fisher 1991; Velinsky and Cutter 1991; Zhang and Moore 1996). Selenate is the least reactive of the 3 forms of Se, and its uptake by plants is slow. If all other conditions are the same, K_d will increase as selenite and dissolved organo-Se concentrations increase (even if that increase is small). Experimental data support this conclusion. Calculations using data from laboratory microcosms and experimental ponds show speciation-specific K_ds of 140 to 493 when selenate is the dominant form, 720 to 2800 when an elevated proportion of selenite exists, and 12 197 to 36 300 for 100% dissolved seleno-methionine uptake into at least some algae or periphyton (Besser et al. 1989; Kiffney and Knight 1990; Graham et al. 1992).

Residence time. The conditions in the receiving-water environment are also important to phase transformation. When selenate is the only form of Se and residence times are short (e.g., streams and rivers), the limited reactivity of selenate means that partitioning of Se into particulate material tends to be low. Similarly, dissimilatory reduction does not seem efficient unless water residence times are extended. Longer water residence times, in sloughs, lakes, wetlands, and estuaries, for example, seem to allow greater uptake by plants, algae, and microorganisms. This is accompanied by greater recycling of selenite and organo-Se back into solution, further accelerating uptake (Bowie et al. 1996; Lemly 2002; Meseck and Cutter 2006). Neither selenite nor organo-Se is easily reoxidized to selenate, because the reaction takes hundreds of years (Cutter and Bruland 1984). Therefore, the net outcome in a watershed that flows through wetland areas or estuaries is a gradual build-up of selenite and organo-Se in water and higher partitioning into particulate material (Lemly 1999; Presser and Luoma 2009). Environments downstream in a watershed can also have higher concentrations of selenite and organo-Se, and higher K_ds, reflecting the cumulative contributions of upstream recycling in a hydrologic system.

Differences in Se bioaccumulation have been described between lentic (stream) and lotic (lake) environments (Hamilton and Palace 2001; Brix et al. 2005; Orr et al. 2006). This could at least partially reflect the observations described above: if other conditions are similar, environments with longer residence times, such as lakes, tend to have greater recycling, a higher ratio of particulate and/or dissolved Se, and higher concentrations of Se entering the food web. Exceptions also occur, however. For example, flow period or season might be a consideration even within individual segments of a watershed.

Particle type. The K_d can also be influenced by the type of material in the sediment. For example, field data for Luscar Creek in Alberta, Canada, show a hierarchy of Se concentrations: 2.4 μg/g in sediment, 3.2 μg/g biofilm, and 5.5 μg/g for filamentous algae (Casey 2005). Using these concentrations with a field-measured water-column Se concentration of 10.7 μg/L yields K_ds of 224, 299, and 514, respectively, with an average K_d of 346. Similarly, field data for a slough tributary to the San Joaquin River, California, USA, show a hierarchy of particulate Se concentrations: 0.47 μg/g in sediment, 2.4 μg/g in algae, and 7.9 μg/g in detritus (Saiki et al. 1993). Using these concentrations with a field measured water-column Se concentration of 13 μg/L yields K_ds of 36, 185, and 608, respectively, with an average K_d of 276. In these instances, the influence of particle type is not as great as that of speciation and residence time.

Calculation of K_d. Knowing the range of K_ds in nature for a specific category of site (e.g., ponds, rivers, estuaries) allows some generalization about the potential range of particulate Se concentrations that could occur at a site under different modeled receiving-water conditions. We compiled data from 52 field studies in which both water-column Se concentrations and particulate Se concentrations were determined and calculated K_ds (Supplemental Data Table A). The K_ds across the complete variety of ecosystems vary by as much as 2 orders of magnitude (100–10 000) and measure up to 40 000 (Table 2). Even higher K_ds have been measured in experimental studies using cultured phyoplankton (Reinfelder and Fisher 1991; Baines and Fisher 2001).

There is, however, some consistency among types of environments. Most rivers and creeks show K_ds of greater than 100 and less than 300 (Table 2). For example, K_ds for the Fording River, British Columbia, Canada, and San Joaquin River are 122 and 146, respectively. Lakes and reservoirs are mainly greater than 300, with many being in the 500 to 2000 range. The K_ds for Salton Sea, California, USA, and the Great Salt Lake, Utah, USA, are 1196 and 1759 respectively. The K_ds for Hyco Reservoir, North Carolina, USA, and Belews Lake, North Carolina, USA, based on data from the 1980s are approximately 3000. Those K_ds greater than 5000 are usually associated with estuary and ocean conditions (e.g., seaward San Francisco Bay and Newport Bay, California, >10 000). Exceptions from this categorization of streams included a set of streams in southeastern Idaho receiving runoff from phosphate mining waste characterized by a majority of selenite plus organo-Se under certain flow conditions (Presser, Hardy, et al. 2004). The overall K_d average for these streams is 1708, with the range among individual streams showing considerable variability (494–3000). These data were for partitioning into mainly attached algae.

Modeling and data requirements. Data collected in site-specific field situations for particulate phases can include benthic or suspended phytoplankton, microbial biomass, detritus, biofilms, and nonliving organic materials associated with fine-grained (<100 μm) surficial sediment (Luoma et al. 1992). For modeling, if the data are available, averaging concentrations of Se in sediment, detritus, biofilm, and algae to define K_d may help to take into account partitioning in different media and best represent the dynamic conditions present in an aquatic system. At a minimum, interpretation and modeling of particulate Se concentration data should take into consideration the nature of the particulate material. In that regard, collection of one consistent type of material that can be compared among locations is an option. Bed sediments are the least desirable choice for calculating K_d, especially if the sediments vary from sand to fine-grained among the samples. In general, sandy sediments dilute concentrations with a high mass of inorganic material and may yield K_ds that are anomalously low (Luoma and Rainbow 2008).

Bioaccumulation: Invertebrates

Biodynamics and kinetic trophic transfer factors. A key aspect of Se risk is bioaccumulation (i.e., internal exposure) in prey and predators (Figure 1; Luoma and Rainbow 2005). Bioaccumulation of Se is modeled here through a biodynamic quantification of the processes that lead to bioaccumulation. These pathway-specific bioaccumulation models (e.g., the dynamic multipathway bioaccumulation [DYMBAM] model) quantify Se tissues concentrations through consideration of 1) the form and concentration of Se in food (i.e., particulate material) and water, and 2) the physiology (AE, IR, k_e, and growth) of invertebrates (Luoma et al. 1992; Wang et al. 1996; Schlekat et al. 2002a) as expressed by

$$C_{species}/dt = [(k_u)(C_w) + (AE)(IR)(C_f)] - (k_e + k_g)(C_{species}), \quad (2)$$

where $C_{species}$ is the contaminant concentration in the animal (μg/g dw); t is the time of exposure (d), k_u is the uptake rate constant from the dissolved phase ($L \cdot g^{-1} d^{-1}$), C_w is the contaminant concentration in the dissolved phase (μg/L), AE is the assimilation efficiency from ingested particles (%) or the proportion of ingested Se that is taken up into tissues, IR is the ingestion rate of particles ($g \cdot g^{-1} d^{-1}$), C_f is the contaminant concentration in ingested material (μg/g dw), k_e is the efflux rate constant (/d), and k_g is the growth rate constant (/d). The differential equation describing these processes can be solved to determine metal concentrations at steady state as

$$C_{species} = \left[(k_u)(C_w) + (AE)(IR)(C_f)\right] \div \left[k_e + k_g\right]. \quad (3)$$

The physiological components of the model are species-specific, and each can be determined experimentally for any given species (see, e.g., Luoma et al. 1992; Wang et al. 1996). The mathematics state that bioaccumulation in an organism results from a combination of gross influx rate as balanced by the gross efflux rate (i.e., biodynamics). Gross efflux is an instantaneous function of the concentration in tissues and the rate constants of loss. Gross influx can come from water or from food. The uptake rate from each is a function of the concentration of Se in that phase.

Biodynamic experiments (Figure 2) mimic dietary pathways in nature by using radiolabeled dissolved selenite to radiolabel food (i.e., particulate material) that is then fed to invertebrates (Luoma and Fisher 1997). A large body of evidence shows that uptake rates of dissolved Se are almost always sufficiently slow in invertebrates that uptake from the dissolved phase is irrelevant compared with uptake from particulate sources such as phytoplankton, detritus, or sedimentary material (Fowler and Benayoun 1976; Luoma et al. 1992; Wang and Fisher 1999; Wang 2002; Schlekat et al. 2004; Lee et al. 2006). For example, the calculated tissue component attributable to dissolved selenite uptake using experimentally determined physiological parameters for the large copepods *Tortanus* sp. and *Acartia* sp. is 1.7% and for the clam *Corbula amurensis* is 1.3% (Schlekat et al. 2002b, 2004; Lee et al. 2006). Thus, a simplification to exposure from only food is justified. The rate constant of growth is significant only when it is comparable in magnitude to the rate constant of Se loss from the organism. Consideration of the complications of growth can usually be eliminated if the model is restricted to a long-term, averaged accumulation in adult animals (Wang et al. 1996).

In the absence of rapid growth, a simplified, resolved exposure equation for invertebrates is

$$C_{invertebrate} = \left[(AE)(IR)\left(C_{particulate}\right)\right] \div [k_e]. \quad (4)$$

To simplify modeling, these physiological parameters can be combined to calculate a $TTF_{invertebrate}$, which characterizes

Table 2. Calculated K_ds based on field studies (supporting data and references for each site are shown in Supplemental Data Table A)

K_d	Ecosystem
107	San Diego Creek, California
110	Alamo River, California
122	Fording River, British Columbia (sediment)
146	San Joaquin River, California
>200	
255	San Diego Creek, constructed pond, California
256	New River, California
269	Tulare Basin, evaporation ponds, California (range 109–500)
272	Upper Newport Bay, California (range 101–776)
276	Mud Slough, California
340	Benton Lake (pool 2), Montana
346	Luscar Creek, Alberta, Canada (range 220–514)
355	Kesterson Reservoir (SLD/pond 2), California (range 200–500)
359	Salt Slough, California
494	Sage Creek, Idaho
≥500	
500	Benton Lake, Montana, pool 5
512	Benton Lake, Montana, pool 1 channel
591	Elk River, British Columbia
611	Lower Great Lakes, Lake Ontario
625	East Allen Reservoir, Wyoming
657	Crow Creek at Toner, Idaho
667	Meeboer Lake, Wyoming
750	Diamond Lake, Wyoming
762	Chevron Marsh (constructed), California (range 214–1241)
767	Miller's Lake, Colorado
784	San Diego Creek constructed marsh, California
818	Mac Mesa Reservoir, Colorado
968	Sweitzer Lake, Colorado
968	Desert Reservoir, Colorado
>1000	
1104	Mud River at Spurlock, West Virginia
1196	Salton Sea, California
1224	Twin Buttes Reservoir, Wyoming
1312	Galett Lake, Wyoming
1341	Angus Creek, Idaho
1388	Lower Great Lakes, Hamilton Harbor
1436	Tulare Basin, evaporation ponds, California
1498	Big Canyon Wash (sites 1 and 2), California
1579	Cobb Lake, Colorado
1619	Timber Lake, Colorado
1717	Larimer Hwy. 9 pond, Colorado
1759	Great Salt Lake, Utah
1800	Upper Mud River Reservoir at Palermo, West Virginia
1818	Crow Creek above Sage Creek, Idaho
1941	Wellington State Pond, Colorado
1943	Thompson Creek, Idaho
>2000	
2143	Highline Reservoir, Colorado
2250	Deer Creek, Idaho
2798	Belews Lake, North Carolina
2902	Kesterson Reservoir (pond 8), California
>3000	
3044	Hyco Reservoir, North Carolina
3150	Big Canyon Wash (site 3), California
3556	Kesterson Reservoir (pond 11), California
4000	Delaware River (tidal freshwater), Delaware
>5000	
6500	Great Marsh, Delaware
7800	San Francisco Bay (1998–1999) (range 3198–26 912)
9456	Salton Sea estuary, Alamo River
12 000	Salton Sea estuary, Whitewater River
13 800	Seaward San Francisco Bay (1998–1999) (range 8136–26 912)
15 000	Xiamen Bay, Fujian Province, China
17 400	Salton Sea estuary, New River, California
18 900	Lower Newport Bay, California (range 6933–42 715)
21 500	San Francisco Bay (1986; 1995–1996) (range 3000–40 000)

the potential for each invertebrate species to bioaccumulate Se. $TTF_{invertebrate}$ is defined as

$$TTF_{invertebrate} = (AE)\,(IR) \div k_e. \quad (5)$$

For clams and mussels, AEs as low as 20% have been found for sediments containing elemental Se (Luoma et al. 1992; Roditi and Fisher 1999; Lee et al. 2006). Assimilation efficiencies of about 40% are typical for experiments in which mussels are exposed to Se adsorbed to particulate materials (see, e.g., Wang and Fisher 1996). However, both elemental and adsorbed Se are probably minor components of the food of most organisms. Assimilation of Se is more efficient when animals ingest living food or detritus, both of which are dominated by organo-Se. From these materials, AEs vary from 55 to 86% among species, with smaller differences among living food types such as different species of algae (see, e.g., Reinfelder et al. 1997; Roditi and Fisher 1999; Schlekat et al. 2004; Lee et al. 2006). If data on particulate speciation are available (see, e.g., Doblin et al. 2006; Meseck and Cutter 2006), then a composite AE may be employed. In this case, the AE for each form of the particulate Se is applied to its fraction of the total Se in sediments. However, particulate speciation data are rarely available. Because most particulate feeders seek organic material in their food, AEs of >50% are probably the best generic representation of assimilation efficiency in nature. Use of species-specific data may result in a more precise value, but validation studies suggest that use of a generic AE, determined for the species of interest with an average-type food, does not add great uncertainty to the calculations (see, e.g., Luoma et al. 1992; Luoma and Rainbow 2005).

Schlekat et al. (2004) determined physiological parameters for the copepods *Tortanus* sp. and *Acartia* sp. of AE = 52% and $k_e = 0.155$. They assumed an IR = 42% from the literature. If the copepods consume diatoms containing 0.5 μg/g Se, then bioaccumulated Se at steady state is

$$C_{copepod} = (0.52)(0.42)(0.5\ \mu g/g) \div 0.155 = 0.72\ \mu g/g. \quad (6)$$

Combining the physiological parameters gives a $TTF_{copepod}$ of 1.4. In contrast, Lee et al. (2006) determined physiological parameters for the bivalve C. *amurensis* of AE = 45%, IR = 25%, $k_e = 0.025$. If C. *amurensis* consumed phytoplankton containing 0.5 μg/g Se, then bioaccumulated Se at steady state is

$$C_{clam} = (0.45)(0.25)(0.5\mu g/g) \div 0.025 = 2.36\mu g/g, \quad (7)$$

and the TTF_{clam} is 4.5. The difference in Se concentrations between the copepod and the clam is primarily driven by the slower rate constant of loss in the bivalve compared with the copepod (i.e., 0.155 vs. 0.025). In both cases, Se concentrations increased from one trophic level to the next (TTF >1), but much more so in the bivalve.

Uncertainties about generic constants are least if species-specific and site-specific information is available for 1) assimilation efficiencies of different types of particulate matter, 2) concentrations of Se in particulate phases (such as suspended particulate material), and 3) proportions of different foods likely to be eaten by that species. Then, a concentration of Se in food can be calculated that takes into account site-specific bioavailability of particulate material to invertebrates. The generalized equation is

$$C_{particulate} = (AE)(C_{particulate\,a})(\text{sediment fraction}) + (AE)(C_{particulate\,b})(\text{detritus fraction}) + (AE)(C_{particulate\,c})(\text{algae fraction}). \quad (8)$$

Hypothetically, let us assume that particulate material is composed of 20% sediment, 40% detritus, and 40% algae and that Se particulate concentrations are 0.5 μg/g in sediment, 2.0 μg/g in detritus, and 4.0 μg/g in algae. From the literature, reasonable assimilation efficiencies for these phases are 15% for sediment, 35% for detritus, 60% for algae. Consequently, the particulate Se concentration for use in modeling is

$$0.02\mu g/g \text{ from sediment} + 0.28\mu g/g \text{ from detritus} + 0.96\mu g/g \text{ from algae} = 1.3\mu g/g. \quad (9)$$

We compiled physiological parameters for invertebrates available in the literature in which AE, IR, and k_e data were determined for an identified test species (Supplemental Data Table B). Sufficient species-specific data, although mainly from marine species, are available from kinetic experiments to calculate $TTF_{invertebrate}$ for a number of species from different feeding guilds. These are enough data at least to begin to model important food webs. A summary of the available laboratory data for the marine environment used for modeling shows that TTFs for invertebrates vary from 0.6 for amphipods to 23 for barnacles (Table 3). The vast majority of TTFs are >1. The TTFs vary 38-fold among species, but increasing Se concentrations from the base of the food web into invertebrates is the rule, rather than the exception, for the available data. This 38-fold variability is propagated up food webs by subsequent trophic transfer steps. The result is that some predators are exposed to much higher Se concentrations than other predators.

Field-derived trophic transfer factors. The kinetic experiments cited above focused mainly on marine species; the freshwater invertebrate kinetic database is weak. However, many field studies are conducted at freshwater sites. When laboratory data are not available, a field $TTF_{invertebrate}$ can be defined from matched data sets (in dw or converted to dw) of particulate and invertebrate Se concentrations as

$$TTF_{invertebrate} = C_{invertebrate} \div C_{particulate}. \quad (10)$$

We calculated freshwater TTFs from field studies documented in the literature (Supplemental Data Table C) and summarized the TTFs by species of invertebrate for modeling (Table 3). We narrowed uncertainties inherent in the field-data approach by constraining the compilation to real-time data that have clearly defined particulate phases and food webs. Either 1) field averages of multiple matched data sets (Se concentrations in particulate material and invertebrates that is time-specific) from sites with similar food webs or 2) regressions of particulate to invertebrate Se concentrations for a series of individual sites with similar food webs were used. Nevertheless, the field TTFs are likely to be more uncertain than the laboratory-derived TTFs. The availability of additional field observed TTFs surely will be improved upon in the future.

Table 3. Summary of selected TTFs for invertebrates, fish, and birds used in modeling and validation (TTFs are derived from data and references shown in Supplemental Data Tables A, B, and C)

Invertebrate	TTF
Amphipod (marine) (*Leptocheirus plumulosus*)	0.6
Amphipod (freshwater) (*Hyalella azteca, Gammarus fasciatus, Corophium* spp.)	0.9
Mysid (marine) (*Neomysis mercedis*)	1.3
Euphausiid (marine) (*Meganyctiphanes norvegica*)	1.3
Copepod (marine) (*Acartia tonsa, Temora longicornis, Tortanus* sp., *Oithona, Limnoithona*)	1.35
Zooplankton (freshwater composite)	1.5
Crayfish (*Procambarus clarki*, Astacidae, *Orconectes* sp.)	1.6
Brine fly (*Ephydra gracilis*)	1.65
Daphnia (Daphnia magna)	1.9
Oyster (*Crassostrea virginica*)	2.05
Corixid (*Cenocorixa* sp.)	2.14
Cranefly (Tipulidae)	2.3
Brine shrimp (young) (*Artemia franciscana*)	2.4
Stonefly (Perlodidae/Perlidae, Chloroperlidae)	2.6
Damselfly (Coenagrionidae)	2.6
Mayfly (Baetidae, Heptageniidae, Ephemerellidae)	2.7
Chironomid (*Chironomus* sp.)	2.7
Clam (*Corbicula fluminea*)	2.8
Aquatic insect (average)[a]	2.8
Caddisfly (Rhyacophilidae, Hydropsychidae)	3.2
Aquatic insect composite	3.2
Brine shrimp (adult)	4.2
Clam (*Macoma balthica*)	4.5
Mussel (*Dreissena polymorpha*)	6.0
Clam (*Corbula amurensis*)	6.25
Mussel (*Mytilus edulis*)	6.3
Clam (*Puditapes philippinarum*)	11.8
Barnacle (*Elminius modestus*)	15.8
Barnacle (*Balanus amphitrite*)	20.3
Clam (*Mercenaria mercenaria*)	23
Fish (whole-body or muscle)	
Leopard shark (*Triakis semifasciata*)	0.52
Gilthead sea bream (*Sparus auratus*)	0.6
Brook trout (*Salvelinus fontinalis*)	0.77
Smooth toadfish (*Tetractenos glaber*)	0.8
Chinese mudskipper (*Periophthalmus cantonensis*)	0.84
Striped bass (juvenile) (*Morone saxatilis*)	0.89
Sucker (*Catostomus* sp.) (Utah and mountain suckers are common in Idaho)	0.97
Rainbow trout (*Oncorhynchus mykiss*)	0.98
Fathead minnow (larval and adult) (*Pimephales promelas*)	1.0
Largemouth bass (*Micropterus salmoides*)	1.0
Cutthroat trout (*Oncorhynchus clarkii*)	1.0
Bluegill (*Lepomis macrochirus*)	1.06
Mangrove snapper (*Lutjanus argentimaculatus*)	1.1
European sea bass (*Dicentrarchus labrax*)	1.1
Chub (*Gila* sp.) (Utah chub is common in Idaho)	1.2
Yellowfin goby (*Acanthogobius flavimanus*)	1.2
Western mosquitofish (*Gambusia affinis*)	1.25
White sturgeon (*Acipenser transmontanus*)	1.3
Brown trout (*Salmo trutta*)	1.3
Mountain whitefish (*Prosopium williamsoni*)	1.3
Sailfin molly (*Poecilia latipinna*)	1.4
Mottled sculpin (*Cottus bairdi*)	1.4
Longnose dace (*Rhinichthys cataractae*)	1.5
Redside shiner (*Richardsonius balteatus*)	1.5
Starry flounder (*Platichthys stellatus*)	1.6
Bird (egg)	
Mallard (*Anas platyrhynchos*)	1.8

[a]Mean of mayfly, caddisfly, crane fly, stonefly, damselfly, corixid, and chironomid.

Freshwater invertebrate TTFs compiled for modeling range from 0.9 for amphipods to 6.0 for zebra mussels (Table 3). Invertebrate TTFs fall into several broad categories in terms of bioaccumulative potential that include means of ≤ 1 for amphipods, 1.3 to 1.9 for crustaceans, 2.8 for aquatic insects, and ≥ 2.8 to 6.0 for clams and mussels. To illustrate the level of uncertainty for one group of organisms, the value for $TTF_{aquatic\ insect}$ used in modeling (2.8) can be compared with several sets of data for insects that include mayfly, caddisfly, cranefly, stonefly, damselfly, corixid, and chironomid (TTF range 2.3–3.2; Supplemental Data Table C and Table 3; Birkner 1978; Saiki et al. 1993; Casey 2005; Harding et al. 2005). Few species-specific comparisons of physiologically derived TTFs with comprehensively derived field TTFs are available (Supplemental Data Tables B and C). However, the range of values for freshwater invertebrates is remarkably similar to that for marine invertebrates determined in the laboratory, as are the values for comparable taxa (Table 3).

TTFs are species-specific because of the influence of the physiology of the animal. They may vary to some extent as a function of the concentration in food, or if AE or IR vary (Besser et al. 1993; Luoma and Rainbow 2005). For modeling here, TTFs from laboratory studies are calculated using a chosen set of physiological or kinetic parameters, usually a mean from the range of experimental data, presented for a specific species. TTFs from field studies are calculated from averages or regressions for specific particulate material–prey pairs. These approaches lead to consideration of a single TTF to quantify trophic transfer from particulate material to invertebrate for each species. If enough data are available to develop diet–tissue concentration regressions specific to inhabitants of a watershed, then use of those regressions would provide more detailed TTFs than single determinations. Additionally, in nature, if it is assumed that organisms regulate a constant minimum concentration of Se, then the observed TTF will increase when the concentration in food is insufficient to maintain the regulated concentration. Data sets from which TTFs are derived for use in modeling here were collected from sites exposed to Se contamination and identified as problematic because of Se bioaccumulation. As noted previously, the relatively small variation of TTF within taxonomically similar animals is evidence that these potential sources of uncertainty may be classified as small (less than 2-fold; see Landrum et al. 1992).

Trophic transfer: Fish

Biodynamics and kinetic trophic transfer factors. Biodynamics can also be applied to fish that feed on invertebrates (Figures 1 and 2). Laboratory test systems extend water–particulate–invertebrate food webs by feeding radiolabeled invertebrates to fish (Reinfelder and Fisher 1994; Baines et al. 2002; Xu and Wang 2002). The mechanistic equations for modeling of Se bioaccumulation in fish tissue are the same as for invertebrates, if whole body concentrations in fish are the endpoint. The choice of C_f (i.e., the contaminant concentration in the ingested food) for fish should reflect the preferred foods of the specific species. Thus, modeling is specific for each fish species in terms of both physiology and food choices.

Uptake of selenite from solution contributes even less to bioaccumulation in fish than it does in invertebrates. For example, the calculated tissue component attributable to dissolved selenite using experimentally determined physiological parameters for mangrove snapper (*Lutjanus argentimaculatus*) is <0.16% (Xu and Wang 2002).

In the absence of rapid growth, the exposure equation for a fish that eats aquatic insects, for example, simplifies to

$$C_{fish} = [(AE)(IR)(C_{invertebrate})] \div [k_e]. \tag{11}$$

A TTF_{fish} characterizes the potential for each fish species to bioaccumulate Se and is defined as

$$TTF_{fish} = (AE)\,(IR) \div k_e. \tag{12}$$

Complete species-specific information (i.e., AE, IR, k_e) from kinetic experiments is available for few fish species (Supplemental Data Table D). To expand the limited kinetic database for fish species, entries that contain some measured values and some assumed parameters (e.g., 5% ingestion rate, 50% assimilation efficiency) are included. For modeling, we compiled TTF_{fish} by combining these physiological parameters for each fish species for which some experimental data are available (Table 3).

Selenium concentration in whole-body fish is calculated in modeling because that type of data is experimentally available, routinely collected, and proposed for Se regulation. Transfer to fish ovaries or egg tissue is more meaningful in terms of a direct connection to reproductive endpoints, but available data are scant (North America Metals Council 2008). Additional conversion factors could be derived to link to ovary or egg Se concentrations (Lemly 2002).

Xu and Wang (2002) determined physiological parameters for mangrove snapper (AE = 69%, IR = 5%, $k_e = 0.027$). To calculate a TTF_{fish}, if a snapper consumes brine shrimp larvae with an Se concentration of 5 μg/g, then the calculated snapper tissue Se concentration is

$$C_{snapper} = (0.69)(0.05)(5\mu g/g) \div 0.027 = 5.6\mu g/g. \tag{13}$$

Some increase in snapper Se concentration is shown in this example, insofar as the $TTF_{snapper}$ is 1.1. For comparison, Baines et al. (2002) determined physiological parameters for juvenile striped bass (*Morone saxatilis*; AE = 42%, IR = 17%, $k_e = 8\%$). If a bass consumes brine shrimp with an Se concentration of 5.0 μg/g, the calculated bass tissue Se concentration is

$$\begin{aligned} C_{striped\,bass} &= (0.42)(0.17)(5.0\mu g/g) \div 0.08 \\ &= 4.46\mu g/g. \end{aligned} \tag{14}$$

The $TTF_{striped\ bass}$ is 0.89, signifying efficient food web transfer but an accumulated body burden slightly less than that occurring in the invertebrate diet.

Field-derived trophic transfer factors. Given the paucity of experimental kinetic data for fish, we reviewed field data to obtain species-specific TTFs relevant to freshwater and marine fish (Supplemental Data Table D). A field derived species-specific TTF_{fish} is defined as

$$TTF_{fish} = C_{fish} \div C_{invertebrate}, \tag{15}$$

where $C_{invertebrate}$ is for a known prey species, C_{fish} is reported as muscle or whole-body tissue, and both Se concentrations are reported in dw. The calculations were constrained as described above for field-derived $TTF_{invertebrate}$ by using real-time data and those studies that have clearly defined food webs (i.e., matched data sets of invertebrate and fish Se concentrations in dw). Derived freshwater TTF_{fish} are summarized by species for modeling (Table 3). For example, a species-specific $TTF_{white\ sturgeon}$ of 1.3 was calculated from field studies of San Francisco Bay using matched data sets for clams and sturgeon. Species-specific TTFs of 1.04 and 0.91 (mean 0.98) were calculated for rainbow trout from field studies in southeast Idaho, USA, and Alberta, Canada, using matched data sets for aquatic insects (mainly mayflies) and trout (Supplemental Data Table D and Table 3). The range of TTFs derived for fish from laboratory experiments and field data is remarkably similar, with a mean TTF of 1.1 for 25 fish species. TTFs for all fish species fall within a relatively narrow range (0.5–1.6, or less than a 4-fold variation) compared with those among invertebrate species (38-fold variation; Table 3). Consequently, variability in bioaccumulated Se among fish species and among food webs is driven more by a fish species' dietary choice of invertebrate and the bioaccumulation kinetics of that invertebrate than by differences in dietary transfer to the fish itself.

Most fish, of course, eat a mixed diet, with tendencies toward certain types of foods. Modeling of Se bioaccumulation can represent a diet that includes a mixed proportion of prey in the diet through use of the equation

$$C_{fish} = (TTF_{fish})[(C_{invertebrate\,a})(\text{prey fraction}) + (C_{invertebrate\,b})(\text{prey fraction}) + (C_{invertebrate\,c})(\text{prey fraction})]. \quad (16)$$

For example, using a hypothetical, but typical, TTF_{fish} of 1.1, a mixed invertebrate diet of 50% amphipods at 1.8 µg/g, 25% daphnids at 3.8 µg/g, and 25% chironomids at 5.6 µg/g, the equation yields

$$1.1[(1.8\mu g/g)(50\%) + (3.8\mu g/g)(25\%) + (5.6\mu g/g)(25\%)] = 3.6\mu g/g. \quad (17)$$

This Se concentration is in contrast to a concentration of 6.2 µg/g if a single component diet of chironomids is considered.

Modeling of fish tissue can also represent stepwise or sequential bioaccumulation from particulate material through invertebrate to fish by combining the equations

$$C_{invertebrate} = (TTF_{invertebrate})(C_{particulate}) \text{ and } C_{fish} = TTF_{fish}(C_{invertebrate}). \quad (18)$$

to give

$$C_{fish} = (TTF_{invertebrate})(C_{particulate})(TTF_{fish}). \quad (19)$$

For example, if a stream contains a particulate Se concentration of 2 µg/g and is inhabited by trout (TTF 1.0) that are eating a single invertebrate diet of mayflies (TTF 2.8), then the fish-tissue Se concentration, C_{trout}, derived from the particulate material Se concentration is 5.6 µg/g.

Modeling can also accommodate longer food webs that contain more than one higher-trophic-level consumer (e.g., forage fish being eaten by predatory fish) by incorporating additional TTFs. One equation for this type of example is

$$C_{predator\,fish} = (TTF_{invertebrate})(C_{particulate})(TTF_{forage\,fish})(TTF_{predator\,fish}). \quad (20)$$

Trophic transfer: Birds

Trophic transfer factors. A link to wildlife, as illustrated here for aquatic-dependent birds, is not as straightforward as in the case for fish (Figure 1). Little information is available for a biodynamic approach to modeling exposure of birds through water and diet. Theoretically, the biodynamic exposure equation for a selected bird species would be similar to that for fish. The equation for calculating a bird tissue Se concentration for a single invertebrate diet is

$$C_{bird} = (AE)(IR)(C_{invertebrate}) \div (k_e). \quad (21)$$

A TTF_{bird} can be defined either as

$$TTF_{bird} = (AE)(IR) \div k_e \quad (22)$$

or

$$TTF_{bird} = C_{bird} \div C_{invertebrate} \quad (23)$$

to give

$$C_{bird} = (TTF_{bird})(C_{invertebrate}). \quad (24)$$

Selenium concentration in bird tissue can be for muscle if desired, but transfer to egg tissue is more meaningful in terms of a direct connection to reproductive endpoints.

Modeling of bird tissue can represent stepwise or sequential bioaccumulation from particulate material through invertebrate to bird by combining the equations

$$C_{invertebrate} = (TTF_{invertebrate})(C_{particulate}) \text{ and } C_{bird} = TTF_{bird}(C_{invertebrate}) \quad (25)$$

to give

$$C_{bird} = (TTF_{invertebrate})(C_{particulate})(TTF_{bird}). \quad (26)$$

Modeling for bird tissue can also represent Se transfer through longer or more complex food webs (e.g., additional TTFs for invertebrate to fish and fish to birds) by combining the equations

$$C_{invertebrate} = (TTF_{invertebrate})(C_{particulate}); C_{fish} = TTF_{fish}(C_{invertebrate}) \quad (27)$$

and

$$C_{bird} = (TTF_{bird})(C_{fish}) \quad (28)$$

to give

$$C_{bird} = (TTF_{invertebrate})(C_{particulate})(TTF_{fish})(TTF_{bird}). \quad (29)$$

Modeling approach. Laboratory data relating dietary Se concentrations to egg Se concentrations are used for modeling and derivation of TTFs of birds. A synthesis of data from controlled feeding of captive mallards (*Anas platyrhynchos*) exposed to known dietary Se concentrations showed the relationship of egg hatchability and egg tissue Se concentration (i.e., a dose–response curve; Ohlendorf 2003). Ohlendorf (2003) conducted logistic regressions on a set of pooled results from different studies to be able to calculate mean Se concentrations that are associated with different percentages of reduction in the hatchability of mallard eggs (e.g., the 10% effect concentration or EC10 is associated with a 10% reduction in hatchability). The range of $TTF_{bird\ egg}$ calculated from the compilation given by Ohlendorf (2003) for mallards is 1.5 to 4.5. Although mallards are believed to be a sensitive species based on reproductive endpoints in the laboratory, chickens and quail were shown to be more sensitive than mallards (Detwiler 2002). An order that reflects the effects of field factors present at Kesterson

Reservoir, California, USA, and is based on the number of dead or deformed embryos or chicks is (coot = grebe) > (stilt = duck = killdeer) > avocet (Ohlendorf 1989; Skorupa 1998).

The model can be run using any chosen $TTF_{bird\ egg}$, but a $TTF_{bird\ egg}$ of 1.8 (near the lower limit from the captive mallard studies) will be assumed here for modeling purposes (Table 3). Generalized species-specific or site-specific, species-specific TTFs for birds may also be derived from field studies, as was suggested for fish, which would take into account variables intrinsic to bird behavior and habitat use. Resident bird species nesting in a contaminated area may be the best choice for such a compilation.

TOXICITY: EFFECTS

Linking modeling to effects requires knowledge of species toxicological sensitivity through 1) effect guidelines for diet or tissue based on chronic Se exposure of predators; 2) toxicity reference values (TRV) specific to target receptor groups, endpoints, exposure routes, and uncertainty levels; or 3) national, state, or local regulatory guidance on diet or tissue Se concentrations. The chosen guideline can link diet, fish tissue, or bird tissue to toxicity.

Several authors give comprehensive compilations of Se guidelines (USDOI 1998; Lemly 2002; Presser and Luoma 2006; Luoma and Rainbow 2008). The controversy over choice of protective levels of Se for fish and birds is intense in part as a result of the steepness of the Se dose–response curves and the use of different models for quantifying those relationships (Skorupa 1998; Lemly 2002; Ohlendorf 2003; Beckon et al. 2008). Specificity in several variables based on experimental conditions when referencing a Se guideline is desirable. These variables include 1) endpoint (e.g., toxicity, reproductive, survival, growth, immunosuppression); 2) life stage (e.g., larvae, fry, adult); 3) form (e.g., selenate, selenite, selenomethionine, selenized yeast); 4) route of transfer (e.g., dietary, maternal); 5) definition of protection (e.g., threshold, toxicity level, criterion, target); and 6) toxicity basis (e.g., EC10). In general, for Se, reproductive endpoints are more sensitive than toxicity and mortality in adult birds and fish (Skorupa 1998; Lemly 2002; Chapman et al. 2010). Within reproductive endpoints, larval survival in fish and hatchability (i.e., embryo survival) in birds are considered the most sensitive endpoints. Effects guidelines that focus on a combination of the most sensitive assessment measures might include, for example, a seleno-methionine diet, parental exposure, and embryonic or larval life stage (Presser and Luoma 2006).

Any criterion, guideline, or target may be used in modeling to predict effects on predators, and, whatever the choice, the model can give its implications. For illustration purposes, we use a single value for each type of effects guideline (dietary = 4.5 μg/g dw, fish whole body = 5 μg/g dw, and bird egg = 8 μg/g dw), while recognizing that debate is still occurring about determining critical tissue values that relate bioaccumulated Se concentrations to toxicity in predators.

VALIDATION AND APPLICATION OF METHODOLOGY

Validation

Validation is necessary to establish sufficient confidence that the predictions from a model can be usefully applied to the environment. Advantages of the ecosystem-scale approach are that some aspects of the model are built from observations from natural systems, and the predictions from the biodynamic model center around bioaccumulated Se in a specific species. Thus, predictions from the model can be unambiguously compared with independent observations of Se concentrations in that same species resident in the environment of interest. The comparison of these 2 independent values illustrates both validity and uncertainty.

We tested the proposed methodology by comparing predictions and observations from 29 locations that were either historically, or are presently, affected by Se (Table 4 and Supplemental Data Tables E and F). The case studies include several types of hydrologic regimes, streams, rivers, ponds, lakes, reservoirs, wetlands, and estuaries, and many species of invertebrates, fish, and birds (see Supplemental Data). Sources of Se and food webs represented at sites used for the validation are also shown in Table 4. All sites are relatively well-known for associated Se contamination, and many are still in remediation or being mitigated because of ecosystem bioaccumulation of Se. In all case studies, reasonable food webs were identified and sufficient high-quality field data were available across media (particulate material, invertebrates, fish and/or bird tissue) and during a constrained time period (i.e., data were temporally and spatially matched; Supplemental Data Tables E and F). In 3 study area investigations (Kesterson Reservoir, McLeod River/Luscar Creek watershed, San Joaquin River), sites identified as reference sites are included to help illustrate the prediction capability of the model at the lower end of the concentration gradient.

The equations used for validation begin with a particulate material Se concentration, and thus do not incorporate the uncertainties associated with dissolved and/or particulate transformations (K_d), which we address below. We progressively calculate 1) invertebrate Se concentrations from particulate material, and 2) fish or bird tissue Se concentrations from the predicted invertebrate Se concentrations. Combining the progressive equations

$$C_{invertebrate} = (C_{particulate})(TTF_{invertebrate}), \quad (30)$$

$$C_{fish} = (C_{invertebrate})(TTF_{fish}), \quad (31)$$

and

$$C_{bird\,egg} = (C_{invertebrate})(TTF_{bird}) \quad (32)$$

yields

$$C_{fish} = (C_{particulate})(TTF_{invertebrate})(TTF_{fish}) \quad (33)$$

and

$$C_{bird\,egg} = (C_{particulate})(TTF_{invertebrate})(TTF_{bird}). \quad (34)$$

Thus, this approach tests whether bioaccumulation at the invertebrate and predator trophic levels can be predicted accurately if particulate Se concentrations are known.

For the predictions of Se concentrations in invertebrates, the observed particulate Se concentration at a site is multiplied by a species-specific TTF for the species of invertebrate in the identified food web (Supplemental Data Table E). The TTFs selected for use in the validation are a subset of those given in Table 3. The case studies allow 101 paired predicted

Table 4. Site locations, associated Se sources, and available prey and predator data for case studies used in model validation (see Supplemental Data Tables E and F for data sets)

Location or watershed	Sources	Available prey data	Available predator data
Belews Lake, North Carolina	Coal fly-ash disposal	Phytoplankton + zooplankton, insect, mollusk, crustacean, annelid	Bluegill, warmouth, redear sunfish, pumpkinseed, largemouth bass
Cienega de Santa Clara, Colorado River Delta	Agricultural drainage	Brine shrimp, crayfish	Sailfin molly, largemouth bass, striped mullet, common carp
Converse County, Wyoming	Uranium mining	Grasshopper	Red-winged blackbird
Elk River and Fording River watersheds, British Columbia, Canada	Coal mining	Insect, composite benthic invertebrate, mayfly, stonefly, caddisfly, cranefly	Cutthroat trout, mountain whitefish, American dipper, spotted sandpiper
Goose Lake, Kendrick Reclamation Project, Wyoming	Agricultural drainage	Composite insect	Eared grebe
Great Salt Lake, California	Copper mining	Brine shrimp, brine fly	American avocet, black-necked stilt, California gull
Hyco Reservoir, North Carolina	Coal fly-ash disposal	Benthic insects	Bluegill
Illco Pond, Kendrick Reclamation Project, Wyoming	Agricultural drainage	Composite insect	Common carp
Imperial National Wildlife Refuge, Lower Colorado River watershed, Arizona and Colorado	Agricultural drainage	Clam, crayfish	Lesser nighthawk, green heron, pied-billed grebe, least bittern
Kesterson National Wildlife Refuge, California	Agricultural drainage	Net plankton, corixid, chironomid, dragonfly, damselfly, beetle, diptera	Western mosquitofish (die-off of other fish species); pied-billed and eared grebe, American coot, mallard, gadwall, cinnamon teal, northern pintail, redhead, ruddy duck, black-necked stilt, American avocet, killdeer, western meadowlark, tri-colored blackbird, cliff and barn swallow
McClean Lake area, Saskatchewan, Canada	Uranium mining	Chironomid, caddisfly, dragonfly, leech, snail	Northern pike, white sucker, stickleback, burbot
McLeod River/Luscar Creek watersheds, Alberta, Canada	Coal mining	Insect	Rainbow, brook, and bull trout, mountain whitefish
Miller's Lake, Colorado	Agricultural drainage	Chironomid, corixid, crayfish	Fathead minnow
Newport Bay, California	Agricultural drainage	Amphipod, bivalve, clam, mussel, isopod, clam, snail	Topsmelt, diamond turbot, deep body anchovy, California halibut, striped mullet, California killifish, shadow, arrow and cheekspot goby, barred and spotted sand bass, staghorn sculpin, black and pile surfperch, American avocet, black-necked stilt, killdeer, clapper rail, pied-billed grebe, least tern, black skimmer
Rasmus Lee Lake, Kendrick Reclamation Project, Wyoming	Agricultural drainage	Composite insect	American avocet
Red Draw Reservoir, Big Spring, Texas	Refinery waste	Chironomid, snail	Inland silverside, sheepshead minnow, gulf killifish

TABLE 4. (*Continued*)

Location or watershed	Sources	Available prey data	Available predator data
Salton Sea, California	Agricultural drainage	Amphipod, corixid, pileworm	Largemouth bass, sargo, redbelly and Mozambique tilapia, Gulf croaker, orangemouth corvina, channel catfish, Caspian tern, white-faced ibis, snowy egret, black skimmer, great egret, black-crowned night heron
San Diego Creek watershed, California	Urban drainage	Zooplankton, corixid, crayfish, clam, snail, backswimmer, chironomid	Western mosquitofish, common carp, American avocet, black-necked stilt, killdeer, pied-billed grebe, American coot, clapper rail
San Francisco Bay–Delta Estuary, California	Oil refinery effluent agricultural drainage	Clam, zooplankton, amphipod, isopod, shrimp	White sturgeon, striped bass, starry flounder, yellowfin goby, leopard shark, Sacramento splittail
San Joaquin River watershed, California	Agricultural drainage	Zooplankton, amphipod, chironomid, crayfish	Bluegill, largemouth bass
Savage River watershed (Blacklick Run), Maryland	Coal stack emissions	Crayfish, mayfly, caddisfly, cranefly, stonefly, dragonfly, dobsonfly	Mottled sculpin, blacknose dace, brook trout
Savannah River (D-area Power Plant), South Carolina	Coal fly-ash disposal	Composite, benthic invertebrates	Lake chubsucker
Sweitzer Lake, Colorado	Agricultural drainage	Damselfly, chironomid, crayfish	Plains killifish
Thompson Creek, Idaho	Molybdenum mining	Composite insect	Slimy sculpin, cutthroat/rainbow trout
Tulare Basin Ponds, California	Agricultural drainage	Brine shrimp, brine fly larvae, corixid, damselfly	American avocet, black-necked stilt, eared grebe
Twin Buttes Reservoir, Wyoming	Agricultural drainage	Plankton, amphipod, corixid, damselfly, chironomid	Plains killifish, Iowa darter, fathead minnow
Uncompahgre River watershed, Colorado	Agricultural drainage	Invertebrates with some insects, crayfish	Bluehead flannelmouth and white sucker, speckled dace, roundtail chub, green sunfish
Upper Blackfoot River watershed, Idaho	Phosphate mining	Insect, composite benthic invertebrate	Cutthroat, brook, and brown trout, mountain whitefish, longnose dace, mottled sculpin, common snipe, American coot, killdeer, eared grebe
Upper Mud Reservoir/Mud River watershed, West Virginia	Coal mining	Dragonfly, crayfish, clam, snail	Bluegill, green sunfish, crappie

and observed data points for invertebrates (Figure 3). The data range across the entire data set probably covers the full extent of Se concentrations that might be expected from the most to the least contaminated environments. The agreement is remarkable, with a calculated correlation coefficient (r^2) for predicted and observed invertebrate Se concentrations of 0.917 ($p < 0.0001$) (Figure 3).

The second correlation compares observed Se concentrations in fish with concentrations predicted from observed particulate concentrations, the previously predicted invertebrate Se concentrations using the most likely food choice of that particular species of fish, and the universal choice of a TTF_{fish} of 1.1 (Supplemental Data Table E). In some cases, when several invertebrate Se concentrations were predicted, an average invertebrate Se concentration was used to predict a fish Se concentration. In cases in which Se concentrations in diet were elevated enough to cause fish die-offs (e.g., Belews Lake, Hyco Reservoir, Kesterson Reservoir, Sweitzer Lake; Skorupa 1998), trophic transfer of Se in fish may be additionally affected by poor feeding efficiency and food avoidance (Hilton et al. 1980; Finley 1985). The case studies allow 46 paired predictions and observations for fish (Figure 4). Again, the agreement is remarkable, with $r^2 = 0.892$ ($p < 0.0001$). These strong regressions show that, if particulate Se concentrations are known and food webs are considered in an ecologically based way, bioaccumulation in the different food webs of an ecosystem can be reliably predicted.

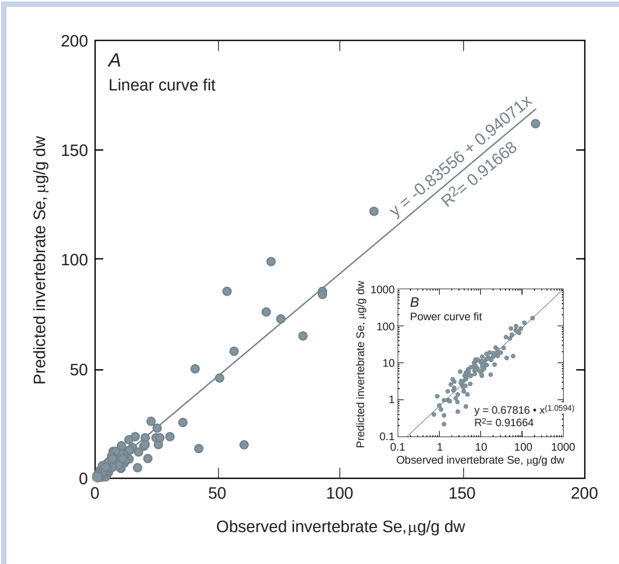

Figure 3. Linear regression and correlation of observed invertebrate Se concentrations from selected field studies and those predicted through ecosystem-scale modeling. Inset shows a power curve fit of data. See Supplemental Data Table E for data and references.

In the same manner, predictions are made of Se concentrations in birds that consume a diet of invertebrates or fish using a TTF_{bird} of 1.8 (Supplemental Data Table F). Because of the severity of exposure at several historical sites (e.g., Kesterson Reservoir, Tulare Basin Ponds, Rasmus Lee Lake, Goose Lake), factors such as food avoidance and poor physical condition might have affected feeding and hence trophic transfer of Se in birds (Ohlendorf et al. 1988; Heinz and Sanderson 1990; Heinz and Fitzgerald 1993; Ohlendorf 1996; Skorupa 1998). At these sites, predicted egg Se concentrations were above observed concentrations. At other sites, predicted bird egg Se concentrations were in the range of observed Se concentrations. The comparison for birds is hampered by the lack of data compared with data for fish, but it is illustrative of a comparable methodology for wildlife. Application of a TTF_{bird} of 1.8 may be useful under certain conditions, but selective regressions of data over a narrow range to represent site-specific conditions or a wildlife criterion methodology (discussed below) may better represent Se transfer at specific sites. This is an area in which greater understanding of the prey-to-predator kinetics in birds is needed.

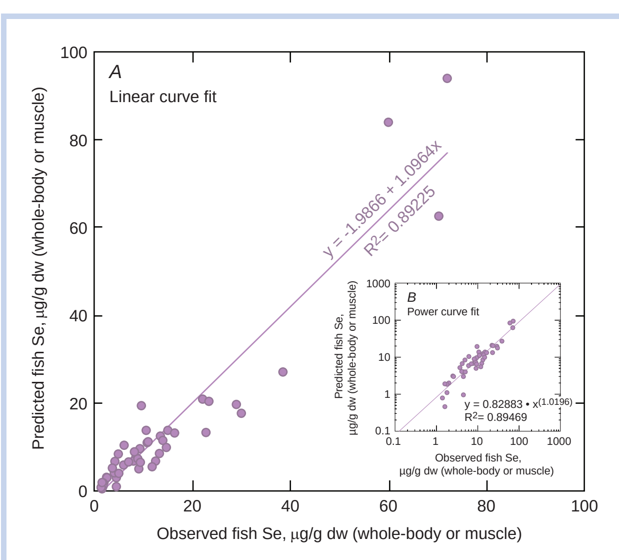

Figure 4. Linear regression and correlation of observed fish Se concentrations from selected field sites and those predicted through ecosystem-scale modeling. Inset shows a power curve fit of data. See Supplemental Data Table E for data and references.

Application

The value of the ecosystem-scale methodology lies in its explanation of how a predator might be accumulating an Se concentration that, for example, exceeds the choice of criterion, guideline, or target concentration in its tissues. The step-by-step approach of the methodology (Figure 1) provides a means of linking water-column Se concentrations to Se bioaccumulation with much more certainty that does the traditional correlation approach. The methodology can also describe implications of different choices of dietary or tissue guidelines. For example, a water-column concentration responsible for an observed bioaccumulated Se concentration can be determined in any specific environment for which some data are available (or a reasonable scenario can be defined). Similarly, it is possible to calculate water-column Se concentrations that might be allowable under a given set of conditions if the environment is to comply with a chosen fish tissue guideline.

Translations to water-column Se concentration and load. The discussions and equations given above address the complexity associated with each major variable listed in Table 1 and quantify the major contributors to Se bioaccumulation within an ecosystem. The complexity of nature is viewed by some as deterring use of such models in simpler applications of effects guidelines. However, even in the absence of site-specific data, simplified choices of model factors can be based on rudimentary knowledge of a watershed and its species-specific food webs, and outputs can be used for the purposes of establishing a perspective on management decisions. For example, one application of the model might be to translate bioaccumulated Se in a predator (observed or established by a model scenario) to the water-column concentration that might be responsible for that body burden, in that specific environment. This could be an instructive exercise for facilitating implementation of a fish tissue or wildlife guideline by allowing visualization of the change in water-column concentration that would be necessary to achieve the tissue guideline.

Several important choices (Table 5) based on information about the watershed or water body must be made to initiate an exercise such as translation.

1. The choice of a predator food web is the basis for derivation of an allowable water-column concentration and allowable load. Several fish species or the most Se-sensitive fish species may be considered as starting points. It should be remembered that sensitivity of a fish species is defined by both potential for exposure (does the fish eat an

Table 5. Steps in ecosystem-scale Se methodology for translation of a tissue Se guideline to a water-column Se concentration for protection of fish

Translation of Fish Tissue Guideline or Criterion to Water-Column Concentration
Develop a conceptual model of food webs in watershed
Choose toxicity guideline for fish in watershed
Choose fish species to be protected in watershed
Choose species-specific TTF_{fish} or use default TTF_{fish} of 1.1
Identify appropriate food web for selected fish species based on species-specific diet
Choose $TTF_{invertebrate}$ for invertebrates in selected food web or use default $TTF_{invertebrate}$ for taxonomic group of invertebrate
Choose K_d indicative of 1) generalized source of Se and receiving water conditions, or 2) site-specific hydrologic type and speciation; or use a default K_d of 1000
Solve equation(s) for allowable water-column concentration for protection of fish
If assume single invertebrate diet · $C_{water} = (C_{fish}) \div (TTF_{fish})(K_d)(TTF_{invertebrate})$
If assume a mixed diet of invertebrates · $C_{water} = (C_{fish}) \div (TTF_{fish})(K_d)[(TTF_{invertebrate\ a})(\text{prey fraction})] + [(TTF_{invertebrate\ b})(\text{prey fraction})] + [(TTF_{invertebrate\ c})(\text{prey fraction})]$
If assume sequential bioaccumulation in longer food webs · $C_{water} = (C_{fish}) \div (TTF_{fish})(K_d)(TTF_{invertebrate\ a})(TTF_{forage\ fish})$ · $C_{water} = (C_{fish}) \div (TTF_{fish})(K_d)(TTF_{TL2\ invertebrate})(TTF_{TL3\ invertebrate})(TTF_{TL3\ fish})$

invertebrate that is a strong bioaccumulator?) and its response in dietary toxicity tests.

2. A TTF must be chosen for invertebrate-to-fish transfer. If a TTF_{fish} specific to the local food web is not available, then a value of 1.1 can be assumed based on the mean value from 25 fish species (Table 3).
3. The choice of a fish species sets the choice of dietary prey; in general, what species of prey does this fish consume?
4. Particulate-to-prey kinetics are incorporated via TTFs for major species of invertebrates, such as those chosen in our validation exercise. These TTFs can then be used to represent a set of common food webs (Table 3).
5. The choice of a value to link water-column concentration to particulate concentration (our K_d) is an exacting challenge. Local data can narrow the range of choices, as long as they are high-quality analytical data. In the absence of a rich data set, the range can be narrowed based on hydrologic and speciation conditions, for example, using the data in Table 2. A K_d of 1000 is a default case that may be an environmentally conservative choice for environments other than reservoirs, estuaries, and the oceans. In any case, it is critical that the assumptions behind the choice of K_d be made explicit, and the potential variability in this crucial factor be recognized. In the absence of well-developed site models, the choice of K_d is usually the greatest source of uncertainty among model parameters.

Once these choices are made, the generalized equation for translation of a fish tissue Se concentration to water-column Se concentration is

$$C_{water} = (C_{fish}) \div (TTF_{fish})(TTF_{invertebrate})K_d, \qquad (35)$$

where $(K_d)(C_{water})$ is substituted for $C_{particulate}$ and the equation is solved for C_{water} (Table 5). An analogous equation for translation of a bird egg Se concentration is

$$C_{water} = (C_{bird\ egg}) \div (TTF_{bird})(TTF_{invertebrate})K_d. \qquad (36)$$

As an illustration, predators are consuming a diet exclusively composed of one invertebrate species. For example, if the effects guideline is an Se concentration of 5 µg/g in whole-body fish tissue and the selected site is a lake (hypothetical K_d of 1000) inhabited by sunfish (TTF of 1.1) that are eating a diet of mayfly larvae (TTF of 2.8), then the allowable water-column concentration for the lake is

$$C_w = 5\mu g/g \div [1.1 \times 2.8 \times 1000] = 1.6\mu g/L. \qquad (37)$$

Under a food web scenario in which a fish with a similar TTF eats *Daphnia* (TTF of 1.9), the allowable Se water-column concentration is

$$C_w = 5\mu g/g \div [1.1 \times 1.9 \times 1000] = 2.4\mu g/L. \qquad (38)$$

Table 5 also shows an equation that considers longer food webs. Despite some uncertainty at every biological step and even greater uncertainty with regard to transformation, the predicted allowable values fall across the range of values characteristic of contaminated situations.

Model sensitivity. To test the sensitivity of the predictions to differences in invertebrate species, dissolved concentrations of Se are predicted across a range of invertebrate species [mysid, *Daphnia*, mayfly, clam (*C. amurensis*), and barnacle (*E. modestus*)] using species-specific TTFs (Figure 5). Assumptions are 1) a guideline for whole-body fish tissue of 5 µg/g, 2) a hypothetical K_d of 1000, and 3) a TTF_{fish} of 1.1. The allowable water-column Se concentrations associated with the 5 specific food web exposures that would protect predators under the specified assumptions range from 3.5 µg/L for an invertebrate diet of exclusively mysids to 0.28 µg/L for an invertebrate diet of barnacles.

If 5 µg/g represents a whole-body Se guideline for fish and the TTF_{fish} is relatively constant (i.e., averaging 1.1 among all species of fish for which data were available), then an alternative strategy is a dietary guideline for fish. For the purposes of illustration, we employ a dietary guideline of 4.5 µg/g under these assumptions. Using a paired 8 µg/g bird egg Se guideline and a TTF_{bird} of 1.8 gives 4.4 µg/g for an allowable diet for birds. This similarity in allowable dietary Se concentrations for both fish and birds reinforces the hypothesis that fish and birds are of similar sensitivity in a general sense. Because the dietary guidelines are similar, the graph depicting protective concentrations for fish would apply to the protection of birds (Figure 5). If this were not the case, 2 graphs would be necessary to depict predictive protective Se concentrations for fish and birds. The difference in protection for fish and birds may also diverge in site-specific instances in which detailed predator-specific data are available to determine TTFs across a range of concentrations.

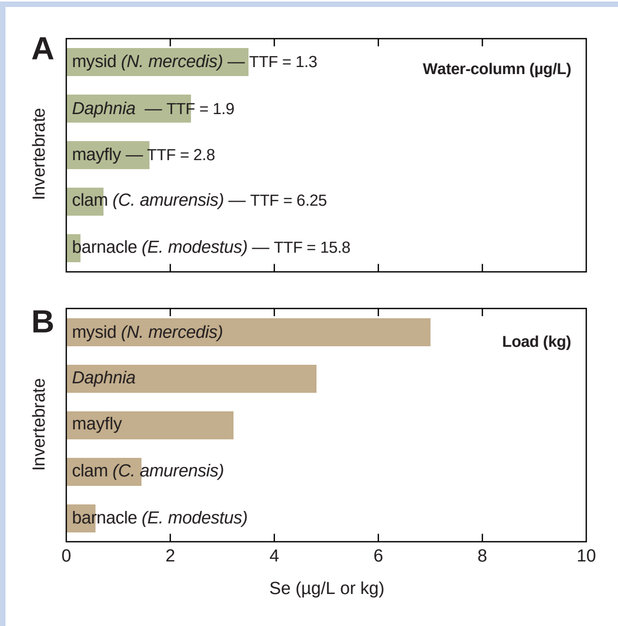

Figure 5. Predicted allowable water-column Se concentrations and Se loads based on choices of invertebrates in food webs. Assumptions are TTF_{fish} of 1.1, whole-body fish guideline of 5.0 µg/g dw, K_d of 1000, and stream flow of 1.2 Mm^3. See Table 3 for TTFs for invertebrates and Equation 39 for consideration of load.

Regulatory considerations such as NPDES permits and TMDLs for 303d listed water bodies put limits on loads. A fundamental equation to calculate load is

$$(C_{water-column})(volume)(10^{-6}) = load, \qquad (39)$$

where the water-column concentration is in µg/L, volume is in cubic meters (m^3), and load is in kilograms (Presser and Luoma 2006). We use this exceptionally simplified approach to consider Se loading at a site to calculate the hypothetical loads associated with the different food webs illustrated in Figure 5A. These loads (Figure 5B) are calculated based on the predicted allowable water-column Se concentrations (Figure 5A) and an assumed waste stream flow of 1.2 million m^3 (Mm^3). Under the different exposure scenarios for fish, loads vary from 0.56 to 7.0 kg depending on the choice of the invertebrate that is consumed by fish in the selected food web (Figure 5B). Of course, this is only an illustration of the ultimate linkage to source loads that modeling can provide (Figure 1). More sophisticated load models are recommended when calculating loads from concentrations and volumes, and, again, it is critical that predictions be explicit about why a specific K_d was chosen and the potential variability in that choice.

The translation approach of the ecosystem-scale model, of course, can start with any media (dissolved, particulate, diet, tissue) and translate to any other media, as long as the food web is known (or assumed; Figure 1). In all cases, it is important to connect the appropriate fish species to the appropriate food (i.e., biologically correct or observed knowledge of prey–predator pairs) to illustrate the potential for bioaccumulation within a watershed. Uncertainties can be greatly narrowed if part of the risk management strategy is for an agency or stakeholders to decide which predators are the most important to protect.

Table 5 formalizes the steps in a fish tissue water-column translation. Following these steps would facilitate risk management for Se based on a tissue guideline. As shown above, equations can be included that are appropriate for mixed invertebrate diets and longer food webs (e.g., forage fish being eaten by predatory fish). The steps in this approach (Table 5) are simple enough to be widely used in a management context but address the complexity of a specified ecosystem sufficiently to reduce uncertainty well below that of conventional approaches.

Hypothetical case studies and site-specific conceptualization. One outcome of the application of the ecosystem-scale model is explicit recognition that allowable dissolved Se concentrations and loads will vary among environments. The degree of such variability that is possible can be shown by predictions of allowable dissolved concentrations for different watershed types and food web scenarios. To illustrate a full range of possible conditions, we modeled realistic scenarios based on the previously compiled field case sites and ecosystem habitats (Figure 6). The illustrated K_d categories are broadly indicative of 1) an estuary, 2) a reservoir, 3) a mainstream river, 4) a backwater, 5) a saline lake or pond, and 6) a wetland (Table 2). Species-specific TTFs are employed based on Table 3. To illustrate the discussion here, translation is for a fish tissue guideline of 5 µg/g dw whole body and an avian egg guideline of 8.0 µg/g dw (see also under *Toxicity*). These targets are applied to starry flounder, white sturgeon, Sacramento blackfish, redear sunfish, bluegill, cutthroat trout, and largemouth bass as examples of fish species and black-necked stilt, American dipper, eared grebe, and greater scaup as examples of bird species. Some of the illustrations reflect food webs of historically contaminated sites (e.g., Kesterson Reservoir, Belews Lake, San Francisco Bay–Delta Estuary), and others reflect food webs of current areas of contamination (e.g., mountain streams in Idaho and British Columbia, Great Salt Lake).

A range of Se water-column concentrations from 0.24 to 34 µg/L is predicted as protective of the different predators that are the targets of the assumed guidelines in the illustrated exposure scenarios (Figure 6). For fish, an exposure scenario that has a very low K_d (mainstream river, 150) and low food web potential (bluegill eating amphipods, $TTF_{fish} = 1.1$, $TTF_{invertebrate} = 0.9$) predicts a water-column Se concentration of up to 34 µg/L (Figure 6A). If the river is transported through a watershed into a hydrologic area of differing K_d, for example, into a backwater where the flow is decreased ($K_d = 350$), then trout consuming insects would require a much lower Se concentration in the water column (4.6 µg/L; Figure 6B).

An exposure scenario for a reservoir with a K_d of 1800 that is reflective of more opportunities for transformation and a food web that contributes to significant accumulate of Se in prey and predators (redear sunfish eating freshwater clams, $TTF_{fish} = 1.1$, $TTF_{invertebrate} = 2.8$) predicts a water-column Se concentration of less than 1 µg/L (Figure 6C). However, if Sacramento blackfish in the reservoir are consuming only zooplankton ($TTF_{fish} = 1.1$, $TTF_{invertebrate} = 1.5$), then modeling predicts a water-column Se concentration of 1.7 µg/L. Estuaries require the lowest water-column Se concentrations

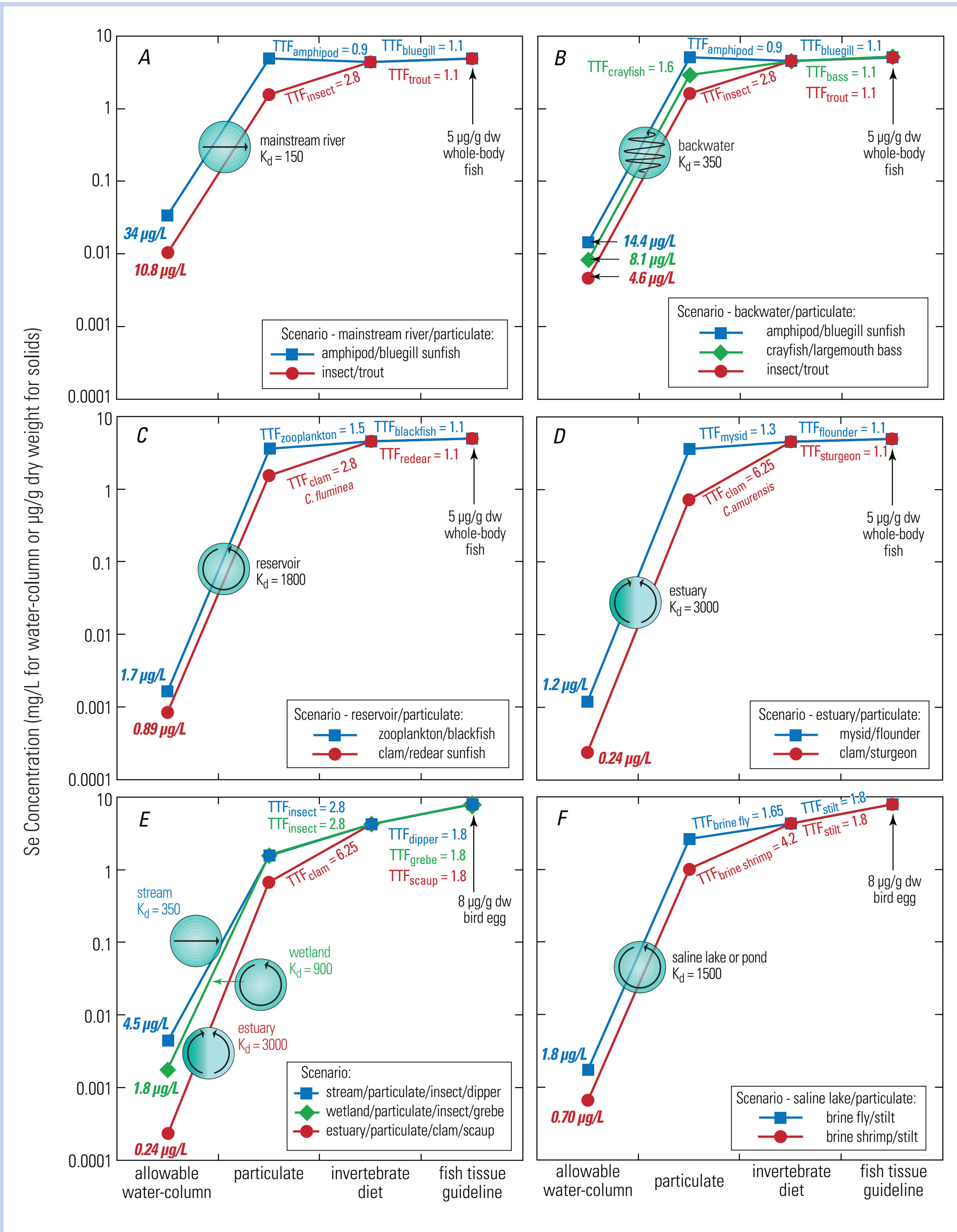

Figure 6. Range of predicted allowable water-column Se concentrations for various environmental exposure scenarios using ecosystem-scale modeling. Hydrologic environment types include an estuary, reservoir, mainstream river, backwater, saline lake, and a wetland. Food webs illustrate invertebrates as prey and fish or birds as predators. Additional food web steps can be added to illustrate more complex food webs (e.g., invertebrate through fish to bird or to include forage fish to predatory fish).

(0.24 µg/L) because of the potential for very high K_ds (Table 2) and the presence of clam-based food webs (sturgeon or scaup eating *C. amurensis*, $TTF_{fish} = 1.1$, $TTF_{invertebrate} = 6.25$; Figure 6D).

For birds, an exposure scenario similar to that at Kesterson Reservoir ($K_d = 900$) where eared grebes are feeding on aquatic insects ($TTF_{bird} = 1.8$, $TTF_{invertebrate} = 2.8$) predicts a water-column Se concentration of 1.8 µg/L (Figure 6E). A scenario for a saline lake or pond (K_d of 1500) inhabited by black-necked stilts that are eating brine flies ($TTF_{bird} = 1.8$, $TTF_{invertebrate} = 1.65$) leads to a 1.8 μg/L water-column Se concentration, or 0.70 μg/L if stilts consume a diet of brine shrimp ($TTF_{bird} = 1.8$, $TTF_{invertebrate} = 4.2$; Figure 6F). A scenario for a mountain stream ($K_d = 350$) where American dippers are eating a diet of mayflies predicts a water-column Se concentration of 4.5 μg/L (Figure 6E).

An additional factor would be necessary to illustrate a scenario, for example, in which birds in an estuary are feeding on fish that prey on aquatic insects. If the selected fish species possesses a low food web potential ($TTF_{fish} = 1.1$) as found here, then the predicted allowable water-column Se concentration would not differ substantially from that predicted from invertebrates alone.

This exercise illustrates both the strengths and the limits of the model. Even when feeding relationships and TTFs are known, potential exists for variability in the translation from water to particulate phase. The model can provide perspective by illustrating that variability around reasonable scenarios for that watershed, but the model is not suitable for explicitly defining one number that will be protective in any habitat. Documenting all decisions, whether mathematical or policy choices, throughout modeling will record all considered pathways between dissolved Se and tissue Se and their outcomes.

Limitations and uncertainties. No model can incorporate all the complexities of nature or make exact predictions of outcomes. The approach presented in this paper is no exception. However, models can provide new insights that advance understanding of value to both science and management. The greatest values of the present model are that it shows why allowable water-column concentrations differ among aquatic environments and that it advances our ability to explain food web bioaccumulation of Se. The combined mechanistic and empirically based approach provides a unified methodology for evaluating how interactions of hydrology, biogeochemistry, biology, ecology, and toxicology affect ecological risks from Se at any given location. However, as with every model, forecasts from the model have limitations and uncertainties, most of which were detailed above.

Sensitivity analyses in earlier work compared the influence of uncertainty on different terms used in kinetic biodynamic modeling (see, e.g., Wang et al. 1996). Variability in TTFs reflects the outcome of those uncertainties when summed for an individual species. Experimentally determined TTFs appear to have low uncertainties judged by repeatable results in different studies. For example, TTFs for estuarine or marine zooplankton range from 1.3 to 1.5 in repeated experiments; TTFs for barnacles range from 15.8 to 20.3 (Table 3). We might expect the most uncertainty in TTFs derived from field observations given the complexity of field variables, but field- and laboratory-derived TTFs for individual species also appear to agree well (within 2-fold) in the few cases in which comparisons are possible. For example, TTFs calculated from Conley et al. (2009) for mayflies (combined mean 2.2) are very similar to the average TTF of 2.8 derived here for larvae of aquatic insects in general (Table 3).

Such conclusions are consistent with the strong correspondence between model-predicted Se concentrations for a specific environment and independent determinations of bioaccumulated Se concentrations in the same species from that environment (Figures 3 and 4). The approximately 2-fold or lower difference between predictions and independent observations for individual species of invertebrates or fish 1) is similar to the degree of uncertainty found with biodynamic modeling of a variety of metals and metalloids (including Se) in earlier studies (Luoma and Rainbow 2005) and 2) is given by Landrum et al. (1992) as sufficient accuracy to define a useful relationship within aquatic modeling. Much greater uncertainties are found in the conventional BAF approaches to modeling Se bioaccumulation at least because they are not typically species, food web, or habitat specific. The 38-fold variability in TTFs observed among invertebrate species illustrates one reason for the poorer performance of the conventional approaches than the present model. The mechanistic reasons for the similarities within taxa and the differences among some taxa are not fully known and deserve further investigation.

The relatively low uncertainty in TTFs and the validation comparisons at least partially result from recognition that such values are species specific, require the appropriate predator–prey match-ups, and should be made within the same or similar environments. The methodology recognizes that modeling of Se partitioning from the dissolved phase into the particulate material phase (transformation) and Se distribution among particulate phases (bioavailability) must mimic adequately the conditions typical of an environmental site to yield results that can be widely extrapolated to nature. Thus, if particulate Se concentrations are known for an environment and trophic transfer pathways are carefully chosen to match nature, then predictions of Se bioaccumulation can be expected that are within an acceptable uncertainty for toxicokinetic modeling (Landrum et al. 1992). Similarly, if tissue concentrations in a fish predator are known, reasonable predictions of the particulate-material Se concentrations in that environment should be feasible (recognizing the caveats described above in defining particulate material).

The concentration dependence of TTFs, as a source of uncertainty, remains largely unstudied. However, the large database of TTFs reported here was derived from a variety of habitats with different degrees of contamination, so this limitation may not normally be of concern for model application except at the extremes of possible system status for Se. Uncontaminated situations and their inhabitants are underreported in our compilation and, as noted above, elevation of TTFs in uncontaminated circumstances might be expected if Se is physiologically regulated at low environmental concentrations. Hence, further direct investigation of this premise is needed to be able to apply the model with certainty across the full spectrum of investigated sites and predators. Use of TTFs and K_ds developed from studies of only systems that fall into the same order-of-magnitude range of Se contamination as the one that someone wants to model may further mitigate this uncertainty.

The greatest potential for variability in predictions and forecasts is the choice of a factor to describe transformation of Se from dissolved to particulate phase (K_d). Representing a hydrologic system in terms of the dynamics of transformation is complex. Geochemical models (equilibrium-based) cannot describe transformation outcomes well because transformation processes are biogeochemically driven. Meseck and Cutter (2006) incorporated hydrodynamic processes, redistribution from sediment to the water column, and the influence of primary productivity in describing the fate and speciation of Se in San Francisco Bay. However, the complexity of this type of modeling, uncertainties about boundary conditions, and lack of consideration of multi-faceted but influential aspects of hydrodynamics limit the applications of such models to date and the questions even such admirable efforts can address. For the present model, we chose a more parsimonious approach, relying on empirical knowledge of the site or watershed to limit uncertainties. Collection of sets of well-matched samples for analysis of dissolved and particulate Se concentrations can document variability within an ecosystem, especially if hydrologic characteristics and speciation are taken into account in the interpretation. For example, data collection that divides modeling efforts into subareas and temporal cycles of rainfall or flow might be employed to reduce uncertainties, even without complex modeling. It is also possible to illustrate potential variability by computing predictions using alternative choices of K_d bracketed by the variability empirically observed in the environment of choice. The database of K_ds derived here from matched data sets shows less variability within broad categories of aquatic systems (lotic, lentic, estuaries) than across the entire data set. Information on speciation may also be another way to constrain the choice of K_d in the absence of empirical data (see above under *Partitioning and transformation environments*). However, the database of K_ds suggests that uncertainties in the transformation coefficient could range from 2-fold to 10-fold in the absence of local data.

The methodology here uses partitioning and food web scenarios to combine variables and illustrate uncertainty. For example, under conditions of an assumed global TTF_{fish} of 1.1 and a backwater K_d of 350 (Figure 6B), a high degree of certainty exists that fish eating an exclusive diet of amphipods will require a less stringent water-column Se concentration (14 μg/L) than if fish are exclusively eating aquatic insects (5 μg/L), given the magnitude of the difference in trophic transfer at the prey level (0.9 vs. 2.8). If a K_d of 500 were chosen for the example, the allowable water-column Se concentrations would be 10 μg/L and 3.2 μg/L, respectively. The exact number may differ in these examples, but the tenets remain unchanged.

A requirement to measure dissolved-phase Se concentrations rather than total water-column Se concentrations would rectify the geochemical inaccuracy of including a suspended-particulate-material Se fraction in a dissolved-phase modeling parameter. Further development of methods for differentiation of particulate material type and for dissolved and particulate speciation is also important to improving the accuracy of this final step in translation.

Quantitative modeling does produce quantitative outcomes, leading to the potential for overexpectations from a model. Given the uncertainties described above, the present model is more suitable for illustrating the implications of different choices of, for example, a site-specific water quality guideline for Se than it is for choosing any specific number for that guideline, but realistically the outcomes of guideline development depend on decisions in addition to mathematical ones. Policy choices based on what scenario or food web the regulator wishes to manage toward are also important decision points. Additional detailed analysis of ecological and hydrological variations for the site (i.e., site-specific conceptualization) could address uncertainty within mathematical choices or ranges but at a level of reasoning different from mathematics (Table 1). For example, 1) clearly defining food webs in conceptual models of fauna and their feeding relationships from empirical knowledge of the investigated site can identify details of species-specific exposure, 2) life cycles of habitat species can be displayed on a yearly basis to identify details of spatial and temporal exposure, 3) identifying feeding areas for wildlife can help determine what percentage of diet comes from the polluted site, 4) dissolved- and particulate-material Se speciation can be related to hydrologic conditions (e.g., high- or low-flow season or residence time), and 5) bioaccumulation dynamics can be related to particulate material characterization. As development of Se protection proceeds, a compilation of site-specific derivations of water-column Se concentrations from diverse sites and their validation through monitoring could ultimately address the sufficiency of data requirements for ecosystem-scale modeling.

Further work is needed to expand the database available for use in quantitative models. Continued work on quantitatively modeling transformation from dissolved to particulate Se under different circumstances is essential. More data are needed on physiological TTFs for invertebrates, fish, and bird species derived from kinetic experiments. Comparisons are also needed for experimental vs. field-derived TTFs (with the latter derived from matched data sets across different field sites). Few biodynamic studies are available for different fish species, so determining the range of TTFs from experimental studies would further assess the importance of the role of fish physiology in understanding food webs. Biodynamic kinetic studies are not available for avian species, and data available for derivation of TTF for different bird species in different dietary settings are limited, so further experiments to develop egg–diet relationships are needed with particular attention to mimicking the bioavailability of a diet found in nature. Inclusion of a database of factors for translation to fish ovary Se concentrations would be an important addition to allow connection of modeling of fish directly to reproductive effects. Developing TTFs specific to the dietary exposure concentration being modeled would require systematic experimental studies of common food web species to generate a set of generalized TTF equations as a function of dietary Se.

In the end, if we are to protect ecosystems with defensible assessment procedures, then the only choice is to incorporate the complexity of multiple route exposures, whatever the challenges. Thus, ecosystem-scale modeling offers a major step forward in terms of confronting and defining uncertainty by formalizing the knowledge necessary to understand the basis of protective criteria for Se. This formalization of knowledge, including choices used to initiate or limit modeling scenarios, thus clearly documents pathways that connect dissolved and tissue Se concentrations and provides a record of supporting data throughout decision-making phases.

Complementary approach: Wildlife criteria

A wildlife criterion (sometimes referred to as a wildlife value or tissue residue guideline, TRG) is the dietary concentration of an element necessary to keep the daily ingested amount of a contaminant at or below a level at which no adverse effects are expected (USEPA 1989; Sample et al. 1996; CCME 1999; USFWS 2003). The use of dietary toxicity testing is one common link with the ecosystem-scale approach. In regulatory terminology, a wildlife criterion is analogous to a tissue residue concentration (TRC) for human health criterion. A common focus for these types of criteria is consumption of fish either by wildlife or by humans (USEPA 2001). The steps for deriving this type of wildlife criterion and applying it in modeling are shown in Table 6 and discussed further in the Supplemental Data. This approach to deriving a wildlife criterion uses body weight (BW, kg wet weight), food ingestion rate (IR, g food/d), and a reference dose (RfD, $\mu g \cdot kg^{-1} d^{-1}$) determined by dietary toxicity testing (Nagy 1987; USEPA 1993; Sample et al. 1996). In effect, the wildlife criterion converts an RfD into a species-specific allowable dietary uptake rate, if 100% assimilation efficiency is assumed, or into an allowable Se concentration in food for each species. In modeling here for birds, an Se wildlife criterion is referred to as an allowable C_{food} (µg/g) and is defined by the equation

$$\text{allowable } C_{food} = (\text{RfD})(\text{BW}) \div \text{IR}. \tag{40}$$

An allowable Se dose, or exposure rate, is defined by the equation

$$\text{allowable dose} = (\text{RfD})(\text{BW}). \tag{41}$$

An allowable Se concentration in food for predators (i.e., wildlife criterion) can be written in terms of allowable dose as

$$\text{allowable } C_{food} = \text{dose} \div \text{IR}. \tag{42}$$

If a Se RfD is assumed for modeling of effects to birds, then an allowable C_{food} for various species of birds can be calculated (see Supplemental Data). For watershed evaluation, the allowable C_{food} is used as a dietary target and compared with 1) existing Se concentrations in dietary items in biologically appropriate food webs, or 2) predicted concentrations as a result of food web modeling. Equations can be added to consider mixtures of food (Table 6).

The wildlife criteria approach and the ecosystem-scale approach could easily be combined by adding values for assimilation efficiency and considering K_d, for example, in the translation to dissolved Se. Validation would be important; uncertainties in the relationship of body weight and ingestion rate, for example, would have to considered, but the combination might be helpful in assessing a watershed in terms of threatened and endangered avian species. A list of species can be developed, wildlife criteria calculated, and species-specific dietary guidelines applied in modeling (USFWS 2003). Steps such as this in the methodology could also serve to harmonize regulation, a goal long sought in obtaining consensus and understanding (Reiley et al. 2003).

Table 6. Steps in Wildlife Value derivation (aquatic birds) and dietary application (invertebrate or fish diet for aquatic birds) for ecosystem-scale Se methodology

Wildlife Value and Dietary Modeling (acquatic bird example)
Develop a conceptual model of food webs in watershed
Choose avian RfD, endpoint, and uncertainty factor · RfD = NOEC or LOEC ÷ uncertainty factor
Choose bird species
Choose body weight and ingestion rate for selected bird species
Calculate allowable concentration in food of selected bird species (i.e., allowable Se C_{food} or species-specific RfD or Wildlife Value) · Wildlife Value = (RfD)(BW) ÷ IR
Identify species-specific diet
Choose dietary items
1. Compare to available food in ecosystem
2. Compare to predicted Se concentrations in invertebrate diet for aquatic birds
Identify food web(s)
Solve equation(s) for dietary Se concentration in invertebrates
If single invertebrate species diet and known particulate Se concentration or K_d and C_{water} · $C_{invertebrate} = (TTF_{invertebrate})(C_{particulate})$ or $C_{invertebrate} = (TTF_{invertebrate})(K_d)(C_{water})$
If sequential bioaccumulation in longer food webs contributes to diet · $C_{invertebrate\ b} = (C_{particulate})(TTF_{invertebrate\ a})(TTF_{invertebrate\ b})$
3. Compare to predicted Se concentrations in fish diet for aquatic birds
Identify food web(s)
Solve equation(s) for dietary Se concentration in fish
If a single invertebrate species and known particulate Se concentration or K_d and C_{water} · $C_{fish} = (TTF_{invertebrate})(C_{particulate})(TTF_{fish})$
If several invertebrate species contribute to diet · $C_{fish} = TTF_{fish}\ (C_{particulate})[(TTF_{invertebrate\ a})$ (prey fraction)] + [$(TTF_{invertebrate\ b})$ (prey fraction)] + [$(TTF_{invertebrate\ c})$ (prey fraction)]
If assume sequential bioaccumulation in longer food webs contribute to diet · $C_{fish} = (C_{particulate})(TTF_{TL2\ invertebrate})(TTF_{TL3\ invertebrate})(TTF_{TL3\ fish})(TTF_{TL4\ fish})$

NOEC = no observable effect level; LOEC = lowest observable effect level.

CONCLUSIONS

Consideration of each step in the sequence that links environmental Se concentrations to Se toxicity is fundamental to deriving effective Se criteria or guidelines for the protection of aquatic life and aquatic-dependent wildlife (Figures 1 and 2). Ecosystem-scale Se modeling provides a context for establishing these linkages and a set of model parameters for common food webs that can be used to predict species-specific responses. A high degree of correlation ($r^2 = 0.9$) is shown between observed bioaccumulation in invertebrates and fish from 29 field locations and bioaccumulation predicted based on particulate-material Se concentration and our compiled TTFs (Figures 3 and 4). This model validation illustrates how variability in food webs result in widely different Se concentrations in different predators in a contaminated ecosystem, but those differences can be explained and quantified using this relatively simple protocol.

The validation also establishes the adequacy of the type of knowledge compiled to represent a specific occurrence of Se.

Analysis from the model shows that 1) a crucial factor ultimately defining Se toxicity is the link between dissolved and particulate phases at the base of the food web (i.e., K_d); 2) collection of particulate material phases and analysis of their Se concentrations are key to representing the dynamics of the system; 3) bioaccumulation in invertebrates is a major source of variability in Se exposure of predators within an ecosystem, although that variability can be explained by invertebrate physiology (i.e., $TTF_{invertebrate}$; Figure 5); 4) TTF_{fish} is relatively constant across all species considered here; and 5) Se concentrations are at least conserved and usually magnified at every step in a food web (Figure 6).

Application of the model to habitat-specific and species-specific exposure scenarios illustrates how, if a desired Se concentration is chosen to protect predators, allowable dissolved Se concentrations will vary among sites depending on how phase transformation and food webs are linked (Figure 6). Much of the controversy about a proper dissolved Se guideline for regulating the chemical, therefore, stems from unavoidable biogeochemical and food web differences within and among environments. The mechanistic aspects of the model and the flexibility of model components in terms of portraying the realities of exposure in nature all increase the reliability of model predictions over traditional approaches that tie water-column concentrations directly to tissue concentrations. Details of hydrology and ecology added to modeling through conceptualization of seasonal hydrologic cycles, food webs, life cycles of predators, and feeding possibilities create several levels of confidence in model outcomes based on mathematics and realistic ecology. Thus, the model can confront complexity to account directly for critical sources of variability and uncertainty in assessing Se effects. The model can run either backward or forward to verify choices and develop scenarios based on knowledge of food webs, hydrology, or proposed management.

The methodology also shows the need for a better understanding of the aspects of ecosystems, such as water residence time and dissolved and particulate speciation, that contribute to the environmental partitioning and bioavailability of Se. In lieu of this, determining Se concentrations in the suspended particulate material phase is the preferred measure of the complex water, sediment, and particulate milieu that forms the base of the food web and is consumed as food by invertebrates. Monitoring invertebrate Se concentrations in food webs that are the most likely to be heavily contaminated may be a practical initial step in a monitoring plan, because the first and second most variable aspect of Se dynamics (i.e., K_d and $TTF_{invertebrate}$) are integrated into invertebrate bioaccumulation. Policy choices such as 1) the predator species to represent an ecosystem (e.g., toxicologically sensitive, ecologically vulnerable based on food web, resident or migratory, commercially or esthetically valuable) and 2) the food web to represent an ecosystem (e.g., potentially restored food webs in addition to current food webs) also serve as important initial inputs into the development of protective scenarios for a site or watershed.

Currently, within USEPA's Clean Water Act programs, aquatic life criteria and wildlife criteria are separate and are derived independently (see, e.g., USEPA 1995, 2004). The USEPA in 1989 identified the need for criteria to protect wildlife as an outgrowth of Se-induced deformities of aquatic birds at Kesterson Reservoir (USEPA 1989) but has not acted nationally to develop a wildlife Se criterion. The USEPA started considering development of a fish tissue aquatic-life criterion for Se in 1998 and proposed a national fish whole-body Se criterion of 7.9 μg/g dw to protect freshwater fish in 2004 (USEPA 1998, 2004). That criterion is now under revision. Our model can be a useful tool in determining scientifically integrated protection for both aquatic life (such as fish) and aquatic-dependent wildlife (such as waterfowl). For example, based on typical TTFs for Se, USEPA's proposed whole-body fish tissue criterion of 7.9 μg/g dw (USEPA 2004) would also allow Se concentrations in aquatic invertebrates that, when eaten by breeding waterbirds, would pose a substantively higher hazard (see, e.g., Ohlendorf 2003; EC50) for avian toxicity than the designed level of protection for fish (USEPA 2004; EC20).

Our ecosystem-scale model for Se is applicable to connecting fish and bird tissue to environmental concentrations in a rigorous way and to providing perspective when deriving site-specific or broader Se guidelines. We now have the knowledge necessary to understand the basis of protective water-quality criteria for Se for fish and birds. Species-specific diets and reference doses for wildlife can also be used to determine an allowable Se concentration in food (i.e., a wildlife criterion or value) using a few outlined supplemental steps. As we noted above, the set of choices to initiate ecosystem-scale modeling implicitly suggests that management of Se requires consideration of biology, ecology, biogeochemistry, and hydrology along with ecotoxicology. Intuitively, this seems an obvious requirement. In practice, it provides a means to move beyond the traditional objections (see, e.g., Cairns and Mount 1990) that we can never understand enough about ecology and hydrology to include them in chemical regulation.

SUPPLEMENTAL DATA

Methodology for ecosystem-scale modeling of selenium: Data and references.

Supplemental Data Table A. Water-column Se concentrations, particulate Se concentrations (dw), and calculated K_ds from field studies.

Supplemental Data Table B. Experimental data for invertebrate physiological parameters and calculated kinetic TTFs for invertebrates (particulate to invertebrate in dw).

Supplemental Data Table C. Calculated TTFs from field studies for invertebrates (particulate to invertebrate in dw).

Supplemental Data Table D. Calculated kinetic or field TTFs for fish (invertebrate to fish in dw except where noted as fish to fish in dw).

Supplemental Data Table E. Model validation for prediction of invertebrate and fish (whole-body or muscle) Se concentrations.

Supplemental Data Table F. Model validation for prediction of invertebrate and bird egg Se concentrations.

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Rancho Cordova, California 95670-6114

Re: Comments on the Draft Waste Discharge Requirements (WDR) for the Grassland Bypass Project

Dear Chairman Longley and Members of the Regional Board:

Pacific Advocates joins a broad coalition of fishing, public health, conservation, environmental justice, and tribal groups in opposing the use of the San Joaquin River and its tributaries as a de-facto drain for agricultural wastewater from the SLDMWA's Westside districts causing downstream users and the Delta Estuary to bear the burden for this pollution. The proposed WDR will not protect beneficial uses, continues to degrade water quality and does not protect the public trust values ensured under the California Constitution.

Below, we address the most critical points of disagreement and deficiencies in the proposed WDR.

The following specific comments outline our disagreements with the proposed reduced monitoring and WDR that do not enforce previously promised EIR/EIS mitigation measures, enforce the required reasonable and prudent measures of the USFWS Biological Opinion, enforce the conditions of the federal use agreements nor adopt binding conditions to ensure water quality will be protected from the pollution discharges:

1. Using the San Joaquin River as a De-Facto Drain sends the problems and costs downstream to utilities, farmers, businesses and communities who rely on a healthy ecosystem.

2. An Interim "2 Year" project to discharge selenium pollution to Mud Slough & the San Joaquin River has grown to almost 25 Years. WDR must call for measureable reductions annually with independent science reviews.

3. Admirable efforts to curb the toxicity of this Westside pollution nevertheless have failed to meet water quality standards—how long will the standards be waived and the pollution spread downstream? Monitoring in existing wetland channels and the San Joaquin River should not be reduced. At a minimum Sites H and G need to include both biological and water quality monitoring for selenium and other pollutants to meet the Clean Water Act mandate of a 4-day average water quality standard measurement protocol.

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4. Finding and funding a cost effective treatment solution has not materialized in 25 years. The proposed demonstration plant discharges need NPDES permit conditions as promised in the Environmental Assessment and discharges to land need WDR enforceable conditions to ensure protection of endangered species, fish and wildlife and public health.

5. Monitoring should not be reduced because the project has not demonstrated success.

6. Time's up—we need an exit strategy to end all the compliance extensions and protect our water quality. The San Joaquin River should not be a de-facto drain.

There is no reasonable, substantive basis for expecting success within the re-set timeframe of success. I urge the SWRCB to work with EPA and the Delta Stewardship Council to establish a clear and legally binding exit strategy from seemingly unending compliance extensions. Extensive data have been collected, but standards are not enforced. A legally binding moment of "Time's up" is what has always been missing from this project. There has been almost a quarter of a century of "promising" to meet compliance dates. A quarter century of moving the compliance date line sure looks like an open-ended license to pollute. It is true the dischargers are trying and perhaps poisoning things less, and yet downstream users and the Delta Estuary continue to bear the burden.

I appreciate the opportunity to comment.

Sincerely,

Patricia Schifferle

Patricia Schifferle
Director
Pacific Advocates[1]

Attachments: 1) Specific Comments &
2) Sierra Club, PCL, FOR, PCFFA Irrigated Lands Testimony 2011

[1] Author of State Assembly Office of Research Publications:
Leaching Fields—A Threat to Groundwater (1985)
Toxic Ponds—Antiquated Methods and Unacceptable Dangers (1984)
Is Our Water Safe to Drink Assembly Office of Research (1983)
Protecting Public Drinking Water—A Program to Combat Toxic Contamination (1983)

Using the San Joaquin River as a De-Facto Drain sends the problems and costs downstream to utilities, farmers, businesses and communities who rely on a healthy ecosystem.

It is no surprise that SLDMWA views the discharge of their agricultural wastewater—with high concentrations of selenium and other contaminants—from their drainage project area to Mud Slough and the San Joaquin River, and ultimately the Delta Estuary and San Francisco Bay, as a good project. They argue that collecting this wastewater and discharging it into the San Luis Drain and then to Mud Slough and San Joaquin River provides benefits to wetland channels and Salt Slough. Indeed it does—by transferring the contamination to Mud Slough and then the River. It also provides significant benefits to them—they are able to send their wastewater downstream, in essence passing the costs on to others and potentially damaging the Estuary's ecological resources.

The Drainers and SLDMWA are correct that shifting the pollution from the wetlands and Salt Slough to Mud Slough has resulted in improvements to the wetland water supply channels and Salt Slough[2], their maps show that this toxic drainage flows next to and through wetland areas, including National and State Wildlife Refuges. This direct discharge of wastewater started in 1987 when the Bureau built a connection from the terminus of the San Luis Drain to Mud Slough in order to discharge to the San Joaquin River.[3] See Figures 2-3 in the attached testimony of the Sierra Club, Planning and Conservation League, Pacific Coast Federation of Fishermen's Association and Friends of the River (Attachment 1: Irrigated Lands Testimony). Waterfowl swimming and feeding in wastewater adjacent to wetland areas do not know that the wastewater is toxic.

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[2] *"Mud Slough (North) is one of the major west-side tributaries of the San Joaquin River, and also conveys drainage water from the Grasslands Drainage Area to the San Joaquin River. Flows are highly variable throughout the year, ranging from high flow during the wet season and during periods of wetland releases to very low flow during the summer and early fall. Agricultural drainage from the selenium-affected area of the Grasslands Basin, conveyed through San Luis Drain, is discharged into Mud Slough at a point about 6 miles upstream from the slough's confluence with the San Joaquin River. Flow in Mud Slough upstream from this discharge point consists of wetland releases from Grasslands Water District and Volta Wildlife Management Area, operational spills from the Delta-Mendota Canal and the Central California Irrigation District Main Canal, and storm water runoff from Los Banos Creek. Mud Slough downstream from the San Luis Drain discharge point is often dominated by water originating from the Grasslands Drainage Area. Flow from San Luis Drain accounts for 20 to 40 percent of the annual flow in Mud Slough (North)."* [pg 30 of PDF]
http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/vernalis_salt_boron/usbr_west_wtrbdgt_meth_draft.pdf

[3] See State Water Resources Control Board Order # 87-201 and NPDES CA 0082171.

Photos document the concerns about discharging agricultural drainage contaminated with selenium, boron, and salt into Mud Slough and the San Joaquin River—the side channels, seasonally flooded areas and wetland areas along Mud Slough, the San Joaquin River—and ultimately to the Delta Estuary.[4] There is fundamental disagreement over the potential impacts of transporting this concentrated drainage through conveyance channels, the Slough, and the River, next to wetland areas, and through State and Federal wildlife refuges. The waterfowl and fish still forage in and use these waters, as seen in photos. [5]

EPA testified to the Stewardship Council on February 2, 2011, regarding the need to review the role played by selenium contamination and the role that Westside irrigators play in using the San Joaquin River and tributaries as a wasteway and the resultant loading to the Delta Estuary and Suisun Bay.[6] Water Board staff have also confirmed the primary source of selenium in the Lower San Joaquin River Basin and the Grasslands Watershed is from the drainage project area.[7] Although portions of the Lower San Joaquin River were removed from the TMDL list for selenium, the portion between the SLDMWA discharge and Crows Landing is still listed as impaired, along with areas within the Grasslands Watershed Basin.

An interim "2 year" project to discharge selenium pollution to Mud Slough & the San Joaquin River has grown to almost 25 years.

[4] The dischargers suggest in their response that references for the downstream impacts of these levels of selenium are not available or misinterpreted. The literature by government scientists is clear: "*Selenium concentrations in agricultural drainwater from this area reach levels that, when bioaccumulated through food chains, cause adverse effects on aquatic and aquatic-dependent wildlife. Where such drainwater is applied to uplands, as in reuse areas, strictly terrestrial wildlife may be impacted as well……Downstream from the San Luis Unit, any drainwater from the Project area is diluted by relatively low-selenium water from rivers that drain the Sierra Nevada Mountains. However, as the San Joaquin River reaches the San Francisco Bay/Delta estuary, flow velocities decrease and salinity increases. In these slow-moving, saline waters, with abundant introduced filter-feeding invertebrates, ecosystems have developed that evidently are much more effective than riverine ecosystems at bioconcentrating water-borne selenium. Therefore, potential downstream effects must be considered." Pg 2-4.*
http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/Beckon_and_Maurer_Effects_of_Se_on_Listed_Species_SLD_2008.pdf

[5] http://www2.epa.gov/sites/production/files/documents/epa-r09-ow-2010-0976-0053-1.pdf

[6] http://pubs.usgs.gov/fs/2004/3091/
http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/san_joaquin_se/se_tmdl_rpt.pdf
http://www.cal-span.org/cgi-bin/archive.php?owner=DSC&date=2011-02-24
http://pubs.usgs.gov/pp/p1646/pdf/pp1646.pdf
http://wwwrcamnl.wr.usgs.gov/tracel/people/robin_stewart.html

[7] http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/san_joaquin_se/se_tmdl_rpt.pdf

Originally this use of the San Luis Drain was an "interim" project to last only 2, possibly 5 years.[8] Then it was extended for an additional ten years to December 2009, when the discharger—SLDMWA—promised to have a treatment method in place to eliminate the need to discharge into Mud Slough and the San Joaquin River.[9] The Basin Plan Amendment approved in 1998 required that the SLDMWA would meet federal water quality standards, and federal aquatic standards to protect waterfowl, fish and aquatic ecosystems in Mud Slough (North) and the San Joaquin River (upstream of the Merced River) in all water-year types after October 2010. As you know, on October 5, 2010, another extension of the Grassland Bypass Project was granted for approximately another decade, providing an extension of the exemption from complying with water quality objectives in Mud Slough (North) and the San Joaquin River. Thus, the project and the contaminated discharges could continue for almost a quarter century. It is true the SLDMWA and its members are trying to comply and trying to meet federal water quality standards for Mud Slough and portions of the San Joaquin River. It is equally true, as they state, that they do meet the federal water quality standards in the river downstream from the Merced River, thanks to dilution of the selenium and other contaminants with those flows. It is also true, however, that their wastewater discharges cause concentrations to exceed water quality standards in the San Joaquin River from Mud Slough to the Merced River. Good intentions, as this situation demonstrates, do not necessarily result in compliance and protection of the public's water resources.

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[8] First Use Agreement: # 6-07-20-w1319, November 1995. "*The original Use Agreement, dated November 3, 1995, allowed the Authority to use a portion of the San Luis Drain (the Drain) to convey agricultural drain water through adjacent wildlife management areas to Mud Slough, tributary to the San Joaquin River…. The 1995 Use Agreement and its extension in 1999 allowed for use of the Drain for a 5-year period that concludes September 30, 2001.*" http://www.usbr.gov/mp/grassland/documents/eis_eir_rpt_overview.pdf pg 2.

[9] NPDES # CA 0082171 Order # 87-201 (USBR connects San Luis Drain to Mud Slough and San Joaquin River. Discharge of Agricultural Wastewater. December 1987.

·NPDES # CA0082368 Order # 90-027 (USBR Discharge of Agricultural Wastewater and Selenium Contaminated water in SLD to Mud Slough and San Joaquin River. March 1996.

·NPDES #CA0083917 (USBR and SLDMWA discharge of Selenium Contaminated Groundwater & Subsurface Drainage to Mud Slough and San Joaquin River) (SLDMWA notifies Board of completion April 23, 1996 also "blending of agricultural subsurface drain water with the accumulated groundwater." March 1996.

·Basin Plan Amendment #96-147-Prohibits Subsurface Drainage Discharges in the San Joaquin Basin with exceptions. SWRCB # 96-078; September 19, 1996. EPA May 24, 2000.

·Order # 98-171, (USBR & SLDMWA discharge of agricultural wastewater to San Joaquin River via SLD and Mud Slough), July 1998.

·Order # 5-01-234, (USBR & SLDMWA extended compliance waiver to allow discharge of agricultural wastewater to San Joaquin River via SLD and Mud Slough), September 2001.

·Basin Plan Amendment No R5-2010-0046 waives compliance for selenium as specified. 5-27-2010 & SWRCB # 2010-0046, October 5, 2010.

Admirable efforts to curb the toxicity of this Westside pollution nevertheless have failed to meet water quality standards—how long will the standards be waived and the pollution spread downstream?

It is true that the selenium levels measured in the San Joaquin River at Crows Landing, after dilution from the Merced River, are in compliance with the Clean Water Act standard of 5 ppb. It is equally true, however, that the 5 ppb standard is exceeded in the San Joaquin River between Mud Slough and the Merced River. (See Sierra Club et.al. Figure 5, Irrigated Lands Testimony). For these water bodies SLDMWA has consistently failed to keep promises made to meet protective standards.[10]

In addition, since 1995 and after the first use agreement, there have been promises to dispose of the sediments in the San Luis Drain. SLDMWA provides a useful clarification that these sediments will be disposed of on agricultural lands rather than housing or industrial sites. These sediments, which measured some 58,000 cubic yards at the start of the project and now have grown to more than 200,000 cubic yards, are a reservoir of selenium that needs to be disposed of where it will not pose a threat to wildlife or water or it needs to be sent to a proper disposal site in a responsible manner. Certainly that appears to be the intent of the SLDMWA. For more than a decade, they have declared this intent in the various use agreements. My point is simply that waste discharge requirements would be an important step to ensure the safe disposal of these selenium tainted sediments that all are in favor of ensuring. Further delay risks these sediments and contaminants being discharged to the river. The WDR must set a timetable and enforcement mechanism to dispose of this toxic selenium safely without discharges to land that would merely perpetuate or spread the toxic problems.

Finding and funding a cost effective treatment solution has not materialized in 25 years.

Finding a long term solution to this complex problem is critically important. As yet a treatment option that is economically and technically viable has not been determined nor has the funding been identified. Everyone is hopeful that federal funding and some cost-effective

[10] *"Based on a review of the available scientific literature, the Regional Board determined that a 2 ppb monthly mean selenium objective would be protection of waterfowl (CRWQCB, Central Valley Region 1996; pg. 61). Consideration was given to translating the selenium water quality objective into a load limit, but water quality data collected in Salt Slough in the late 1980's through early 1990's showed little change in concentration even in response to significant load reductions. (CRWQCB, Central Valley Region; 1995 pp. 5-7)" http://www.waterboards.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/salt_slough_se/salt_slough_se_tmdl.pdf*

treatment option can be found in order to stop the discharge of selenium and other contaminants into the San Joaquin River and the Delta Estuary. The disagreement is over the enforcement of water-quality standards. We believe the law should be enforced. Further, the pollution should not be transferred to other downstream users and ecological resources while waiting for some treatment process that has yet to materialize after more than 20 years. The WDR must set a time line with strict enforcement limits for the continued import of water to irrigate of these toxic soils in the event that the treatment promises are a mirage.

State or federal funds have been a 'promise' of the project now for some time. Some grants and funds have been provided, but no economically successful treatment method has been found. It is great that SLDMWA is working to obtain those funds. As SLDMWA points out, it is equally true that the funding for redirection of the unregulated sumps discharging selenium into the Delta Mendota Canal, the increased monitoring costs, and the federal funding for yet to be determined In-Valley treatment solutions, are pending and not secured. On April 1, 2011, the Declaration of Donald Glaser, Regional Director, Mid-Pacific Region United States Department of the Interior, Bureau of Reclamation indicated that the Bureau is still operating under a series of continuing resolutions or temporary spending measures. Moreover, all of this funding is subject to Congressional appropriation, which is not a reliable assumption in this day and age.

The essential point, which is confirmed by SLDMWA, is that funding at the federal and State levels is not guaranteed either for sufficient monitoring or for a treatment technology that is reliable and cost-effective. The WDR must enforce the USBR Use Agreement Conditions that required SLDMWA and the Grassland Drainers to fund all monitoring for the continued discharge of pollutants to the waters of the state and nation. Failure to monitor adequately will merely mask the pollution impacts and delay enforcement action needed to protect beneficial uses.

Monitoring should not be reduced because the project has not demonstrated success.

The latest draft monitoring plan proposes reductions in the extent of monitoring (Draft for the Technical Data Team the "Draft Monitoring Program for the Grassland Bypass Project January 1, 2010-December 31, 2019."). Although not yet adopted, you can see from the proposed monitoring program that there are numerous changes and reductions contemplated. For example, Sites H on the San Joaquin River downstream of the toxic discharge to the River has been dropped completely. Equally wetland monitoring sites L2 and M2 where Selenium pollution is found regularly to exceed safe levels are also dropped. The Clean Water Act requires a total "daily" maximum load measurement or assessment of concentrations measured across a 4 day average. Dropping sites or failing to obtain sufficient samples to calculate the 4 day average makes compliance with concentration measurements and reliable loads improbable. The frequency and sites on the San Joaquin River from the discharge to the Merced River are slated to be reduced or eliminated. As USGS has pointed out on numerous occasions regarding the inadequacy of the monitoring to assess the full impacts to biological resources, the river and bioaccumlative impacts in the ecosystem and Delta Estuary.[11] Also, it appears that key biological monitoring would not be collected consistently to assess the cumulative impacts from this discharge of selenium into the river and estuary.[12] The WDR should at a minimum require a reinstatement of the 2001 Grassland Bypass Project Monitoring Program and should consider further the promises made by USBR for the selenium fate and ground water monitoring in the 1998 EIR/EIS and 1999 Use Agreement. Monitoring should not be reduced.

The SLDMWA and the Grassland Drainers recognize that storm water and unregulated flows do enter into the wetland channels. We agree. We disagree, however, over the potential impacts and control of these unregulated discharges. In 2000, the Regional Water Quality Control Board Staff Report confirmed that discharges from unregulated sumps, ground water, and flood events cause the wetland channels within the project to be subject to elevated levels of selenium above the federal aquatic life protective standard.[13] Municipal storm water comingled with irrigated drainage is also discharged from the City of Los Banos.[14] USFWS also raised objections to unregulated discharges of selenium to the wetland supply channels in November 2002. [15] These impacts are further confirmed in the USFWS scoping comments for the extension

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[11] See http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/Presser_etal_GBP_monitoring_plan_1996.pdf Theresa S. Presser Memorandum to Michael Delamore and Joseph McGahan. Subject Comments on Draft EIS/EIR for the nine year renewal of the Grassland Bypass Project. February 26, 2001.

[12] Toxicity response curves for sensitive species of fish and birds are extremely steep. This means there is almost no room for error once toxicity thresholds are crossed; once the threshold is crossed increasing food chain Se concentrations by just one or two parts per million can mean the difference between a relatively low level effect (10% embryo toxicity) and a catastrophic effect (90% embryo toxicity). As demonstrated by researchers from UC Davis working in the Sierra Nevada on a selenium fertilization project, aquatic food chains are sometimes more sensitive to the short-term peak pulse of Se that moves through a system than to longer-term "average" exposure. This work was published in: Maier, K.J., C.R. Nelson, F.C. Bailey, S.J. Klaine, and A.W. Knight. 1998. "Accumulation of selenium by the aquatic biota of a watershed treated with seleniferous fertilizer." Bulletin of Environmental Contamination and Toxicology, 60:409-416. This environmental behavior of selenium was noted in the first comprehensive review of the environmental toxicology of selenium by Professor Charles Wilber 30 years ago and led him to write... "Toxicologists especially should be sensitive to the biology of extremes as being more realistic than is the biology of means." Wilber, C.G. 1980. "Toxicology of selenium: a review." Clinical Toxicology, 17:171-230.

Also See http://menlocampus.wr.usgs.gov/50years/accomplishments/agriculture.html

[13] http://www.swrcb.ca.gov/rwqcb5/water_issues/water_quality_studies/2ppbrpt.pdf
Also See: http://www.swrcb.ca.gov/rwqcb5/water_issues/water_quality_studies/sjr9900.pdf

[14] See: CCID Agreement with the City of Los Banos11-11-87 and new agreement May 4, 2005, allowing municipal storm water discharges comingled with agricultural drainage to be discharged into wetland channels and Mud Slough for 25 years.

[15] Ibid. USFWS at 7 and See http://www.swrcb.ca.gov/rwqcb5/water_issues/grassland_bypass/usfws_att_c.pdf

of discharge for almost another decade.[16] Without adequate monitoring, the sources and biological impacts of the project will remain unknown. The WDR should not add to this delay. Clear controls and conditions upon this unregulated discharge should be included. The man made conduit connecting the San Luis Drain to Mud Slough and the San Joaquin River promised these protections in the original project. These promises are decades old and need to be enforced and regulated.

All monitoring reports and biological data should be readily available to the public. Monitoring discharges of polluted drainage water to "treatment areas" are akin to a selenium sink and need careful monitoring and disclosure to ensure compliance with state and federal endangered species laws and the federal Migratory Bird Treaty Act. The discussion of monitoring biological conditions and photographic data on impacts on wildlife and waterfowl is important to the scientific record. These are important public records to retain and must be made available to the scientific community to further our understanding of the project.[17]

> *.....Part of Monitoring and Reporting Program No. SJR027 has demonstrated that, at least on an annual basis, discharges from one of the Firebaugh sumps has exceeded hazardous waste levels for selenium. Further, discharge of agricultural subsurface drainage water to the DMC (source waters of the Grassland wetland supply channels) continues even though exceedances of water quality objectives in the Grassland wetland supply channels are occurring. We concur with the CVRWQCB's previous finding (Pierson et a], 1987) that these discharges are a management problem capable of control.....*
> *The issue of selenium contamination in the DMC was discussed in the Grasslands Bypass Project Biological Opinion (Service File No., 1 - 1-0 1 -F-0 153), a copy of which was sent to both the CVRWQCB and SWRCB. The Service also provided both Boards with a copy of a memo from the Service to Reclamation on the Water Quality Monitoring Program for the Delta Mendota Canal dated July 11, 2002, (Service File No., 1-1-02-1-1880). In this memo, the Service recommended that Reclamation include more intensive sampling of DMC waters just upstream and downstream of the Firebaugh sumps, and systematic, direct sampling of discharges from the Firebaugh sumps. The Service stated that relative to selenium contamination in the DMC, "Past data are adequate to justify implementing preventative measure(s) now."*

http://www.swrcb.ca.gov/rwqcb5/water_issues/grassland_bypass/usfws_att_c.pdf

[16]http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/san_luis_articles/USFWS_CEQA_Scoping_Comments_CVRWQCB_GBP_Extension_3-19-09.pdf

[17] See: Theresa S. Presser to Michael Delamore, USBR and Joe McGahan, *Comments on Draft EIS/EIR for the nine-year renewal of the Grassland Bypass Project.* February 26, 2001. *"Concern remains for control of loads during wet years and the overall effectiveness of planned actions because of the basin-wide nature of ground water degradation in the western San Joaquin Valley....Mitigation calls for a Sediment Management Plan. .....Among these is the fact that samples of bed sediment from the SLD contain elevated concentrations of SE that approach hazardous waste levels (100pp, wet weight)..As noted above, concern remains that long-term drainage management planning...will continue to be limited without development of information relating to groundwater conditions and to concentrations of SE in the regional system that influence SE discharges...A systematic long-term monitoring program is crucial to understanding the fate and impact of the management changes in regards to protection of ecosystems receiving SE discharges...Little is known about SE concentrations in the Delta, yet this is the system that could be most impacted by SE discharges from the San Joaquin Valley."* Pgs 4-8
Luoma and Presser, 2000. "Monitoring of vulnerable foodwebs specific to water bodies, such as the San Joaquin River ecosystem, affect by the GBP would enable site-specific measures of SE bioaccumulation."
United States Fish and Wildlife Service Comments to Central Valley RWQCB Mary 8, 2010
http://www.swrcb.ca.gov/rwqcb5/water_issues/grassland_bypass/usfws_com.pdf

Reference to "Kesterson Effects" is a term used in the scientific community to describe the particular biological impact of selenium.[18] Attached are the references for the photos of the Kesterson- like deformities found near Five Points California taken by the USFWS. The monitoring data on selenium in eggs and embryos in the Grasslands drainage reuse area document concentrations greater than those that caused deformities at Kesterson. The concentrations found in these samples are consistent with the types of effects shown in the photos and monitoring near Five Points, California.[19] The WDR reduces the biological monitoring and clearly given the anecdotal photographic evidence to date, needs to systematically test for impacts from the discharge of toxic drainage to 'treatment sites' to ensure the food chain is not becoming contaminated and undetected impacts are occurring to wildlife and migratory birds.

Time's up—we need an exit strategy to end all the compliance extensions and protect our water quality. The San Joaquin River should not be a de-facto drain.

There is no reasonable, substantive basis for expecting success within the re-set timeframe of success. The CVRWQCB needs to work with EPA and the Delta Stewardship Council to establish a clear and legally binding exit strategy from seemingly unending compliance extensions. Extensive data have been collected, but standards are not enforced. A legally binding moment of "time is up" is what has always been missing from this project. There has been almost a quarter of a century of "promising" to meet compliance dates. A quarter century of moving the compliance date line sure looks like an open-ended license to pollute. It is true the dischargers are trying and perhaps poisoning things less, and yet downstream users and the Delta Estuary continue to bear the burden.

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[18] http://menlocampus.wr.usgs.gov/50years/accomplishments/agriculture.html

[19] "San Joaquin River Water Quality Improvement Project, Phase 1 Wildlife Monitoring Report, 2008." H.T. Harvey and Associates. July 2009. Page 22. http://www.sfei.org/sites/default/files/sjrip_2008.pdf The geometric mean, egg selenium concentration in recurvirostrid eggs collected at the SJRIP Phase I area in 2008 (50.9 µg/g) exceeded all geometric mean selenium concentrations in recurvirostrid eggs collected at Kesterson Reservoir from 1983 to 1985.

See: http://www.c-win.org/content/c-win-letter-delta-stewardship-council-toxic-lands.html

April 7, 2011

Ms. Katherine Hart, Chair
Regional Water Quality Control Board, Central Valley Region
11020 Sun Center Drive, #200
Rancho Cordova, CA 95670

Re: Irrigated Lands Regulatory Program Framework Comments

Dear Chairperson Hart and Board Members:

In America we hold a value that each of us must not foul downstream water supplies with our waste, just as we expect those upstream of us to do the same. The problem is, the proposed irrigated lands program falls short of this value and falls short of enforcing laws that require our waste to not degrade our neighbors' water or create a nuisance.

Some give praise to the program governing discharges from irrigated agricultural of polluted groundwater waste from the Grasslands Watershed Basin to the San Joaquin River. Since 1995, the San Luis Delta-Mendota Water Authority (SLDMWA) and United States Bureau of Reclamation (USBR) have been discharging polluted groundwater with high levels of selenium and other contaminants using the federal San Luis Drain for discharge to the San Joaquin River at levels lethal to fish and wildlife. Dilution flows downstream of the Merced River have been the method used to meet water standards downstream. From Mud Slough down to the Merced River, because of this discharge of polluted water, the river often has concentrations that exceed Clean Water Act standards. (See Figures 3-4).

The program where dischargers consolidate and concentrate these wastes toxic to fish and waterfowl, and then discharge them under a permit with some monitoring, is considered exemplary by the polluters. But it has relied on waivers of water quality rules and dilution to meet the law. (See Figure 1) Not enforcing water quality standards has its costs. But in this case the costs are passed along to others downstream. It is a case study of how irrigating toxic soils is proceeding largely unchecked, consolidating pollution and damaging downstream uses.

Selenium is a metalloid that can be very dangerous under some circumstances. Most significantly, it bio-accumulates in the food chain, concentrating as it moves up the food chain. This is what happened to Merced County cattle ranchers Jim and Karen Claus 30 years ago when selenium-tainted drainage water leaked from ponds at the Kesterson National Wildlife Refuge. The Claus's cattle, along with that of other nearby cattle ranchers, started getting sick and dying, after consuming the tainted drainage water and eating tainted grasses.

Kesterson was ordered cleaned up and closed as a public nuisance in 1985, yet for a quarter of a century, some Westside irrigation districts have been permitted to continue draining their selenium-laced waste waters directly to the San Joaquin River where it flows to the Delta.[1]

Monitoring the impacts of this essentially unregulated drainage has been sparse.[2] Chinook fry and splittail who feed in the San Joaquin River sloughs and floodplains and intermittent flooded wetlands are exposed to lethal doses. Bottom fish along with white and green sturgeon are particularly threatened as they feed on aquatic life that collects selenium and further concentrates the impacts in these fish. Dungeness crabs were recently added to the list. The lethal deformities in waterfowl and migratory birds at Kesterson and the Tulare Basin caused by selenium have been well documented.[3]

We know the costs of spreading this contamination in sloughs, wetlands, estuaries and slow moving water is costly to clean up (if that is even possible) and if the selenium buildup and accumulation cannot be halted the consequences may be catastrophic to the downstream biosphere. And yet, we continue with a regulatory program that transfers these dangers to downstream users, both human and wildlife.[4]

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[1] USFWS November 8, 2002 Exceedances of Water Quality Objective for Grassland Wetland Supply Channels. http://www.swrcb.ca.gov/rwqcb5/water_issues/grassland_bypass/usfws_att_c.pdf & http://www.pcl.org/files/USGSDrainageMgmt.pdf pg 26.
Selenium removal from agricultural drainage from the western San Joaquin Valley is hampered by the large amounts of associated salt in any waste stream subjected to treatment. Extensive testing of technologies for removal of selenium from the water-column utilizing chemical and biological processes as part of the SJVDP achieved little operational success or cost-effectiveness (SJVDP, 1990c). Drainage treatment to remove selenium was not one of the strategies recommended by the SJDVP (1990a). In the *Preface* to the San Joaquin Valley Drainage Program final report (1990a), Edgar Imhoff, head of the program, wrote that "…*hopes for a master drain and expectations of a technological breakthrough in drainage water treatment are the reasons that the drainage problem has grown to nearly 500,000 acres and is adversely affecting the environment*."

[2]See http://www.swrcb.ca.gov/rwqcb5/water_issues/grassland_bypass/usfws_att_c.pdf

http://pubs.usgs.gov/pp/p1646/pdf/pp1646.pdf pg 26. ... "*monitoring was not sufficiently frequent to accurately characterize loads during variable flows."…annual data are not available from individual farm-field sumps to help qualify source-area shallow groundwater conditions and determine long-term variability in selenium concentrations…compliance monitoring sites are 50 and 130 miles downstream from the agricultural discharge. Pg 118-119.*

http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/Presser_etal_GBP_monitoring_plan_1996.pdf

[3] http://pubs.usgs.gov/pp/p1646/pdf/pp1646.pdf pg 2.

[4] http://pubs.usgs.gov/fs/2004/3091/ U.S. Department of the Interior U.S. Geological Survey Fact Sheet 2004-3091 August 2004

At the same time state and federal budgets are being cut.[5] The hodge podge of treatment methods to stop this discharge of selenium pollution to downstream neighbors is unlikely to succeed. Monitoring budgets are being cut. In February 2011, Central Valley Regional Water Quality staff announced they would no longer conduct monitoring for the project at 12 sites and Fish and Game representatives indicated they also would no longer conduct biological monitoring. The Bureau promises to pick up the costs and yet, the proposed draft monitoring program suggests significant cuts in both water quality and biological monitoring, despite promises to the contrary.[6] Compliance monitoring for loads is very different from monitoring for water contaminants, sediment movements and biological impacts both for aquatic and wildlife. Cutting the days, time periods and parameters *can render the analysis from the monitoring useless in terms of analyzing the impacts from the spread of this pollutant and the synergistic impacts with other contaminants.* Averages minimize the peak exposures which are often lethal and stay in the aquatic system long after the discharge recedes.[7]

Relying on load measurements is a misleading measurement for compliance with Clean Water Act standards and pollution controls.[8] For example over more than a ten-year life of the discharges from the Grasslands Watershed to the San Joaquin River from Mud Slough, U.S. Geological Survey scientists estimate a cumulative hazard of 6.6 Kestersons (ksts) as the cumulative hazard load.[9] Uncontrolled discharge of selenium-tainted groundwater and storm water exceeding protective standards is

---

" The dry years and low flow seasons will be the ecological bottleneck (the times that will drive impacts) with regard to Se. Surf scoter, greater and lesser scaup, and white sturgeon are present in the estuary during the low flow season and leave before high flows subside. Animals preparing for reproduction, or for which early life stages develop in September through March, will be vulnerable."

[5] http://www.assembly.ca.gov/acs/committee/c26/hearings/03012011/030111%20hearing%20materials%20-%20fed%20program%20cuts.pdf

http://www.nwf.org/News-and-Magazines/Media-Center/News-by-Topic/General-NWF/2011/02-22-11-House-Continuing-Resolution-Passes.aspx

http://wwwrcamnl.wr.usgs.gov/tracel/references/pdf/Estuaries_v26n4Ap956.pdf

[6] Third Supplemental Declaration of Donald R. Glaser, CV-F-88-634-OWW/DLB, CV-F-91-048-OWW/DLB, Document 865 Filed 04/-1/11 Firebaugh Canal Water District et.al. v US at page 7

[7] http://pubs.usgs.gov/pp/p1646/pdf/pp1646.pdf
http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/pollutants/selenium/fs.cfm
http://wwwrcamnl.wr.usgs.gov/Selenium/library.htm

[8] http://pubs.usgs.gov/pp/p1646/pdf/pp1646.pdf pg 18 and 152.
"The selenium loads measured as the input to the system (drainage canals) are perpetually different from those measured as the outputs from the system (downstream in wetland sloughs or the San Joaquin River)" pg 153.
[9] http://pubs.usgs.gov/pp/p1646/pdf/pp1646.pdf pg 119.

permitted in wetland areas during periods of wet weather. [10] (See Figure 2) In periods of low flows selenium concentrations increase, but loads typically go down.[11]

Under the proposed irrigated lands regulatory program upstream selenium waste water stored in ground water aquifers in the Westlands subarea will measure only electrical conductivity and elevation.[12] Previous USGS and USBR studies show vast ground water areas with selenium contamination that exceeds hazardous waste levels. (See Figure 8) There is no requirement to monitor the spread of this pollution to downstream neighbors and to the San Joaquin River where eventually it accumulates in the Delta estuary, sloughs, wetlands, and temporal floodplains. State and federal scientists predict this pollution from irrigated agriculture unless halted, will harm beneficial use.[13] Mobilization of selenium by irrigation and contamination of ground water has resulted in concentrations of groundwater greater than hazardous waste levels. (See Figure 8) This pollution violates federal (40 CFR 131.12) and state anti-degradation regulations.[14] Under worse case scenarios government scientists conclude that selenium contamination could create an ecological crisis in the Bay-Delta similar to that created at Kesterson National Wildlife Refuge in the 1980s.[15]

Scientists and water board staff estimate that more than 85% of the pollutant loads of selenium in the San Joaquin River that reach the Delta Estuary are from the west side irrigators.[16] They estimate the daily discharges of selenium to the Delta Estuary from the San Joaquin River is 10 to 30 times the combined total of selenium discharges from the combined Sacramento River sources and the Bay Area oil refineries.[17]

Selenium is also being exported to southern California's water supplies through the California Aqueduct threatening drinking water quality and likely is accumulating in fish and reservoirs in Southern California as a result.[18]

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[10] Ibid pg 17.
[11] Ibid pg 70-90.
"During the first two years of the project, loads were above load targets. It is notable that drain water discharged to the San Joaquin River through the San Luis Drain is more consistently concentrated than were historic discharges to the wetlands channels system." pg 121
[12] See proposed Waste Discharge Requirements for Westlands Water District &
Ibid. pg 25.
[13] http://pubs.usgs.gov/pp/p1646/pdf/pp1646.pdf pg 15 & 25.
http://www.pcl.org/files/USGSDrainageMgmt.pdf

[14] Ibid pg 14.

[15] Ibid. pg 18.
[16] http://esd.lbl.gov/files/about/staff/nigelquinn/comp_model.pdf
see also http://www.swrcb.ca.gov/rwqcb5/water_issues/water_quality_studies/sjr9900.pdf

[17] http://pubs.usgs.gov/of/2000/ofr00-416/#pdf ; pp 1-2.
[18] http://calitics.com/tag/Selenium Napolitano, Garamendi, et al., November 26, 2010.

Do we have enough water in California to continue to pollute it and expect dilution to meet clean water standards while clean up costs are passed on to downstream users? No. It is time to clean up the source of the pollution and enforce the law. It is time to enforce the law, including the State Board 1985 Kesterson cleanup or, WQ 85-1, which addressed San Joaquin River drainage pollution. Clean Water Act standards and state laws designed to protect water quality from unreasonable use, nuisance, and degradation need to be enforced. The proposed Irrigated Lands Regulatory program falls short of protecting water supplies and the public from contamination caused by irrigated agriculture.

Thank you for the opportunity to comment. Attached are the charts and figures referenced herein.

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Attachments Charts and Slides 1-9.

Selenium Contamination of Groundwater & Surface Waters:

A case history in the failure to enforce water quality standards

Irrigated Lands Framework
Agenda Item #7
April 7, 2011

Sierra Club California
Friends of the River
PCFFA
Planning and Conservation League

Permit History for Selenium Discharges From Grasslands Basin to Mud Slough and San Joaquin River:

A Case History in the Failure to Enforce Water Quality Standards

1987
NPDES: USBR Reopens SLD to Mud Sl and SJR

1989
EPA Disapproves SWRCB 8 ug/L Standard for SJR

1990
EPA adopts 5 ug/L standard for SJR and 2 ug/L for Wetlands

1990
NPDES: USBR GW Seepage to SLD and to Mud Sl and SJR

1995
SLDMWA Unpermitted discharge to SLD and to Mud Sl and SJR

1996
NPDES: USBR & SLDMWA GW&Subsurface Drainage to SLD and to Mud Sl and SJR

1998
State waives 5 ug/L Se Standard to allow USBR & SLDMWA Discharge to SLD and to Mud Sl and SJR

2001
State waives 5 ug/L Se Standard to allow USBR & SLDMWA Discharge to SLD and to Mud Sl and SJR

2010
State waives 5 ug/L Se Standard to allow USBR & SLDMWA Discharge to SLD and to Mud Sl and SJR

SLDMWA-San Luis Delta Mendota Water Authority
USBR- United States Bureau of Reclamation
SLD- San Luis Drain
Mud Sl-Mud Slough
SJR-San Joaquin River

Figure 1

Toxic Levels of Selenium Flowing Through:

- State & Federal Wildlife Refuges
- Wetlands
- San Joaquin River

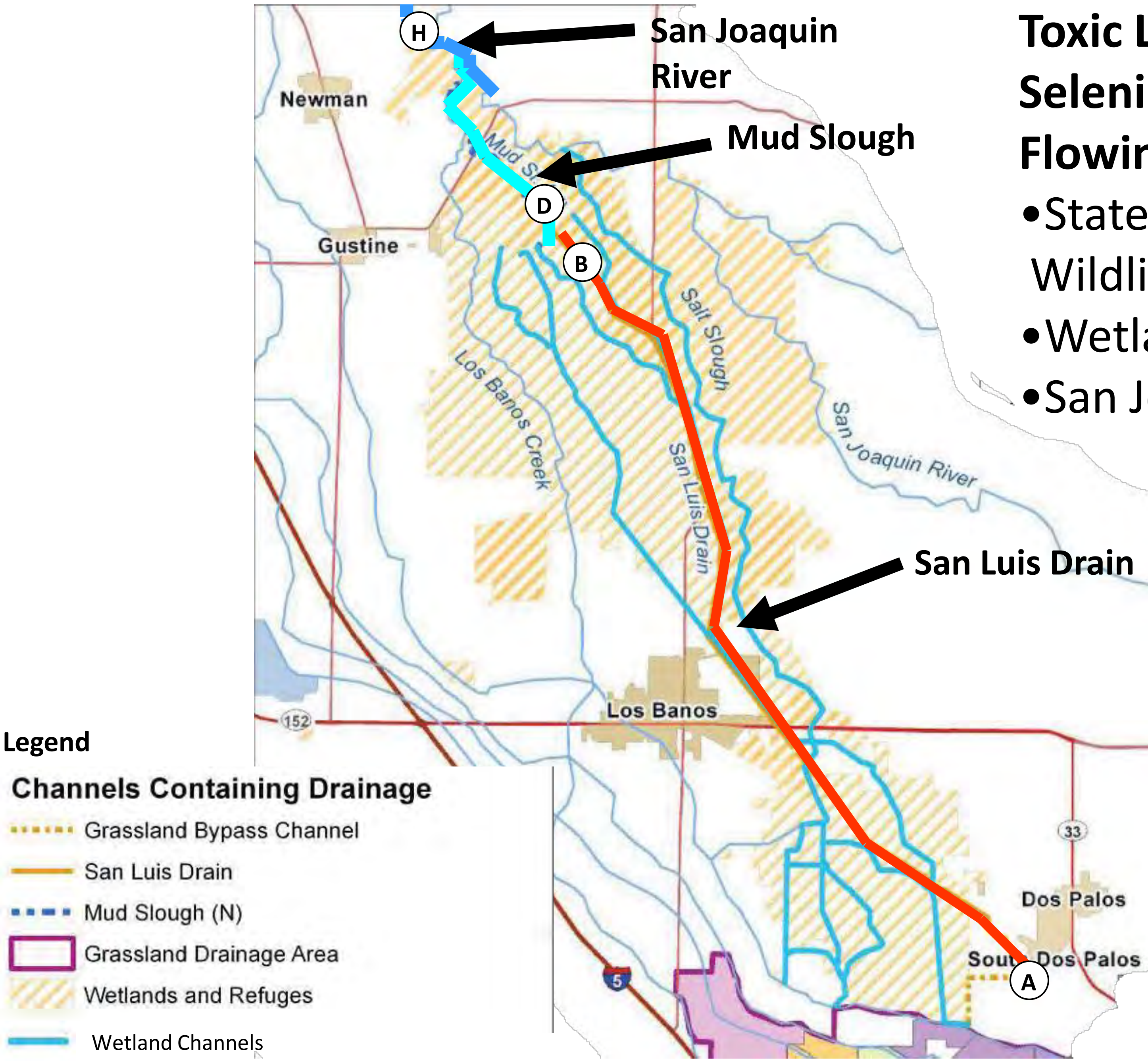


Figure 2

Lethal Concentrations of Selenium in Irrigation Drainage Discharged from the San Luis Drain (Site B)

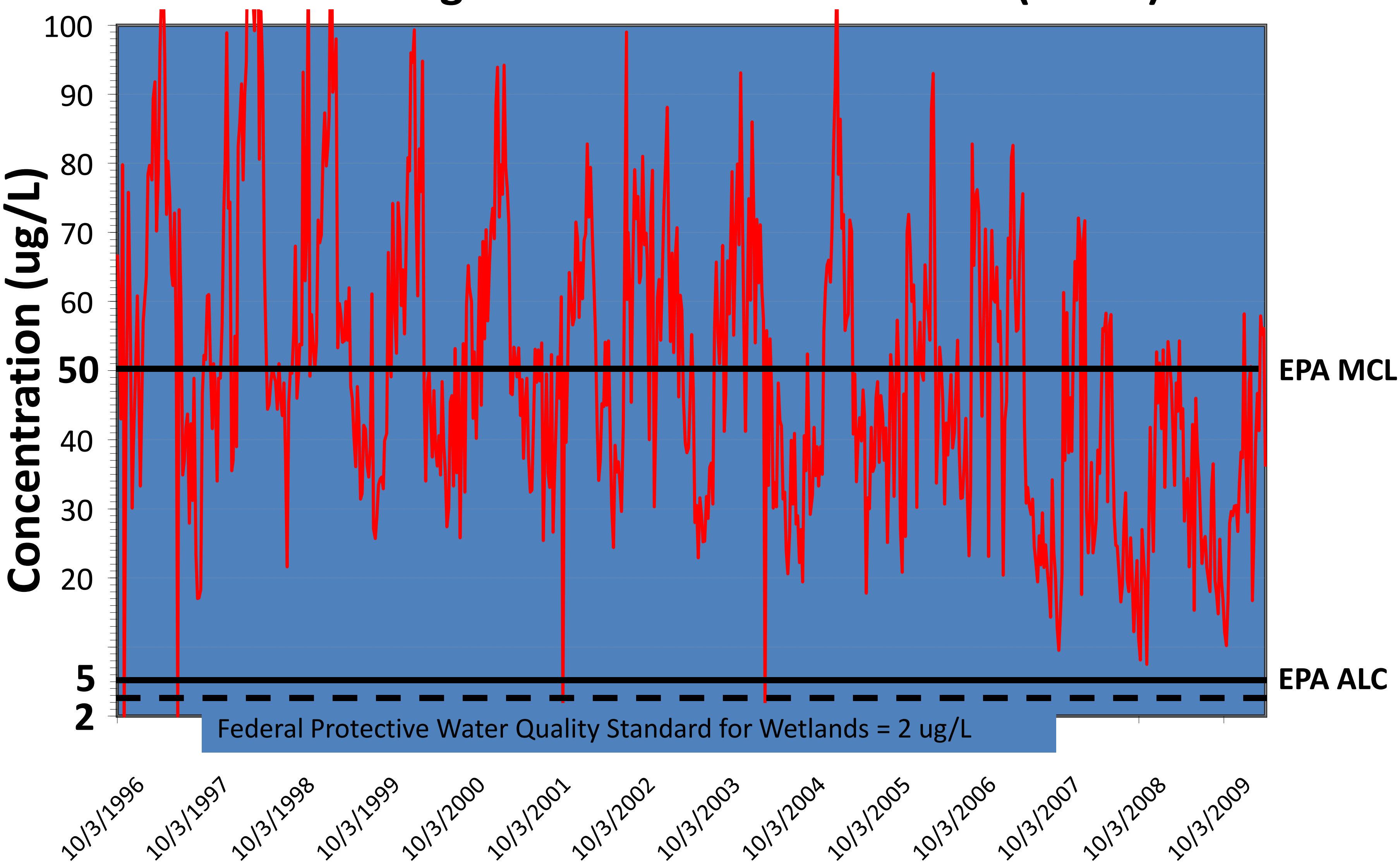


Figure 3

Data from USBR MCL=Maximum Contaminant Level for Drinking Water ALC=Aquatic Life Criterion

Lethal Concentrations of Selenium in Mud Slough (Site D) Through State and National Wildlife Refuges

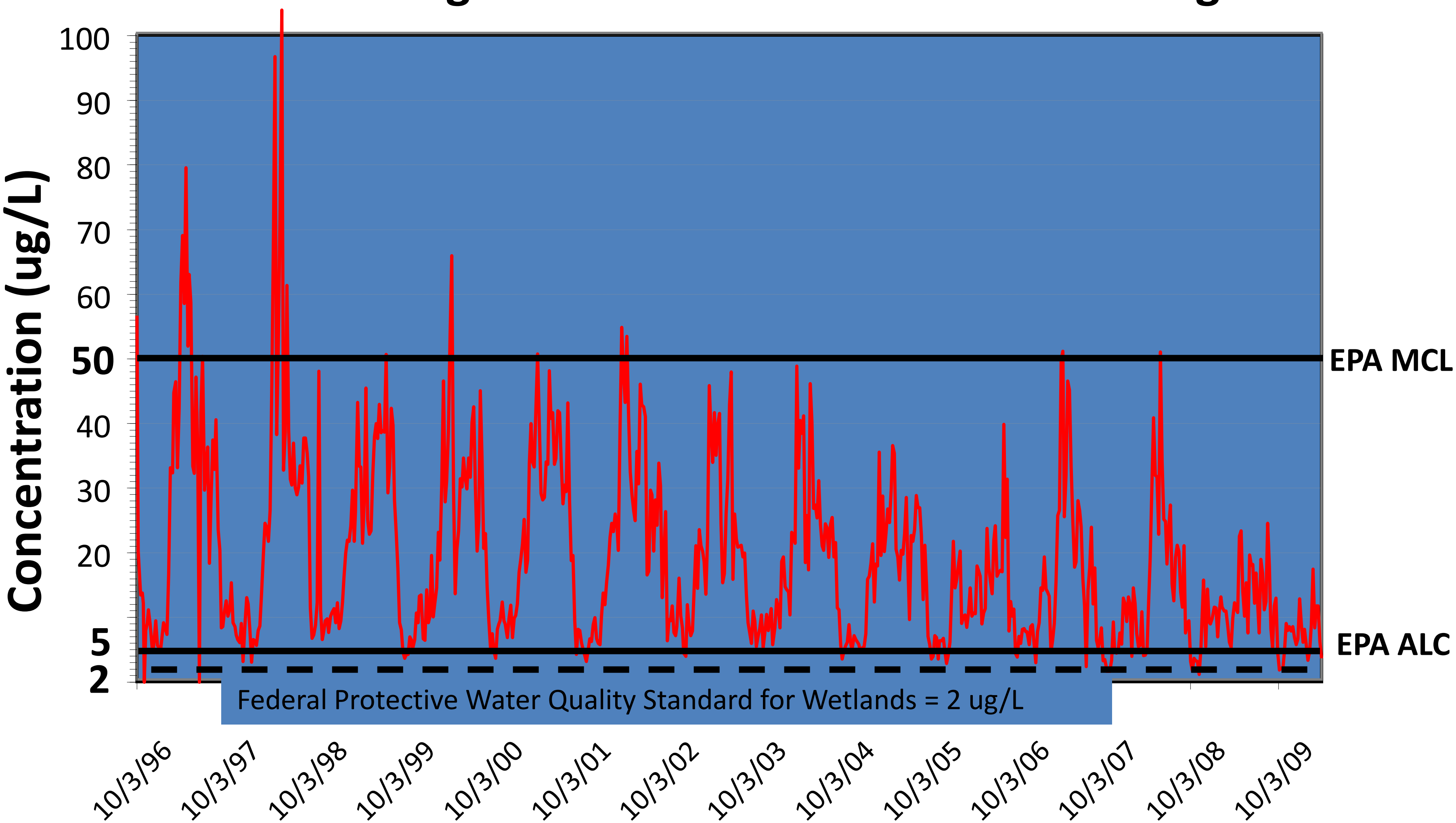


Figure 4

Data from USBR MCL=Maximum Contaminant Level for Drinking Water ALC=Aquatic Life Criterion

Lethal Concentrations of Selenium in San Joaquin River (Site H) Downstream of Mud Slough

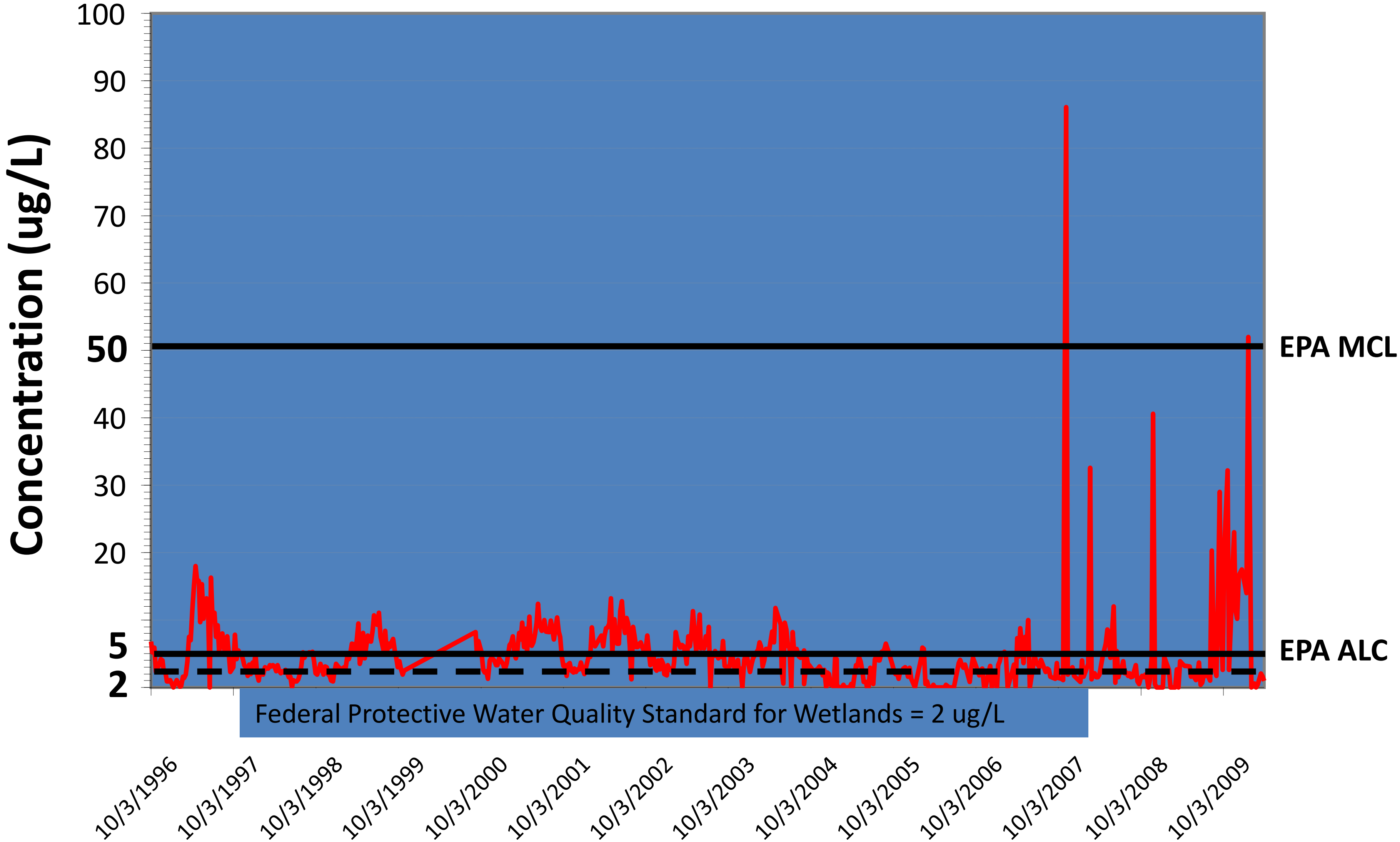
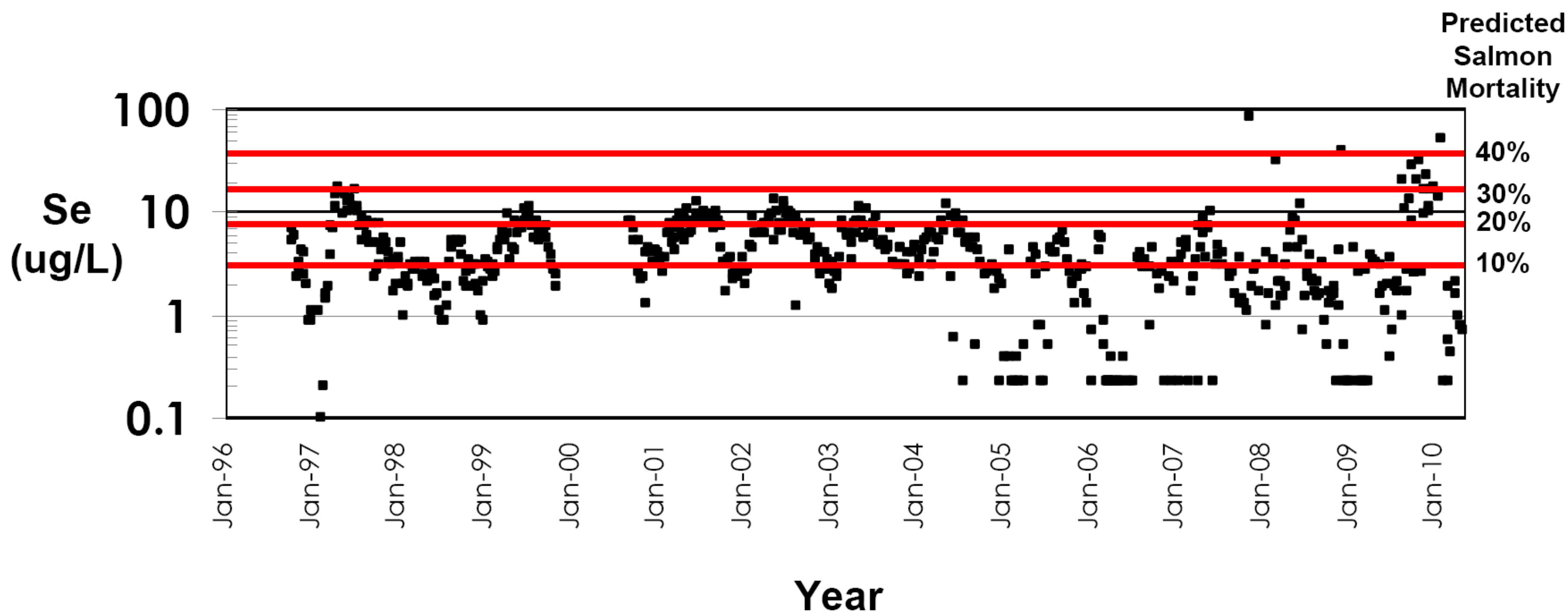


Figure 5

Data from USBR MCL=Maximum Contaminant Level for Drinking Water ALC=Aquatic Life Criterion

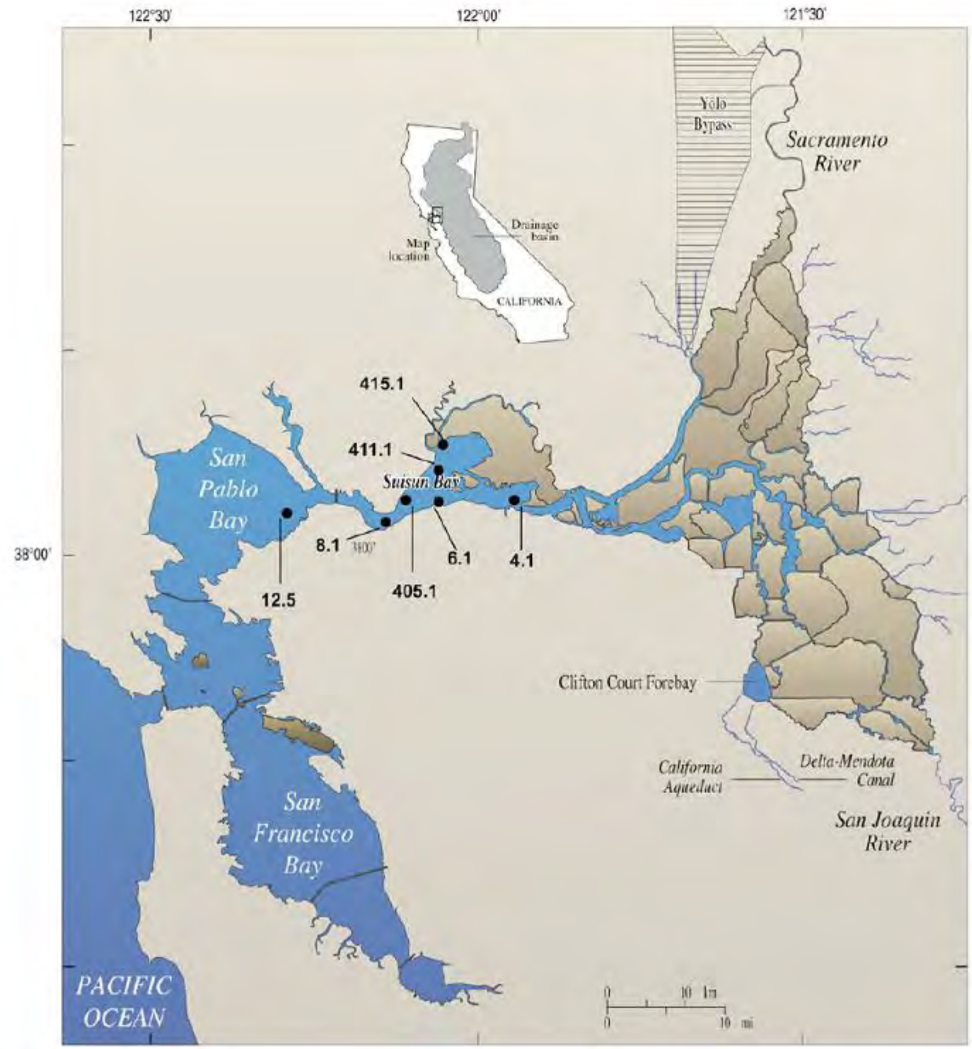
Selenium Levels in the San Joaquin River are not Safe for Salmon



Selenium concentrations measured in the San Joaquin River at Hills Ferry (data from the U.S. Bureau of Reclamation)

Figure 6

Selenium Impacts in Bay-Delta



Unsafe levels of Selenium concentrations found in Suisun Bay and Northern San Francisco Bay. (2 to 22 ppb)*

Selenium loads per day from Westside irrigators contribute approximately 10 to 30 times daily selenium load compared to the Sacramento and Oil refineries combined.**

* Kleckner, A.E., Stewart, A.R., Elrick, K., and Luoma, S.N., 2010, Selenium and stable isotopes of carbon and nitrogen in the benthic clam Corbula amurensis from Northern San Francisco Bay, California: May 1995b

** http://pubs.usgs.gov/pp/p1646/

Figure 7

Imported irrigation leaches selenium and moves it into aquifers and surface waters. Unregulated and unmonitored, highly toxic Selenium-laden wastewater is being stored in aquifers harming beneficial uses.

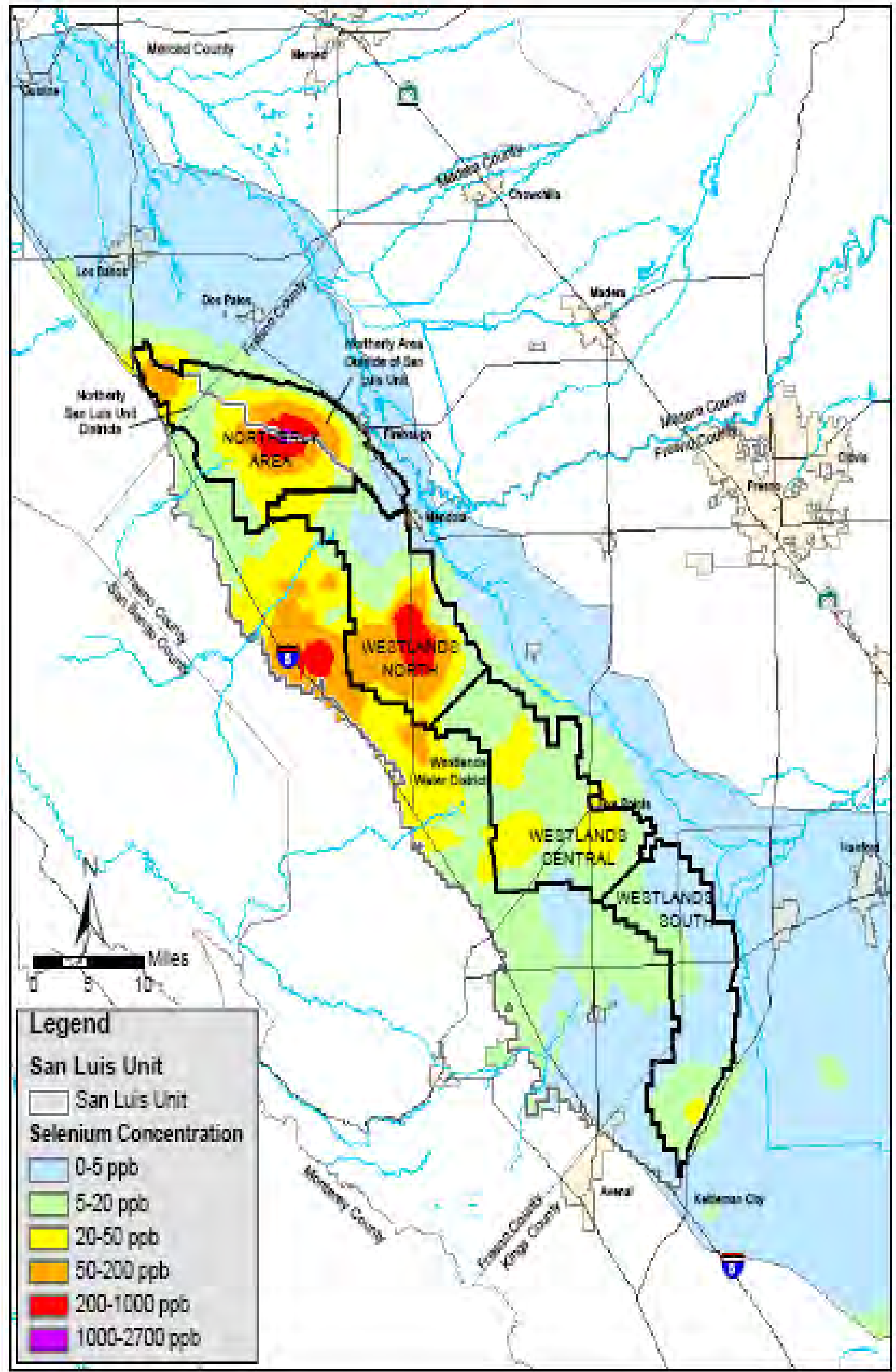


Figure 8

Ecological Threat

Don't repeat the problems found in the San Joaquin Valley in the Delta

2003 CVRWQCB Measured 1480 ppb Selenium in Shallow Groundwater Near Five Points CA.

2003 University of California Salinity Drainage Program Annual Conference: Drainage Solutions, Joseph Skorupa, U.S. Fish and Wildlife Service Available at: http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/joepond.pdf

Figure 9

From: Joseph_Skorupa@fws.gov [mailto:Joseph_Skorupa@fws.gov]
Sent: Friday, October 28, 2011 4:32 PM
To: Patricia Schifferle
Cc: Thomas_Maurer@fws.gov; William_Beckon@fws.gov
Subject: Fw: Panoche embryos

----- Forwarded by Joseph Skorupa/ARL/R9/FWS/DOI on 10/28/2011 07:31 PM -----

"Jeff Seay" <jseay@harveyecology.com>

09/29/2009 01:33 PM

To "Joe Skorupa (E-mail)" <joseph_skorupa@fws.gov>
cc
Subject Panoche embryos

Jeff Seay
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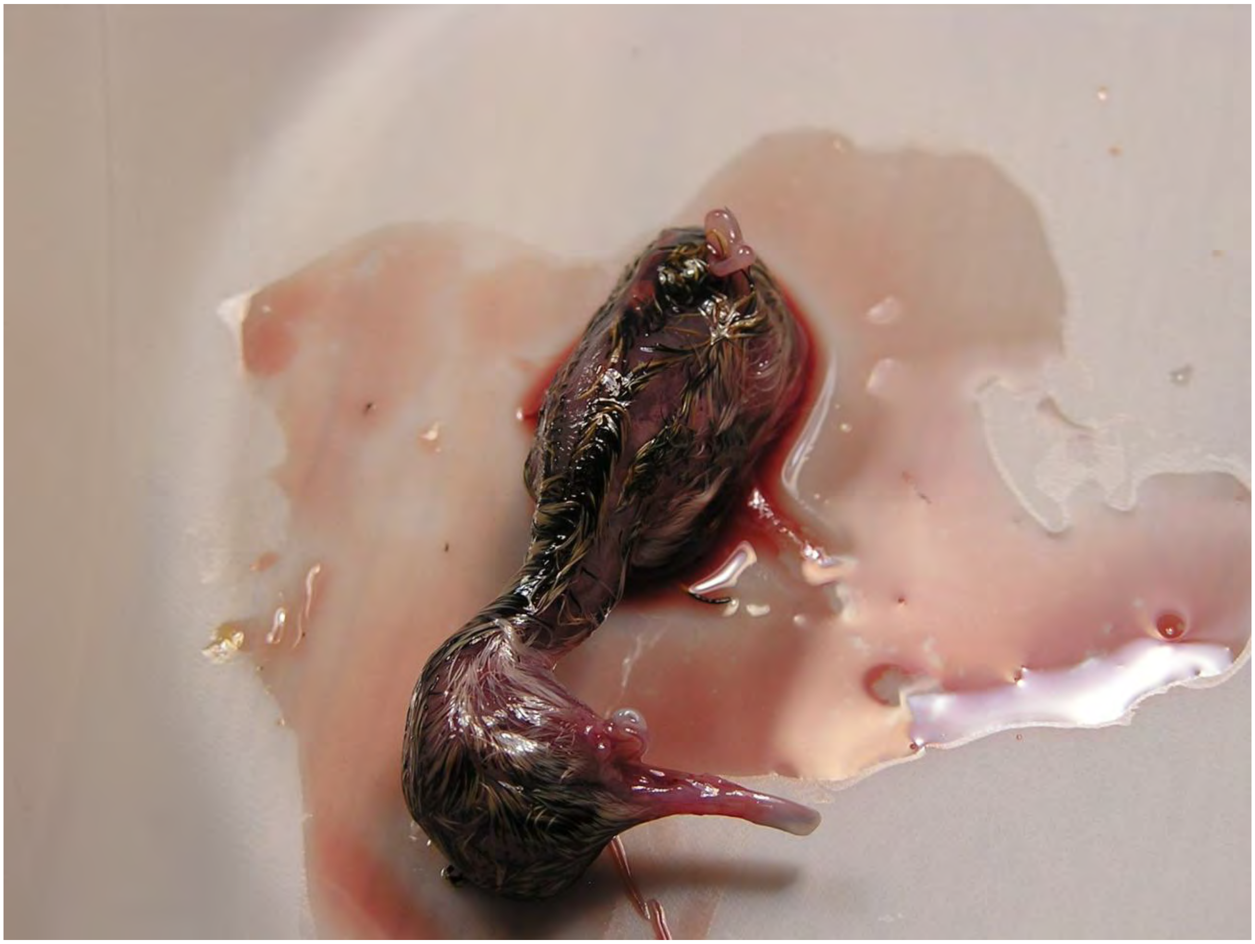
<<P-R-04.JPG>> <<P-R-04A.JPG>> <<P-R-04B.JPG>> <<P-R-04C.JPG>> <<P-R-04D.JPG>>


P-R-04



Dear Ms. Schifferle,

A formal FOIA request will not be necessary. As I understand it from the letters you attached below, both SLDMWA and Panoche WD have implied that they would share with you the photos you are seeking if they possessed them, but they do not possess them. Accordingly, I have an opportunity to assist all parties equally by providing the photos to you and requesting that you please, in turn, provide them to SLDMWA and Panoche WD. This of course is all predicated on an assumption that the photos I am providing are indeed the photos you are seeking.

Results of the 2008 wildlife monitoring program for the San Joaquin River Water Quality Improvement Project were released in a July, 2009 report. As described on page 10 of the July, 2009, wildlife monitoring report, part of the normal monitoring protocol implemented by H.T. Harvey & Associates (hereafter H.T. Harvey) is to photograph each avian embryo that is examined. While I was employed in the Sacramento Office of FWS, those sets of photos were routinely forwarded to FWS along with the monitoring reports by Dr. Andy Gordus of H.T. Harvey (now employed by California Department of Fish & Game). Since I moved to the FWS office in Arlington, VA, I occasionally continue to receive the monitoring reports and accompanying photos, usually via my colleagues remaining in the Sacramento Office of FWS, but sometimes via an independent request to H.T. Harvey, as in this instance.

As you already noted, the narrative description of the condition of the embryo in question can be found on page 22 of the July, 2009, wildlife monitoring report. Also note that this embryo is identified in Table 4 on page 25 of the July, 2009, report as ID Number 04, Field Number S-03, from an egg collected May 23rd, 2008, and containing 74.6 ppm Se dw. The embryo was estimated to be at an incubation stage (age) of 17 days when the egg was collected.

As a separate transmission, I am going to forward to you the email from H.T. Harvey that I received with the photos as attachments. My understanding is that all the photos labeled 04 and 04A thru 04D are of the same specimen, the one documented in Table 4 of the July, 2009, wildlife monitoring report and described narratively on page 22. The photo labeled 06, also attached to the email I am separately forwarding to you, is presumably of the embryo listed as ID Number 06 in Table 4 of the July, 2009, report; a normal black-necked stilt embryo estimated to be at 20 days of incubation when the egg was collected and assessed as a normal embryo.

Lastly, I can confirm that the types of embryo deformities illustrated in photos 04 and 04A thru 04D are quite typical of what I have observed and documented in my own research examining black-necked stilt embryos from eggs containing similar concentrations of selenium. At egg exposures as high as 70-80 ppm Se dw, black-necked stilt embryos have about an 80% probability of being deformed based on 16 randomly sampled eggs in that exposure range that I have compiled records for (13 of the 16 eggs contained deformed embyros) during about the last 25 years.

If you have any further questions, please don't hesitate to contact me again.

Sincerely,

Joe

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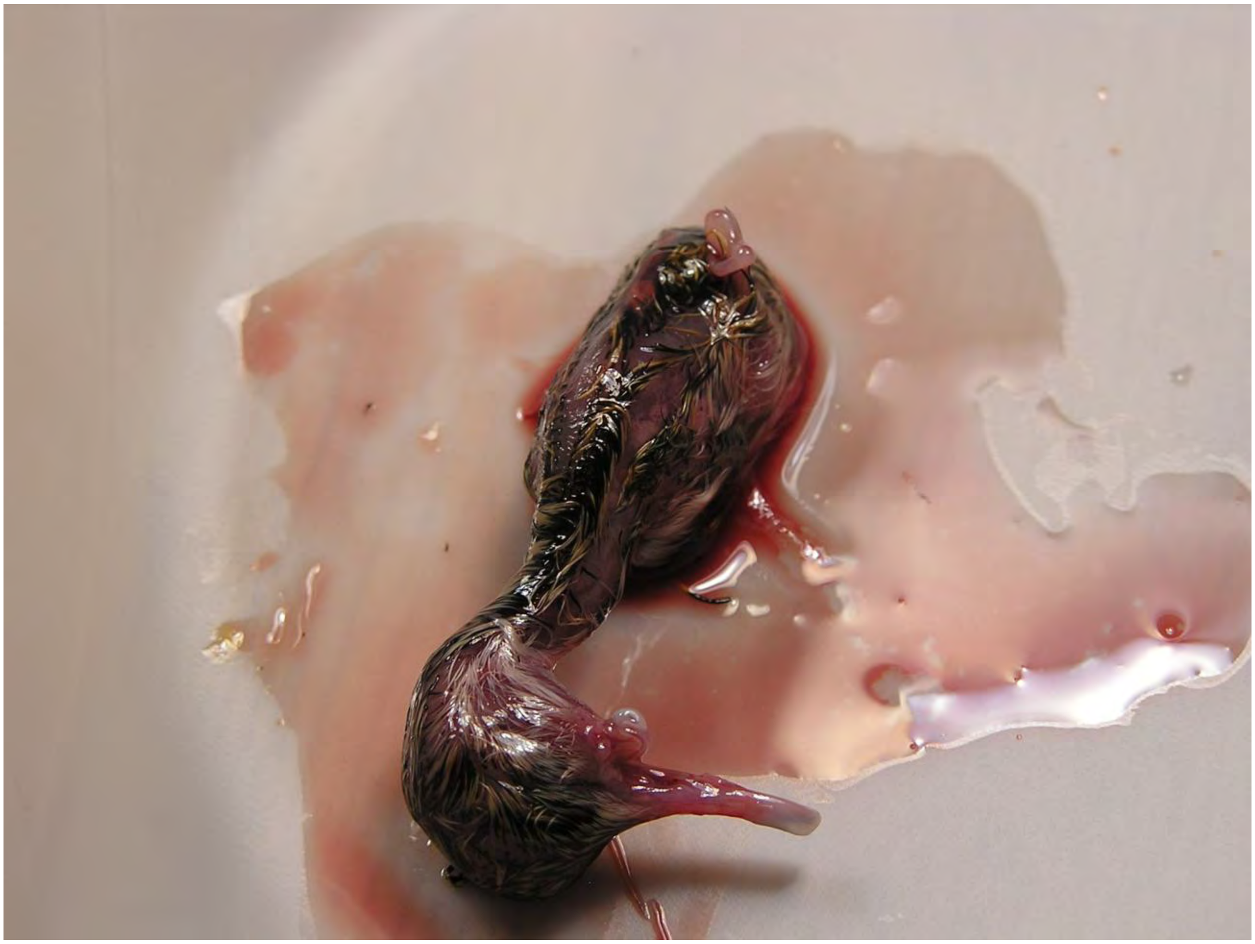
P-R-04



Southern California Watershed Alliance

food&water watch

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Planning and Conservation League

Sierra Club California

Friends of the River

NORTH

COAST

RIVERS

ALLIANCE

california water impact network

PCFFA Pacific Coast Federation of Fishermen's Associations Stewards of the Fisheries

California Sportfishing Protection Alliance CSPA Since 1983

Center for Biological Diversity Because life is good.

Northern California Council Federation of Fly Fishers

SalmonWaterNow Working to make what is wrong, right again

AquAlliance Defending Northern California Waters

Restore the Delta Fishable, Swimmable, Drinkable, Farmable by 2010

August 11, 2011

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Project Manager/Soil Scientist
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San Joaquin Drainage
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Re: Opposition to the Proposal to Curtail Monitoring at the Grassland Bypass Project

Dear Grassland Bypass Project Data Collection & Review Team and Oversight Committee:

The undersigned groups oppose reductions in the monitoring program for the Grassland Bypass Project and, furthermore, recommend a comprehensive reassessment of the need for enhanced monitoring and scientific evaluation. We can see no technical justification or rationale for this reduction in monitoring for a project that has exceeded water-quality objectives and standards for more than fifteen years. We urge the Oversight Committee to reject this unjustified reduction in monitoring and require a reassessment of monitoring and study needs in view of the historical experience with the Grasslands Bypass Project and the long-ignored scientific recommendations of the United States Geologic Survey (USGS) and others to take a systematic, mass-balance approach to understanding the impacts of selenium and other contaminants from the Project. The discharge of selenium and other contaminants in excess of Federal and State water-quality standards threaten populations of Salmon, Steelhead, and Sacramento Splittail, as well as the waterfowl and wildlife resources of the State and Federal National Wildlife Refuges in the area. At the proposed concentrations, mortality of Chinook salmon, steelhead, Sacramento Splittail, waterfowl, and other wildlife are predicted in or adjacent to Mud Slough, the San Joaquin River, and the Delta Estuary. (See Figure 6)

We appreciate the opportunity to comment upon the United States Bureau of Reclamation (USBR) and San Luis Delta Mendota Water Authority (SLDMWA) draft monitoring proposal pending before the Data Technical Committee. The draft proposal would curtail the monitoring program for the discharge of selenium, salt, boron and other contaminants being drained into Mud Slough and the San Joaquin River, using the Federal San Luis Drain as the wastewater collection and discharge conduit. The monitoring proposal would reduce the frequency of monitoring for critical contaminants and supporting parameters at various sites, with no technical justification or analysis of increased bias and uncertainty in tracking water-quality compliance and Project effectiveness. These reductions will mask the pollution spikes in the watershed, river and estuary and provide insufficient data needed to model impacts to the

San Joaquin River and the Delta Estuary. These deficiencies have been previously outlined by the scientific community, but continue to be ignored.

In a declaration before the United States District Court for the Eastern District of California filed by Mr. Glaser, Mid-Pacific Region Director, USBR, on April 1, 2011[1], Mr. Glaser and USBR reported, "On February 16, 2010, the Regional Board staff announced that it would no longer conduct water quality monitoring at twelve sites for the GBP, because of funding and staffing shortage. In addition, staff for the California Department of Fish and Game expressed doubts that they could continue biological monitoring for the project due to staff losses. Reclamation is working with other agencies to revise the Project's monitoring program, and will assign staff and seek funding to assure that the water quality and biological monitoring requirements are met."[2]

Operating under State of California Waste Discharge Requirements (WDRs), USBR and SLDMWA (Dischargers) have transported selenium and other contaminants from the San Luis Drain to the San Joaquin River starting in 1995 as a "temporary" two year project that was next extended to 2000, and then again extended to 2009, and recently extended again to 2019.(See Figure 1) USBR data document that, from 1996 to 2008, the dischargers have dumped 85,954 lbs of selenium, 25,251,000 lbs of Boron and 9,772,610 tons of salt to Mud Slough, the San Joaquin River, and the Delta Estuary.[3]

Even before 1995, these Dischargers drained selenium and other contaminants from the San Luis Drain, via Mud Slough to the San Joaquin River actually began under two Clean Water Act National Pollutant Elimination System (NPDES) permits.[4] (See Figure 1) Under those permits the selenium pollution controls and monitoring frequencies were much stronger. The compliance monitoring took place at the point of discharge not some 30 miles downstream. And concentrations at the point of discharge were much lower for Mud Slough (north) along with concentrations measured in the San Joaquin River monitoring sites. First, in November of 1987, USBR was allowed to drain the Kesterson ponds via Mud Slough into the San Joaquin River. A second NPDES permit to discharge selenium contaminated groundwater was issued to the Dischargers, USBR and SLDMWA, in March of 1996, where toxic drainage and ground water discharged also had similar monitoring and water quality compliance requirements.[5]

Under the previous and present permits Dischargers use sumps and pumps to move groundwater collected from subsurface drainage systems, which collect contaminated groundwater from as deep as 100 feet drawing from contaminated water from basically horizontal groundwater wells some 50- 100 feet in depth[6] to collect pollution from over 97,000 acres and discharge toxic contaminants that exceed federal and state water quality standards, violate the Sacramento-San Joaquin Valley Basin plan, degrade beneficial uses, and create a nuisance and burden for downstream users to clean up, thus passing these environmental hazards and treatment costs to downstream users.

What is the rationale for curtailing monitoring?

Repeated requests to develop a comprehensive and effective monitoring program for the Grasslands Bypass Project have not been acted upon.[7] There has been a consistent failure to develop monitoring to determine the fate and transport of selenium and other contaminants in the food chain where it's magnified effects result in a narrow window of exposure before mortality. Despite the lack of monitoring, selenium concentrations in avocet and stilt eggs at the Grasslands Drainers' reuse area have been found to exceed those found at Kesterson National Wildlife Refuge![8] Further the project has failed to track the selenium loading from the Grassland Drainage Area into the San Joaquin River, the Sacramento-San Joaquin Delta and the North Bay (e.g. Suisun Bay), as required in the 2001 Record of Decision for the GBP.[9] Biological monitoring and impacts especially to coldwater fish have not been monitored.[10] For example 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, are not sampled there. Selenium is being exported to southern California's water supplies through the California Aqueduct threatening drinking water quality and likely is accumulating in fish and reservoirs in Southern California as a result.[11]

Also the GBP has failed to monitor and consider the long term impacts of discharging selenium through wetland and slough areas adjacent to federal and state wildlife refuges, the San Joaquin River and Delta Estuary.[12] This history of inadequate monitoring and insufficient scientific assessment will be made far worse if the proposed reductions in monitoring are allowed. We find absolutely no evidence that the proposed reductions are based on documented scientific analysis.

Models Accurately Document an Ongoing Failure to Meet Water Quality Standards in the San Joaquin River and Mud Slough (North) and Continue to Impair the Bay-Delta.

Since 1994, models used to establish the amount of selenium loads to be discharged to the San Joaquin River and Delta Estuary have accurately documented that these loads of pollution do not meet Federal and State standards for minimal protection of water quality.[13] [See Figures 3-5] Moreover, since 2000 the load models used have even been modified to permit greater discharges of pollution without triggering a violation. These modifications include relaxing criteria for violation rates, choosing a monthly mean instead of a 4 day average, and changing the water years.[14] Environmental Defense Fund estimates the change from the four-day flow averaging period to a one month averaging period resulted in a 21 percent to 44 percent increase in allowable loads.[15] "If implemented as an interim compliance, this change in the averaging period would be expected to cause numerous violations of the water quality standards. Similarly, relaxing the once-in-three year excursion rate to a once-in five-month per year rate resulted in a significantly higher allowable load."[16] These predicted violations have proven accurate.[17] Using similar calculation assumptions, USBR figures for 2009-2019 predict violations also for the continued loads of pollution allowed.[18] The dischargers use these generous load targets and the ability to meet them as a sign of success. The fact remains, however, that they fail to meet safe concentrations in the Mud Slough (north) wetland channels through State and Federal Wildlife Refuges and concentrations remain extremely high in Mud Slough (north) and in the San Joaquin River above the compliance point measured some 30 miles away. Along with the violations of the federal and state water quality standards, concentrations of selenium in fish and wildlife also remain high. Scientists predict a high mortality for coldwater fish such as salmon and green sturgeon from these concentrations.[19]

The San Joaquin River downstream of the Merced River has been delisted as water quality impaired because of dilution water from the Merced River, weak standards and inadequate monitoring mentioned above. The selenium contamination, however, continues to drain into the Bay-Delta with predictable results. The Clean Water Act Section 303(d) list of water quality limited stream segments lists 41,736 acres in the Delta, 5,657 acres in the Carquinez Straights, 70,992 acres in San Francisco Bay Central, 9,024 acres in San Francisco Bay south and 68,349 acres in San Pablo Bay as impaired by selenium.[20] The west side discharges are a major source of those water quality impairments.[21] Health advisories are in effect for scaup, scoter and benthic feeding ducks in many of those areas.

A study by the U.S. Fish and Wildlife Service[22] for USEPA identified that several bird species protected under the Migratory Bird Treaty Act (MBTA) are considered "species most at risk" from selenium contamination in the San Francisco Bay. Greater scaup, lesser scaup, black scoter, white-winged scoter, surf scoter and bald eagle are listed as "species most at risk" from selenium contamination and all are covered by the Migratory Bird Treaty Act (MBTA). By allowing continued discharges of selenium in excess of Basin Plan objectives from the Grasslands Bypass Project, there is downstream contamination and selenium bioaccumulation in the Bay-Delta, and increasing likelihood of MBTA and ESA violations by the United States.

Government Scientists Have Criticized the Existing Monitoring Program and Proposed Reductions Further Erode Protection of Public Resources

EPA has urged the development of a comprehensive monitoring program if the project is extended.[23] USFWS comments have identified numerous monitoring deficiencies with regard the fate and transport of selenium and the long term effects on especially on coldwater fish, wildlife and endangered species.[24]

In 1996 USGS scientists provided the Oversight Committee with a comprehensive critique of the proposed monitoring plan, developed in cooperation with USBR. [25] Many of USGS comments still apply. They include recommendations for assessing the fate and transport of selenium in the project area; evaluation of selenium in sediment and its transport; evaluation of suspended particulate forms of selenium from the discharges; and for better biological and water quality monitoring. One of the main findings of the USGS review is that a monitoring program and study is needed to evaluate the mass balance of SE that includes the dissolved and suspended particulate forms of selenium. This continuing lack of comprehensive monitoring for the management of selenium contamination is also echoed in a recent scientific article, by Luoma & Presser 2009:[26]

"Uncertainties in protective criteria for Se derive from a failure to systematically link biogeochemistry to trophic transfer and toxicity (Figure 1). In nature, adverse effects from Se are determined by a sequence of processes (12). Dilution and redistribution in a water body determine the concentrations that result from mass inputs. Speciation affects transformation from dissolved forms to living organisms (e.g., algae, microbes) and nonliving particulate material at the base of the food webs. The concentration at the base of the food web determines how much of the contaminant is taken up by

animals at the lower trophic levels. Transfer through food webs determines exposure of higher trophic level animals such as fish and birds. The degree of internal exposure in these organisms determines whether toxicity is manifested in individuals. Se is first and foremost a reproductive toxicant (both a gonadotoxicantanda teratogen): the degree of reproductive damage determines whether populations are adversely affected. Adverse effects on reproduction usually occur at lower levels of exposure than acute mortality, but such effects can extirpate a population just as effectively as mortality in adults."

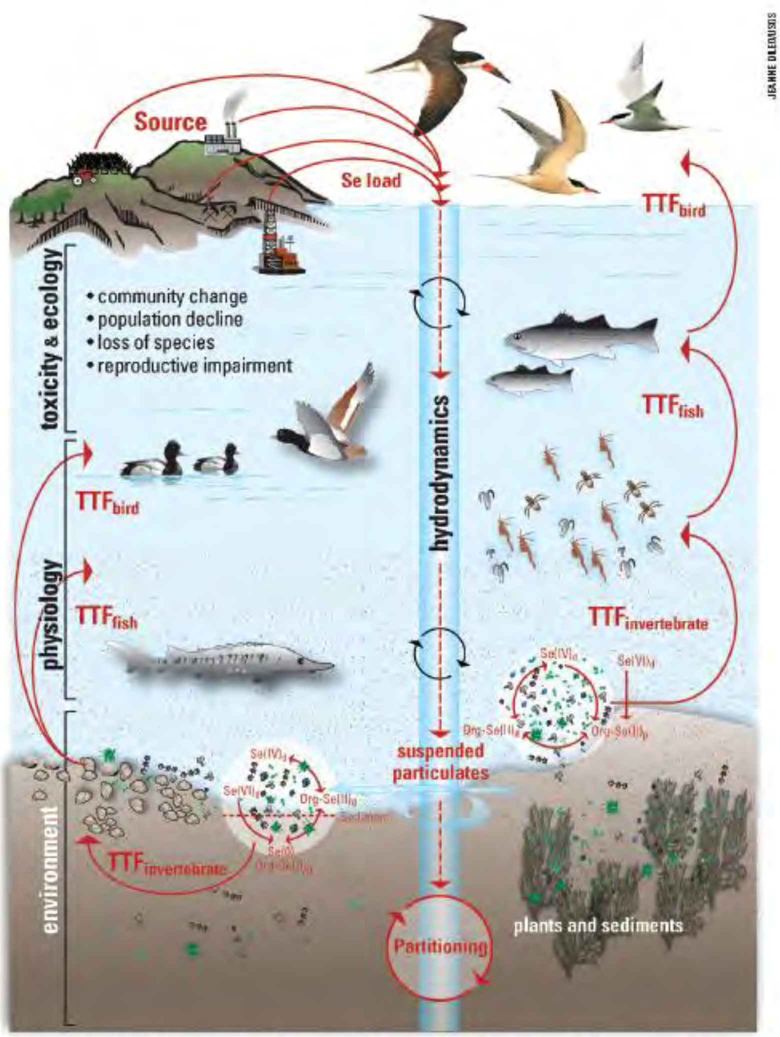

FIGURE 1. Conceptual model of Se fate and effects emphasizing the roles of speciation, biogeochemical transformation, and trophic transfer factors in modeling two aquatic food webs: a water column food web and a benthic food web. TTF = trophic transfer factor. Subscript d means dissolved, subscript p means particulate.

As of 2007 an estimated 222,025 cubic yards of sediment has accumulated in the San Luis Drain.[27] This is nearly a four-fold increase over the original 55,788 cubic yards of sediment that were recommended for removal at the beginning of the project, but never carried out.[28] Also contained in the USGS report on the Review of the Grassland Bypass Channel Project Monitoring Program is the following assessment of the entire monitoring program: "The original Monitoring Plan is not adequate because it does not account for all appropriate sources and sinks of selenium, salt, and boron within the GBCP area and because the sampling design does not adequately address temporal, width, and depth variability in chemical concentrations and loads."[29] These contaminated sediments and suspended particulates in the water pose a toxic danger in the Drain, as well as, in Mud Slough and the San Joaquin River, that continue to grow and the proposed reductions in monitoring do not remedy these problems and shortcomings.

Conclusion: Continued Monitoring and a More Rigorous Approach are Necessary to Protect the Public Interest and Water Quality.

Rather than reduce monitoring, as proposed, we urge a substantial increase in the current 2001 monitoring plan to ensure compliance with state and federal law, while at the same time immediately initiating a comprehensive, peer-reviewed reevaluation of the monitoring program and the amounts of selenium being discharged under the current Total Maximum Daily Load (TMDL) and WDRs implementing the TMDLs. As noted in the November 3, 1995 agency letter, "There is no commitment, at this time, to approve long-term use of the Drain." [30] Further in 2001 the Regional Board staff reported, "If monitoring demonstrates that the water quality objectives are not being met then additional load reductions or amendments to the TMDL will be required."[31] As noted previously and documented in figures 3-5, discharges exceed federal and state water quality standards. The Waste Discharge Requirements and compliance monitoring need to be strengthened not relaxed.

Based on current science, the continued extension of discharges from the Grasslands Bypass Project make it more important than ever to ensure that a long-term monitoring and scientific assessment finally address the impacts of the Project and the realistic chances of future reductions in contamination. Please add us to any notifications regarding changes in the monitoring program or waste discharge requirements.

Sincerely,

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Karen Schwinn & Eugenia McNaughton, US Environmental Protection Agency
Julie Vance and John Shelton, California Department of Fish and Game
Kim Forrest, Wildlife Refuge Manager
San Luis National Wildlife Refuge Complex U. S. Fish and Wildlife Service
Interested Parties

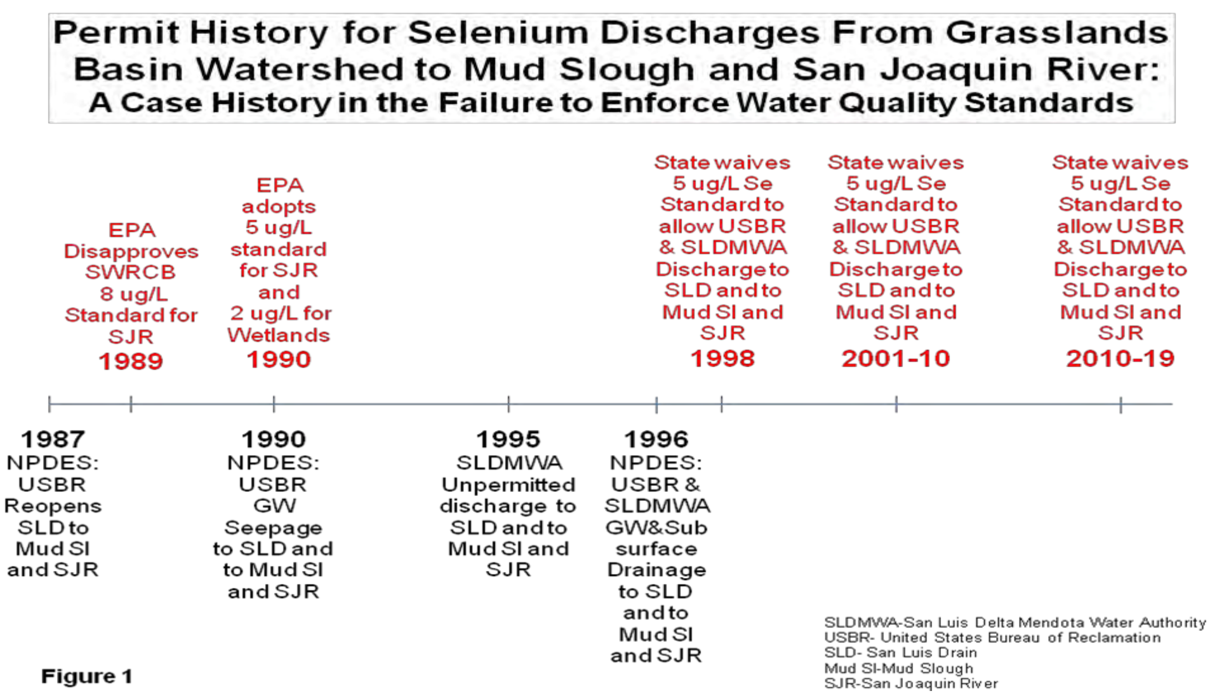


Figure 1

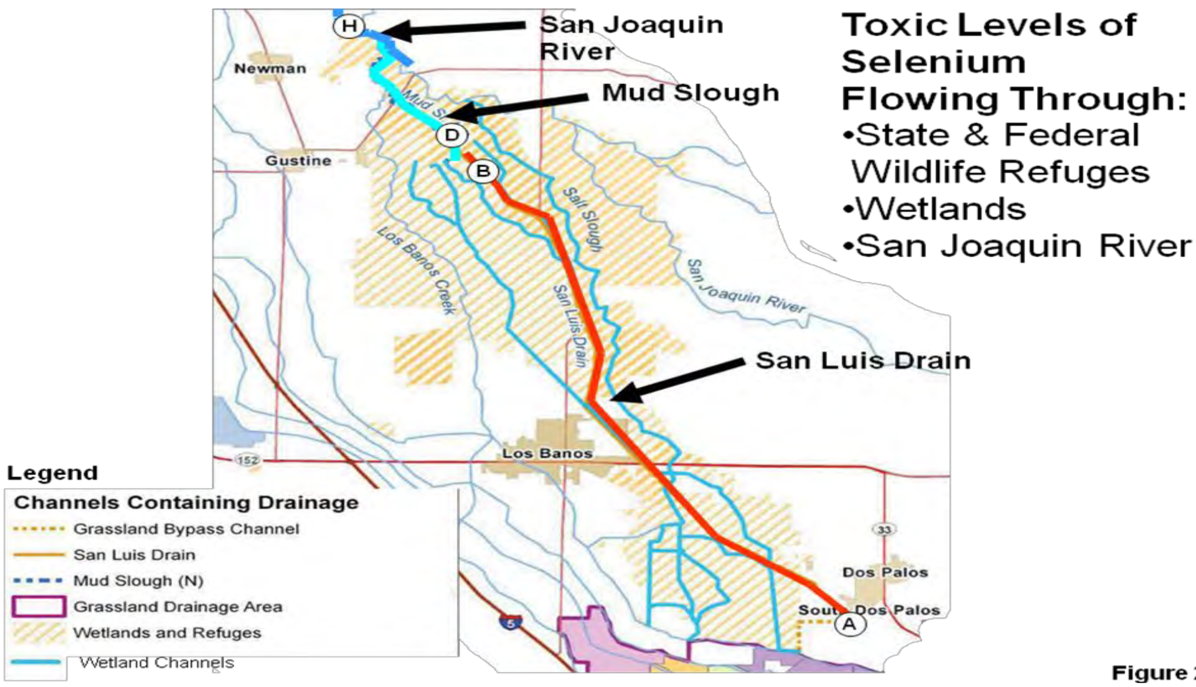


Figure 2

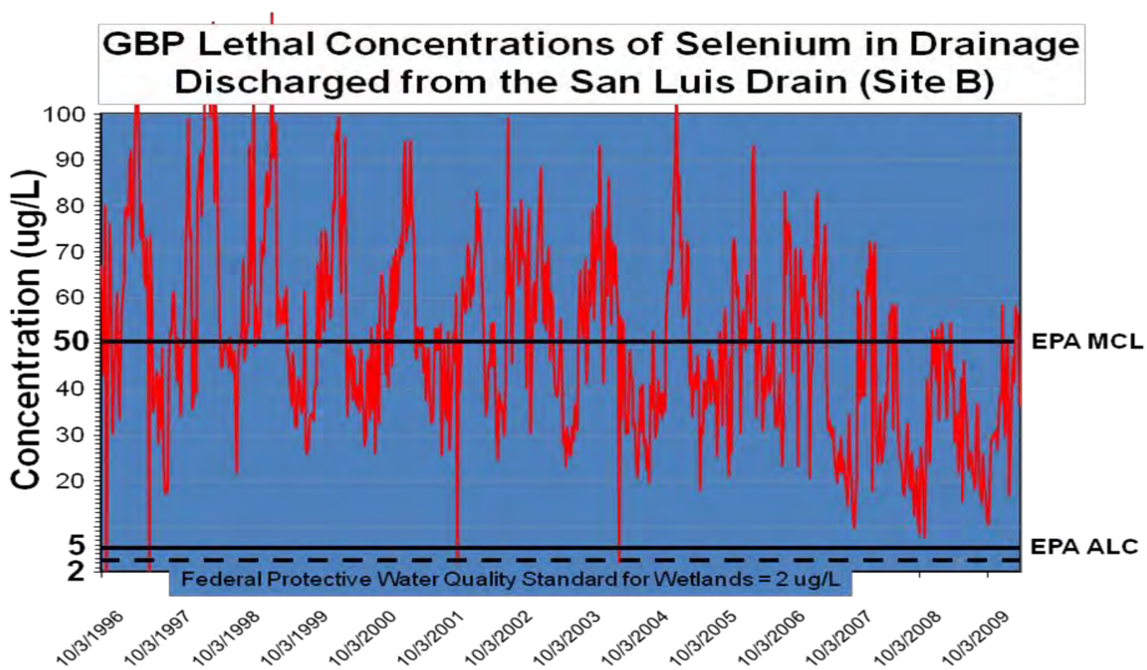


Figure 3

Data from USBR-Eacock MCL=Maximum Contaminant Level for Drinking Water ALC=Aquatic Life Criterion

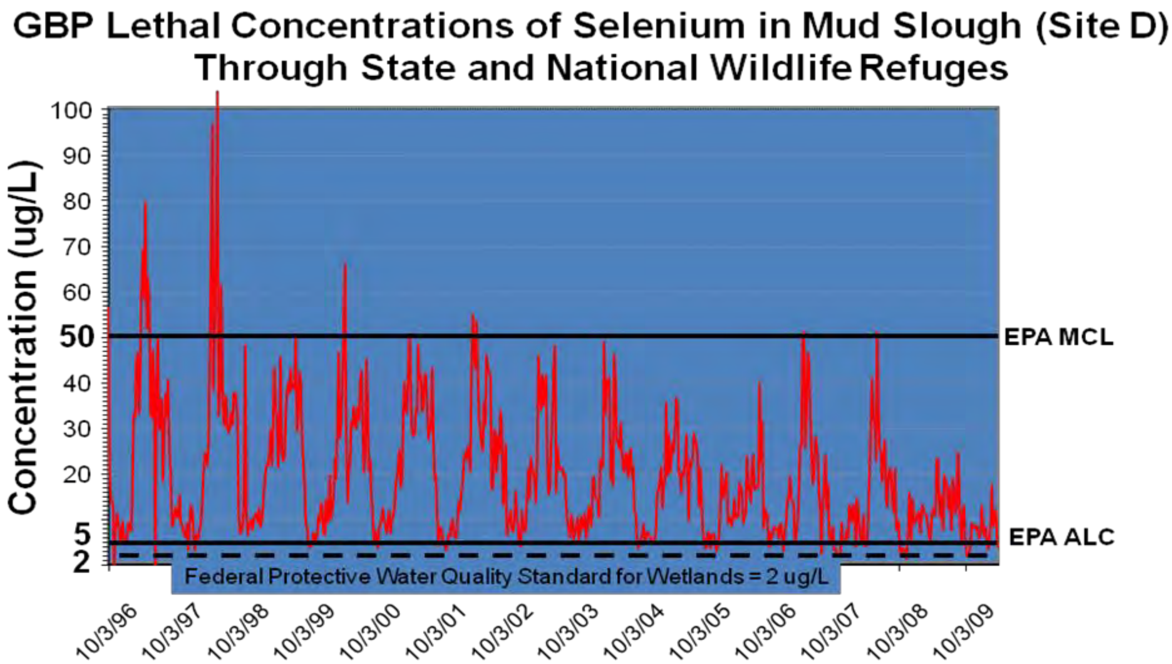


Figure 4

Data from USBR=Eacock MCL=Maximum Contaminant Level for Drinking Water ALC=Aquatic Life Criterion

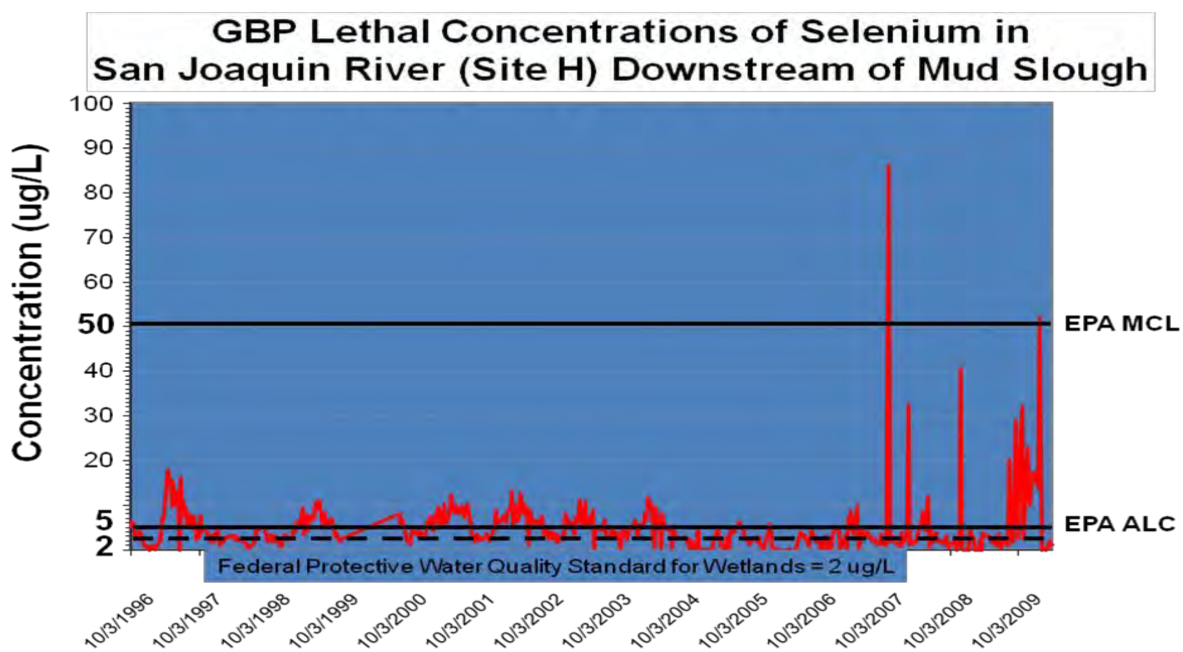
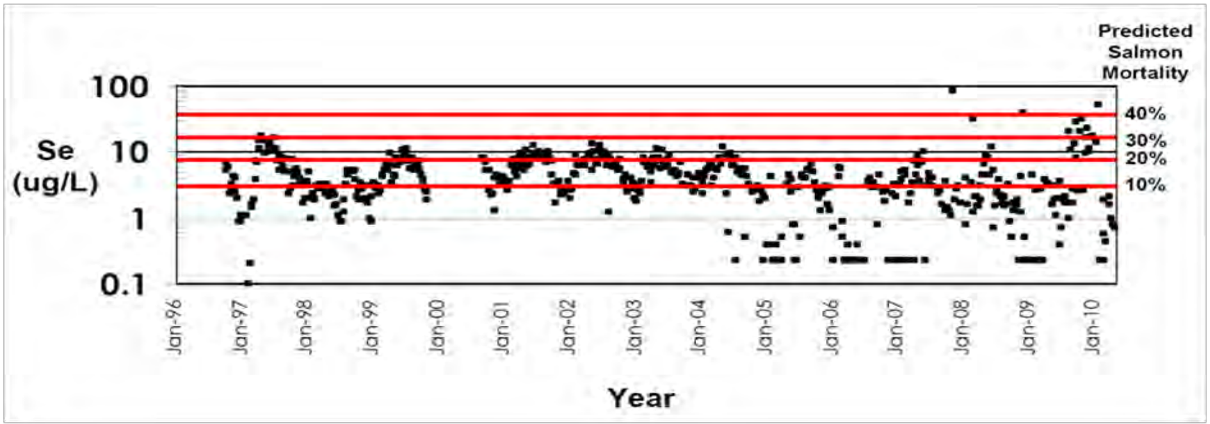


Figure 5

Data from USBR Eacock MCL=Maximum Contaminant Level for Drinking Water ALC=Aquatic Life Criterion

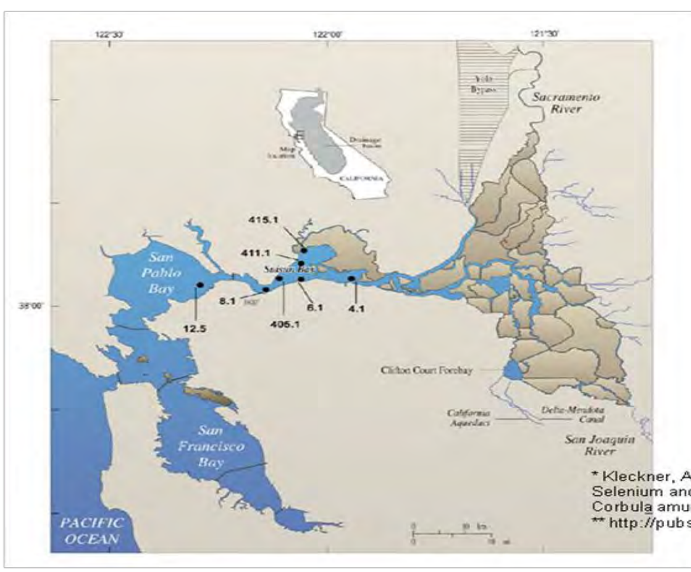
Selenium Levels in the San Joaquin River are not Safe for Salmon



Selenium concentrations measured in the San Joaquin River at Hills Ferry (data from USBR [Eacock]and USFWS [Maurer & Beckon])

Figure 6

Selenium Impacts in Bay-Delta



Unsafe levels of Selenium concentrations found in Suisun Bay and Northern San Francisco Bay 2 to 22 ppb.*

Selenium loads per day from Westside irrigators contribute approximately 10 to 30 times daily selenium load compared to the Sacramento and Oil refineries combined.**

* Kleckner, A.E., Stewart, A.R., Elrick, K., and Luoma, S.N., 2010, Selenium and stable isotopes of carbon and nitrogen in the benthic clam Corbula amurensis from Northern San Francisco Bay, California: May 1995b
** http://pubs.usgs.gov/pp/p1646/

Figure 7

ENDNOTES

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[1] Federal Defendants' Status Report of April 1, 2011. Case 1:88-cv-00634-OWW-DLB Document 864 Filed 04/01/11 page 6 & Glaser Third Declaration pg 6-7

[2] Ibid.

[3] http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4418 pg 26 of 66 FEIR/EIS Final EIS/EIR, Private/individual comments Part 2, Grassland Bypass 2010-2019

[4] Order No. 87-201 NPDES No. CA 0082171 Waste Discharge Requirements for United States Department of the Interior Bureau of Reclamation & Order No 90-027 NPDES NO CA 0082368 WDRs for USBR.

[5] Order No 96-0922 NPDES No. CA 0083917 Waste Discharge Requirements for USBR and San Luis Delta Mendota Water Authority adopted March 22, 1996.

[6]http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4413 "Tile drainage systems affect groundwater-flow in upper parts of the semi-confined aquifer. Seasonal changes in groundwater levels and drain flow indicate field conditions are affected by upslope irrigation activities. Furthermore, observation well data show that groundwater movement is upward towards the drainage systems from depths as great as 100 feet below land surface (Deverel and Fio, 1991; Fio, 1994)." Pg 236 of the PDF

[7] http://www.epa.gov/region9/nepa/letters/Grassland-Bypass-FEIS.pdf EPA March 30, 2009 Detailed EIS/EIR Comments RE Grassland Bypass Project Continued Use of San Luis Drain: *"Develop a comprehensive monitoring program that includes multiple contaminants and follow-up for detected biological effects…this program should cover biological as well as water quality and sediment components."*

http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4415 pg 15 -52 of PDF USFWS March 22, 2009 Comments RE Continuation of GBP 2009 to 2019 USFWS recommends… "*An evaluation of the environmental effects of continued acute spikes of selenium to the biota in the vicinity of the Grasslands wetland supply channels…Selenium bioaccumulates rapidly in aquatic organisms and a single pulse of selenium (>10 µg/L) into aquatic ecosystems could have lasting ramifications….Maier et al. found that the invetebrate food web was still contaminated at >4 µg/L 12 months after selenium treatment when the monitoring ended even though water concentrations were <1 µg/L."*

http://pubs.usgs.gov/pp/p1646/pdf/pp1646.pdf pg 26. ... "monitoring was not sufficiently frequent to accurately characterize loads during variable flows."…annual data are not available from individual farm-field sumps to help qualify source-area shallow groundwater conditions and determine long-term variability in selenium concentrations…compliance monitoring sites are 50 and 130 miles downstream from the agricultural discharge. Pg 118-119.

Grassland Bypass Project 1999-2000 Annual Report at page 4, "The Oversight Committee recommended that additional studies be undertaken to establish the sources of selenium." http://openlibrary.org/books/OL23302134M/Grassland_bypass_project

Grassland Bypass Project 2001-2002 Annual Report at page 4, “The Oversight Committee recommended that additional studies be undertaken to establish the sources of selenium.”
http://openlibrary.org/books/OL23302136M/Grassland_bypass_project

“ A Review of the Grassland Bypass Channel Project Monitoring Program” Presser, Sylvester, Dubrovsky and Hoffman, December 1996
http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/Presser_etal_GBP_monitoring_plan_1996.pdf
http://www.swrcb.ca.gov/rwqcb5/water_issues/grassland_bypass/usfws_att_e.pdf Email From Tomas Mauer, Chief, Investigations and Prevention Branch Sacramento Fish and Wildlife Office, U.S. Fish and Wildlife Service to Shauna McDonald [USBR], 11-18-09: “*Site H is not as problematic a sampling site as it is described for monitoring selenium levels in this stretch of the San Joaquin River. Although the site is inappropriate to use for selenium load calculations, the historic data clearly shows that selenium concentrations here can reach high levels throughout much of the year regardless of Merced River influences. The highest selenium levels occur in the summer when Merced River flows through the side channel would not be influencing site H. Currently, sampling at site H is less frequent, and thus potential spikes of selenium may not be observed. A more detailed analysis of the data at this site may assess how well the current sampling regime would detect the highest selenium levels. Even the current reduced sampling effort shows concentrations over 9 µg/L. This is above the 20 percent mortality level and three times higher than the 10 percent mortality level for salmonids (attached chart includes more recent data for 2007).”*

[8] USFWS 2009 Biological Opinion for the Grasslands Bypass Project page 90.
http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4826 “It is notable that the geometric mean, egg-selenium concentration in recurvirostrid eggs collected at the SJRIP Phase I area in 2008 (50.9 µg/g) exceeded all geometric mean selenium concentrations in recurvirostrid eggs collected at Kesterson Reservoir from 1983 to 1985 (Ohlendorf and Hothem 1994)…”

[9] USBR 2001 Record of Decision page 6. http://www.usbr.gov/mp/grassland/documents/rod_final_09-28-01.pdf

[10] http://www.swrcb.ca.gov/rwqcb5/water_issues/grassland_bypass/usfws_com.pdf “*Selenium concentrations in the food-chain of these impacted waters have often reached levels that could impact or even kill a substantial proportion of young salmon (Beckon et al. 2008) if the salmon, on their downstream migration, are exposed to those selenium-laden food items for long enough for the salmon themselves to bioaccumulate selenium to toxic levels. Based on existing water quality data for selenium in specific reaches of the San Joaquin River, Beckon and Maurer (2008) concluded that there remains a substantial ongoing risk to migrating juvenile Chinook salmon and steelhead in the San Joaquin River as noted in Attachment E. The Service asks that the Regional Board consider the protection of Chinook salmon and steelhead in the San Joaquin River, including the reach between Sack Dam and the Merced River, in this Basin Plan Amendment.”[page 6 of pdf]*

[11] http://calitics.com/tag/Selenium Napolitano, Garamendi, et al., November 26, 2010.
Personal Communication Rudy Schnagl to Ms Schifferle, 8-8-11 ‘Flow models document most of the San Joaquin River is diverted to the California Aqueduct, thus contaminants are likely captured and sent south.’

[12] Suisun Bay in the Delta is selenium impaired and agriculture is listed as a source in the 303(d) listing of this water body. Further, EPA is in the process of developing a site specific selenium objective for the Delta, so reduced monitoring of the GBP could further hinder compliance with this future objective.

[13]http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/san_joaquin_se/se_tmdl_rpt.pdf *"There would be effectively no allocation of selenium load in the absence of Merced River dilution flows. The source analysis has shown that subsurface agricultural return flows from the DPA are the primary source of selenium load in the lower SJR Basin." [page 14]* Also see 1994 Regional Board staff report, Total Maximum Monthly Load Model for the San Joaquin River (Karkoski, 1994),

[14] November 3, 1995, Letter to Karl Longley Central Valley Regional Water Quality Control Board from Dan Nelson, SLDMWA, Roger Patterson, USBR; Felicia Marcus, USEPA; Joel Medlin USFWS.
"A commitment to specific monthly and annual selenium load values which assure that within 2 years, the Water Authority will implement actions sufficient o reduce selenium loads to the River by at least 5 percent per year up through the end of the 5th year. …the parties agree that for the purpose of establishing selenium load reductions, the following water quality objectives are now applicable: (a) 5 ppb selenium, measured as a 4-day average, in the San Joaquin River and Mud Slough and (b) 2 ppb selenium, measured as a monthly mean, in Salt Slough and the wetland channels.

[15] 1994 Environmental Defense Fund, Terry Young and Chelsea Congdon "Plowing New Ground" pg 35.

[16] Ibid.

[17]http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/san_joaquin_se/se_tmdl_rpt.pdf pg 20 of the PDF

"Load allocations in this TMDL [for the SJR] are established for meeting the selenium water quality objective in the SJR downstream of the Merced River confluence. There would be effectively no allocation of selenium load in the absence of Merced River dilution flows. The source analysis has shown that subsurface agricultural return flows from the DPA are the primary source of selenium load in the lower SJR Basin….. Attainment of the selenium water quality objective upstream of the Merced River confluence may require significant changes to the DPA discharge, including the relocation of the discharge point."
http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/sjr_selenium/comments092210/susan_moore.pdf pg 2 of the PDF

[18] http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4418 pg 26 of 66 FEIR/EIS Final EIS/EIR, Private/individual comments Part 2, Grassland Bypass 2010-2019
http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=3513
Also see Appendix C of the December 17, 2009 Agreement for the Continued Use of the San Luis Drain Agreement No. 10-WC-20-3975. Predicted violations of CWA standards will continue with proposed loads approximately until years 9 and 10. They will be violated for those years unless "highly speculative treatment" is achieved. See http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4415 pg 4 of 40 of the PDF. EPA comments on the DEIS/EIR for Continued Use of the San Luis Drain for Discharge into Mud Slough and the San Joaquin River.

[19] http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=3513

[20]http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/303dlists2006/epa/state_usepa_combined.pdf
[21]http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/sjr_selenium/comments092210/susan_moore.pdf see page 2 of the PDF
[22]http://www.swrcb.ca.gov/rwqcb2/water_issues/programs/TMDLs/northsfbayselenium/Species_at_risk_FINAL.pdf, accessed 4/20/11.
[23] http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4415 see EPA comments pg 5 of 40 of the PDF.
[24] http://www.waterboards.ca.gov/centralvalley/water_issues/grassland_bypass/
http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/sjr_selenium/comments092210/susan_moore.pdf
[25]

http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/Presser_etal_GBP_monitoring_plan_1996.pdf and see USFWS comments and EPA comments RE USBR NEPA Document at http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4415
[26] http://pubs.acs.org/doi/abs/10.1021/es900828h
[27] http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4415 see USFWS comment pg 33 of 40 of the PDF.
[28]http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/Presser_etal_GBP_monitoring_plan_1996.pd @ pg 81 of the pdf.
[29]http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/Presser_etal_GBP_monitoring_plan_1996.pdf @ pg 15 of the pdf
[30] November 3, 1995 Letter From USBOR, USFWS, US EPA and San Luis Delta Mendota Water Authority to Karl Longley, Chair of the Regional Water Quality Control Board: Re Basin Plan Amendment for the San Joaquin River. *"The Selenium load reductions proposed will not necessarily achieve these water quality objectives by the end of the 5th year, and thus a long-term implementation schedule will be required……It is understood that load reductions of this sort are only a first step and do not fully protect against the environmental impacts which may result from selenium discharges during months when water levels are low in the San Joaquin River*" at pages 3-4.
[31]http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/san_joaquin_se/se_tmdl_rpt.pdf *"Load allocations in this TMDL are established for meeting the selenium water quality objective in the San Joaquin River (SJR) downstream of the Merced River confluence. There would be effectively no allocation of selenium load in the absence of Merced River dilution flows. The source analysis has shown that subsurface agricultural return flows from the Drainage Project Area (DPA) are the primary source of selenium load in the lower SJR Basin….. Attainment of the selenium water quality objective upstream of the Merced River confluence may require significant changes to the DPA discharge, including the relocation of the discharge point."*

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ENDANGERED SPECIES COALITION

food&waterwatch

April 22, 2013

Stacy Brown,
Bureau of Reclamation
South-Central California Area Office
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Sent via FAX and e-mail to: 559-487-5397
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RE: Grassland Bypass Project Revised Monitoring Plan Comments

We oppose adoption of the proposed Monitoring Plan for the Grasslands Bypass Project. The reduction in frequency and locations is insufficient to provide information needed to protect public trust values, endangered species and evaluate compliance with water quality standards. We recommend a vigorous monitoring program that does not hide or understate the ongoing discharge of selenium and other toxins into Mud Slough and the San Joaquin River. We also oppose plans to direct stormwater discharges through the San Luis Drain without a publicly vetted Stormwater Management Plan, which was promised years ago and is still not available.

Since the August 2011 initial announcement of reductions in monitoring for the discharge of pollutants from the San Luis Drain to the San Joaquin River from the Grassland Drainers, there have been further reductions in the frequency of pollution monitoring. [See our August 2011 letter for details- Attachment 1]. The compliance point is still some 30 to 50 miles away from the initial discharge of pollutants and relies on dilution from the Merced River to achieve compliance [See Figure 1]. For over two decades, what was supposed to be a temporary two-year program to divert Westside pollutants to the San Joaquin River and Delta Estuary has received a pollution waiver, allowing lethal levels of selenium to be discharged into Mud Slough North, the San Joaquin River and ultimately to bio-accumulate in the Sacramento-San Joaquin River Delta Estuary [See Figure 2].

Figure 1

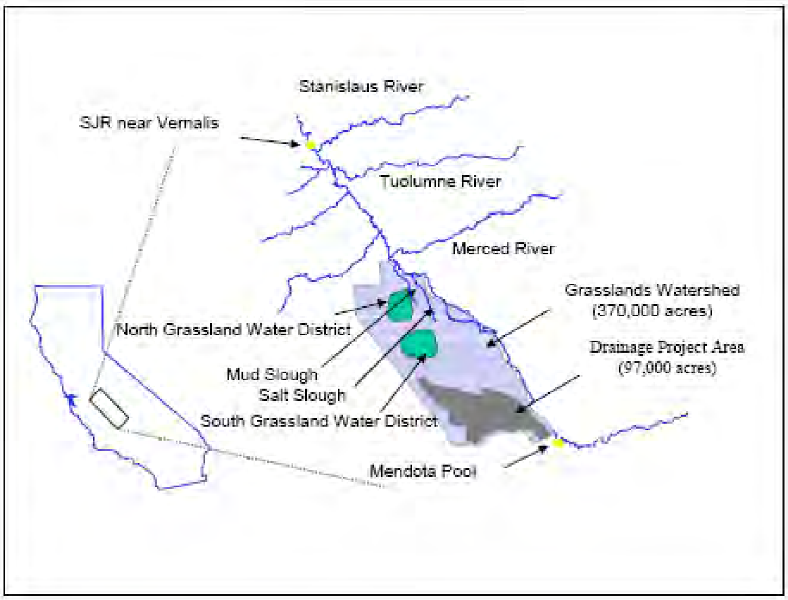
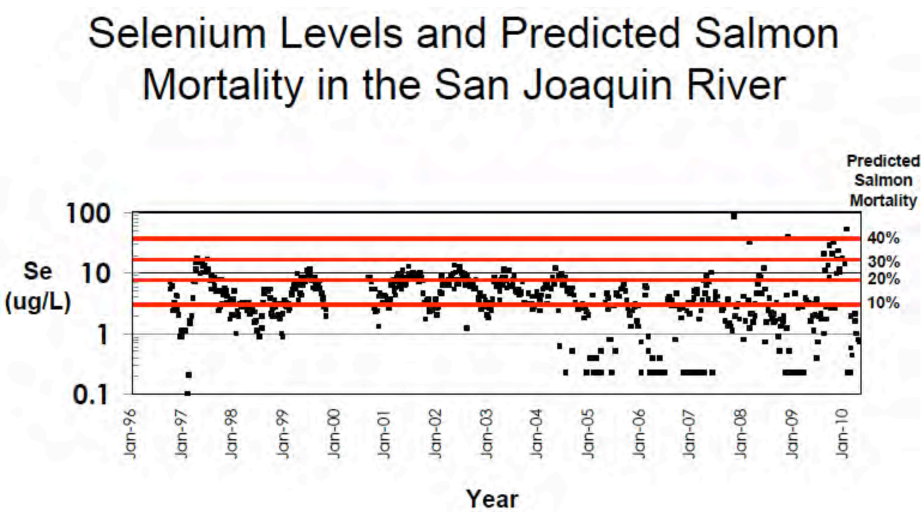


Figure 2



Selenium concentrations measured in the San Joaquin River at Hills Ferry (data from the U.S. Bureau of Reclamation)

Since conception of the project, the key to adopting this transfer of pollutants from Westside drainers to our public water resources rested upon a comprehensive biological, water quality, and sediment monitoring program in order to protect beneficial uses. And yet this monitoring program has been consistently curtailed so that it is likely the data collection will be insufficient to accurately measure and predict the fate of this selenium contamination and other contaminants on downstream uses, including salmon, steelhead and sturgeon facing extinction, other aquatic resources, and ground water supplies.

At the present time, the rationale for these monitoring reductions is insufficient money. And yet the primary source of selenium and other contaminants being discharged is from the drainers in the Drainage Project Area [see Figure 1]. The costs of this monitoring program are part of the contractual agreements allowing this pollution to be transferred to downstream areas. Absent a guaranteed funding stream, this discharge should be stopped per the original 1995 USBR use agreement.

The reduction of monitoring frequency tends to underestimate the pollution and overestimates the "success" of the project as follows:

- The nature of the selenium and other contaminants' variability during any given month, with spikes due to various hydrologic and management events, minimizes or underestimates pollution because there is only a small chance that the important spikes in concentration will be sampled. USBR and the Grassland Drainers regularly collect samples aimed at estimating monthly means, but fail to assess the fate and transport of selenium contamination that is discharged into the San Luis Drain, travels adjacent to state and federal wetlands, then flows into Mud Slough North before being discharged to the San Joaquin River and ultimately to the Delta. This overly simplified approach leaves a major and unacceptable gap in our understanding of where and how ecosystems are exposed to selenium.
- The enforceable concentration standard is some 30-50 miles away from where the high concentrations of selenium are initially discharged, which allows a major stretch of river and sloughs unprotected.
- Monitoring of selenium contamination in sediments proposed for discharge to residential or industrial sites per the 2009 Grasslands Bypass Project Record EIS/EIR (see Attachment 3) is insufficient to protect these areas from selenium contamination and potentially further spreading this contaminant.
- Monitoring stations have been dropped and, in the case of Fremont Ford on the San Joaquin River, the reduction from weekly samples to monthly makes obtaining a meaningful monthly mean improbable.

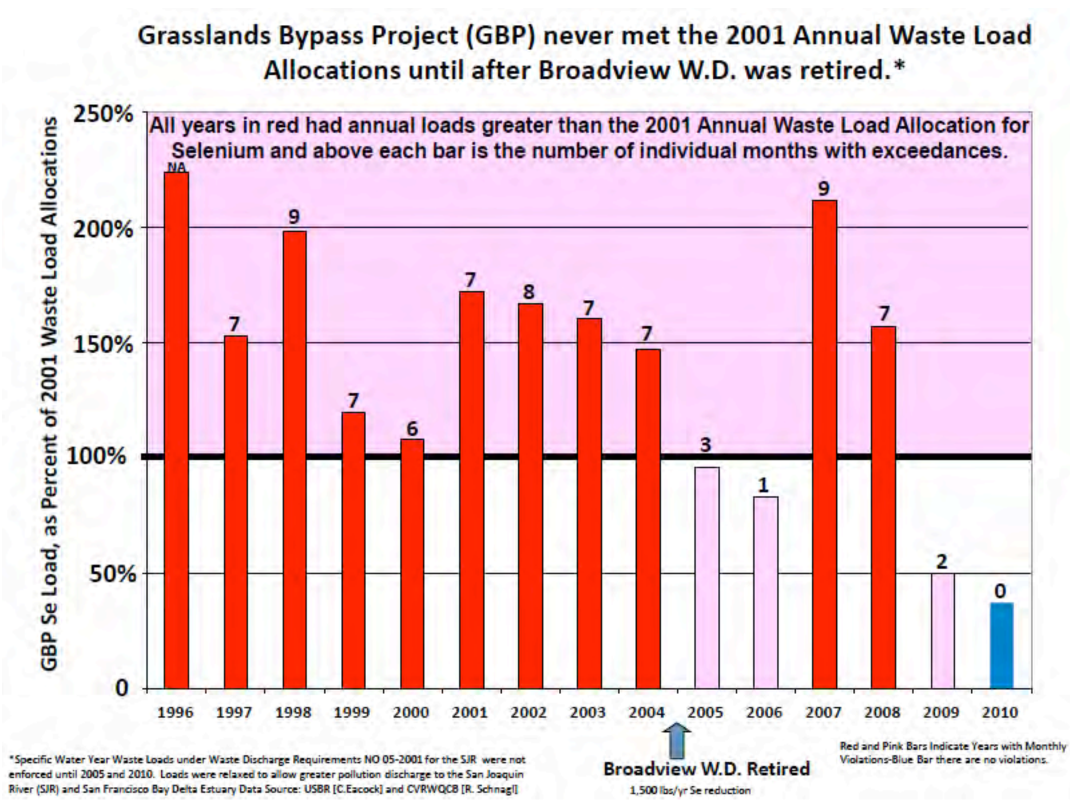
Furthermore, there is no clear commitment from the dischargers and federal government that even this reduced program will be funded sufficiently. This absence of reliable funding support creates an unacceptable level of uncertainty to measure the outcomes of this pollution transfer from one watershed to another.

Other projects related to the Grassland Bypass Project including the discharge of drain waste water to two projects located on land owned by the Panoche Drainage District—The San Joaquin River Improvement Project (SJRIP) and Selenium Treatment Demonstration Project—are not considered in the monitoring program. Monitoring the fate of pollutants in this drain water used to irrigate crops as part of the SJRIP, the inflow and outflow of the Selenium Treatment Demonstration project, and the fate of selenium and other contaminants in treated water used for irrigation is critical to understanding if ground water supplies and plant material are collecting and concentrating selenium along with other pollutants being discharged or treated.

As you can see from Figure 3, most of the success in the reduction of source drainage discharge has occurred through land retirement. The significant progress made in reducing loads is most likely from retirement of 10,000 acres in Broadview and 44,000 acres in Westlands' Northerly area that drains into Grasslands. Extrapolating the savings from the Broadview Contract Assignment EA in 2004, the retirement of 54,000 acres should conservatively result in a reduction of 7,500 lbs. of selenium, 85,000 tons of salt and 260,000 lbs. of boron. Those reduced loads could account for virtually all of the progress made to date in reducing polluted groundwater discharges from Grasslands.

Monitoring to document how the mass balance of pollutants being discharged from the drainage area is largely left out of the analysis. The proposal to utilize the San Luis drain to discharge stormwater from the west side to the San Joaquin River will further compound this transfer of pollution costs to other downstream beneficial uses.

Figure 3



The heart of the problem rests with the fact that the monitoring plan does not have an appropriate success or failure measurement against a specific benchmark. The benchmark or compliance point is downstream of the Merced. While there have been reductions in the wetlands of the Grasslands

Watershed, the gathering and concentrating all this pollution that travels through state and federal refuges and then discharges to the river have exceeded safe levels most of the time.

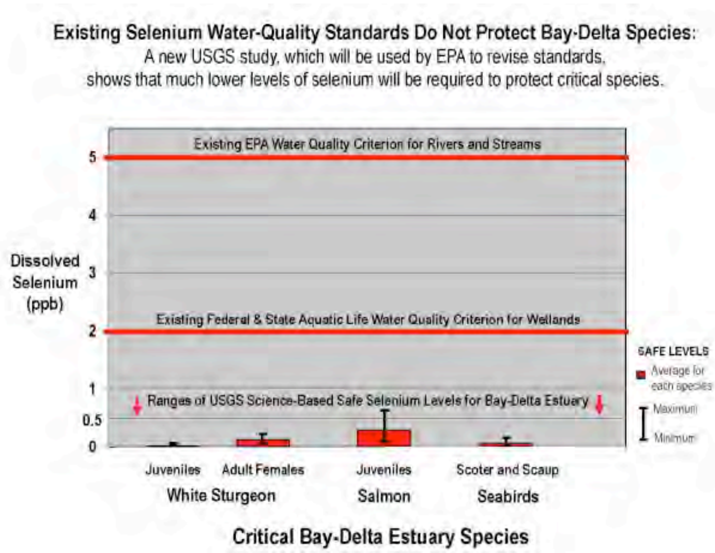
The pledge to have the "data" or monitoring "peer reviewed" does not meet scientific peer review standards. Basically the pledge amounts to relying on a nonprofit group that has a financial stake in continuing the project. Being funded for 20 years by the drainers and USBR to post the data, this group has not had the expertise to peer review it. This is not a scientifically grounded peer review. Basically those polluting will collect and disseminates data which is then posted. These groups, including the dischargers along with the Grasslands Water District, own the data. Many have found that obtaining or conducting an independent analysis of the data that is not biased is difficult.

The United States Geological Survey listed as technical advisors have the expertise to statistically analyze the monitoring program. They are not funded, however, to determine if the reduced frequency of monitoring and relying on means or averages instead of the legally required CWA 4 day average is accurate in reflecting the amount and concentrations of selenium or other contaminants being discharged into the system. The issue is compounded when the program underestimates the amounts by not measuring the peaks of selenium which have been shown to stay in the ecological system for weeks after the event. .

Ironically reduced monitoring for selenium and other Westside contaminants is stated as necessary to save money in order to add monitoring for pesticides and mercury.

In addition to the Monitoring Plan's lack of benchmarks for success or failure, our understanding is that no action will be taken on the discharge of sediments unless they exceed hazardous waste standard of 100 µg Se/g wet weight [see Attachment 3]. Biological impacts of selenium occur at much lower levels than that. A recent study by the U.S. Geological Survey found that existing selenium water quality objectives of 2 µg/l and 5 µg/l respectively, are inadequate to protect aquatic and avian species [see Figure 4]

Figure 4



In addition, monitoring and analysis of the impacts of water transfers from the San Joaquin River Exchange Contractors (SJREC) to other areas should be included. The reduction in tailwater and groundwater in the area is likely to increase the concentration of selenium in water supplies for refuges and other wildlife areas and the canals serving them. One of the key assumptions in the environmental documents for the water transfer program is that the methods used to develop water for transfer will not cause a change in current hydrologic conditions in waterways. Reclamation committed in the most recent SJREC Water Transfer Program environmental document to conduct a formal coordination process to identify other programs that could significantly affect the assumptions or effectiveness of the water transfer program including the following:

- The Westside Integrated Resources Plan
- Various CVP yield improvement studies
- Land retirement studies and implementation
- San Luis Drainage Feature Re-evaluation Drainage Program implementation
- Grassland Bypass Project and related studies
- All components of the San Joaquin River Restoration Program, as described in the San Joaquin River Settlement Act and related Stipulation for Settlement, including but not limited to Restoration Flow releases and measures taken for the protection, recirculation, and recapture of Restoration Flows.

The addition of a single annual monitoring sample for selenium at the China Island State Refuge is largely ineffective in accurately predicting the impacts to that section of the river. The discharge of contaminants in San Joaquin River from Mud Slough and the Merced River will remain largely unknown under the proposed monitoring reductions.

We find the proposed monitoring plan lacking in both comprehensiveness and scientific rigor. Instead of providing information about toxic discharges of selenium and other toxins, and their environmental fate in the hydrologic system, it will mask their impacts on the environment.

Sincerely,

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Attachment 1- August 2011 Coalition Letter on GBP Monitoring
Attachment 2- September 2011 Coalition Letter on exclusion of public
Attachment 3 Sediment Management Plan From Appendix B of the Final EIS/R for the Grasslands Bypass Project, p 4-1

Attachment 1

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Planning and Conservation League

Sierra Club California
Friends of the River
NORTH COAST RIVERS ALLIANCE
california water impact network

PCFFA Stewards of the Fisheries
California Sportfishing Protection Alliance CSPA Since 1983
Center for Biological Diversity Because life is good.
Northern California Council Federation of Fly Fishers

SalmonWaterNow Working to make what is wrong, right again
AquAlliance Defending Northern California Waters
Restore the Delta Fishable, Swimmable, Drinkable, Farmable by 2010

August 11, 2011

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Re: Opposition to the Proposal to Curtail Monitoring at the Grassland Bypass Project

Dear Grassland Bypass Project Data Collection & Review Team and Oversight Committee:

The undersigned groups oppose reductions in the monitoring program for the Grassland Bypass Project and, furthermore, recommend a comprehensive reassessment of the need for enhanced monitoring and scientific evaluation. We can see no technical justification or rationale for this reduction in monitoring for a project that has exceeded water-quality objectives and standards for more than fifteen years. We urge the Oversight Committee to reject this unjustified reduction in monitoring and require a reassessment of monitoring and study needs in view of the historical experience with the Grasslands Bypass Project and the long-ignored scientific recommendations of the United States Geologic Survey (USGS) and others to take a systematic, mass-balance approach to understanding the impacts of selenium and other contaminants from the Project. The discharge of selenium and other contaminants in excess of Federal and State water-quality standards threaten populations of Salmon, Steelhead, and Sacramento Splittail, as well as the waterfowl and wildlife resources of the State and Federal National Wildlife Refuges in the area. At the proposed concentrations, mortality of Chinook salmon, steelhead, Sacramento Splittail, waterfowl, and other wildlife are predicted in or adjacent to Mud Slough, the San Joaquin River, and the Delta Estuary. (See Figure 6)

We appreciate the opportunity to comment upon the United States Bureau of Reclamation (USBR) and San Luis Delta Mendota Water Authority (SLDMWA) draft monitoring proposal pending before the Data Technical Committee. The draft proposal would curtail the monitoring program for the discharge of selenium, salt, boron and other contaminants being drained into Mud Slough and the San Joaquin River, using the Federal San Luis Drain as the wastewater collection and discharge conduit. The monitoring proposal would reduce the frequency of monitoring for critical contaminants and supporting parameters at various sites, with no technical justification or analysis of increased bias and uncertainty in tracking water-quality compliance and Project effectiveness. These reductions will mask the pollution spikes in the watershed, river and estuary and provide insufficient data needed to model impacts to the

San Joaquin River and the Delta Estuary. These deficiencies have been previously outlined by the scientific community, but continue to be ignored.

In a declaration before the United States District Court for the Eastern District of California filed by Mr. Glaser, Mid-Pacific Region Director, USBR, on April 1, 2011[1], Mr. Glaser and USBR reported, "On February 16, 2010, the Regional Board staff announced that it would no longer conduct water quality monitoring at twelve sites for the GBP, because of funding and staffing shortage. In addition, staff for the California Department of Fish and Game expressed doubts that they could continue biological monitoring for the project due to staff losses. Reclamation is working with other agencies to revise the Project's monitoring program, and will assign staff and seek funding to assure that the water quality and biological monitoring requirements are met."[2]

Operating under State of California Waste Discharge Requirements (WDRs), USBR and SLDMWA (Dischargers) have transported selenium and other contaminants from the San Luis Drain to the San Joaquin River starting in 1995 as a "temporary" two year project that was next extended to 2000, and then again extended to 2009, and recently extended again to 2019.(See Figure 1) USBR data document that, from 1996 to 2008, the dischargers have dumped 85,954 lbs of selenium, 25,251,000 lbs of Boron and 9,772,610 tons of salt to Mud Slough, the San Joaquin River, and the Delta Estuary.[3]

Even before 1995, these Dischargers drained selenium and other contaminants from the San Luis Drain, via Mud Slough to the San Joaquin River actually began under two Clean Water Act National Pollutant Elimination System (NPDES) permits.[4] (See Figure 1) Under those permits the selenium pollution controls and monitoring frequencies were much stronger. The compliance monitoring took place at the point of discharge not some 30 miles downstream. And concentrations at the point of discharge were much lower for Mud Slough (north) along with concentrations measured in the San Joaquin River monitoring sites. First, in November of 1987, USBR was allowed to drain the Kesterson ponds via Mud Slough into the San Joaquin River. A second NPDES permit to discharge selenium contaminated groundwater was issued to the Dischargers, USBR and SLDMWA, in March of 1996, where toxic drainage and ground water discharged also had similar monitoring and water quality compliance requirements.[5]

Under the previous and present permits Dischargers use sumps and pumps to move groundwater collected from subsurface drainage systems, which collect contaminated groundwater from as deep as 100 feet drawing from contaminated water from basically horizontal groundwater wells some 50- 100 feet in depth[6] to collect pollution from over 97,000 acres and discharge toxic contaminants that exceed federal and state water quality standards, violate the Sacramento-San Joaquin Valley Basin plan, degrade beneficial uses, and create a nuisance and burden for downstream users to clean up, thus passing these environmental hazards and treatment costs to downstream users.

What is the rationale for curtailing monitoring?

Repeated requests to develop a comprehensive and effective monitoring program for the Grasslands Bypass Project have not been acted upon.[7] There has been a consistent failure to develop monitoring to determine the fate and transport of selenium and other contaminants in the food chain where it's magnified effects result in a narrow window of exposure before mortality. Despite the lack of monitoring, selenium concentrations in avocet and stilt eggs at the Grasslands Drainers' reuse area have been found to exceed those found at Kesterson National Wildlife Refuge![8] Further the project has failed to track the selenium loading from the Grassland Drainage Area into the San Joaquin River, the Sacramento-San Joaquin Delta and the North Bay (e.g. Suisun Bay), as required in the 2001 Record of Decision for the GBP.[9] Biological monitoring and impacts especially to coldwater fish have not been monitored.[10] For example 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, are not sampled there. Selenium is being exported to southern California's water supplies through the California Aqueduct threatening drinking water quality and likely is accumulating in fish and reservoirs in Southern California as a result.[11]

Also the GBP has failed to monitor and consider the long term impacts of discharging selenium through wetland and slough areas adjacent to federal and state wildlife refuges, the San Joaquin River and Delta Estuary.[12] This history of inadequate monitoring and insufficient scientific assessment will be made far worse if the proposed reductions in monitoring are allowed. We find absolutely no evidence that the proposed reductions are based on documented scientific analysis.

Models Accurately Document an Ongoing Failure to Meet Water Quality Standards in the San Joaquin River and Mud Slough (North) and Continue to Impair the Bay-Delta.

Since 1994, models used to establish the amount of selenium loads to be discharged to the San Joaquin River and Delta Estuary have accurately documented that these loads of pollution do not meet Federal and State standards for minimal protection of water quality.[13] [See Figures 3-5] Moreover, since 2000 the load models used have even been modified to permit greater discharges of pollution without triggering a violation. These modifications include relaxing criteria for violation rates, choosing a monthly mean instead of a 4 day average, and changing the water years.[14] Environmental Defense Fund estimates the change from the four-day flow averaging period to a one month averaging period resulted in a 21 percent to 44 percent increase in allowable loads.[15] "If implemented as an interim compliance, this change in the averaging period would be expected to cause numerous violations of the water quality standards. Similarly, relaxing the once-in-three year excursion rate to a once-in five-month per year rate resulted in a significantly higher allowable load."[16] These predicted violations have proven accurate.[17] Using similar calculation assumptions, USBR figures for 2009-2019 predict violations also for the continued loads of pollution allowed.[18] The dischargers use these generous load targets and the ability to meet them as a sign of success. The fact remains, however, that they fail to meet safe concentrations in the Mud Slough (north) wetland channels through State and Federal Wildlife Refuges and concentrations remain extremely high in Mud Slough (north) and in the San Joaquin River above the compliance point measured some 30 miles away. Along with the violations of the federal and state water quality standards, concentrations of selenium in fish and wildlife also remain high. Scientists predict a high mortality for coldwater fish such as salmon and green sturgeon from these concentrations.[19]

The San Joaquin River downstream of the Merced River has been delisted as water quality impaired because of dilution water from the Merced River, weak standards and inadequate monitoring mentioned above. The selenium contamination, however, continues to drain into the Bay-Delta with predictable results. The Clean Water Act Section 303(d) list of water quality limited stream segments lists 41,736 acres in the Delta, 5,657 acres in the Carquinez Straights, 70,992 acres in San Francisco Bay Central, 9,024 acres in San Francisco Bay south and 68,349 acres in San Pablo Bay as impaired by selenium.[20] The west side discharges are a major source of those water quality impairments.[21] Health advisories are in effect for scaup, scoter and benthic feeding ducks in many of those areas.

A study by the U.S. Fish and Wildlife Service[22] for USEPA identified that several bird species protected under the Migratory Bird Treaty Act (MBTA) are considered "species most at risk" from selenium contamination in the San Francisco Bay. Greater scaup, lesser scaup, black scoter, white-winged scoter, surf scoter and bald eagle are listed as "species most at risk" from selenium contamination and all are covered by the Migratory Bird Treaty Act (MBTA). By allowing continued discharges of selenium in excess of Basin Plan objectives from the Grasslands Bypass Project, there is downstream contamination and selenium bioaccumulation in the Bay-Delta, and increasing likelihood of MBTA and ESA violations by the United States.

Government Scientists Have Criticized the Existing Monitoring Program and Proposed Reductions Further Erode Protection of Public Resources

EPA has urged the development of a comprehensive monitoring program if the project is extended.[23] USFWS comments have identified numerous monitoring deficiencies with regard the fate and transport of selenium and the long term effects on especially on coldwater fish, wildlife and endangered species.[24]

In 1996 USGS scientists provided the Oversight Committee with a comprehensive critique of the proposed monitoring plan, developed in cooperation with USBR. [25] Many of USGS comments still apply. They include recommendations for assessing the fate and transport of selenium in the project area; evaluation of selenium in sediment and its transport; evaluation of suspended particulate forms of selenium from the discharges; and for better biological and water quality monitoring. One of the main findings of the USGS review is that a monitoring program and study is needed to evaluate the mass balance of SE that includes the dissolved and suspended particulate forms of selenium. This continuing lack of comprehensive monitoring for the management of selenium contamination is also echoed in a recent scientific article, by Luoma & Presser 2009:[26]

"Uncertainties in protective criteria for Se derive from a failure to systematically link biogeochemistry to trophic transfer and toxicity (Figure 1). In nature, adverse effects from Se are determined by a sequence of processes (12). Dilution and redistribution in a water body determine the concentrations that result from mass inputs. Speciation affects transformation from dissolved forms to living organisms (e.g., algae, microbes) and nonliving particulate material at the base of the food webs. The concentration at the base of the food web determines how much of the contaminant is taken up by

animals at the lower trophic levels. Transfer through food webs determines exposure of higher trophic level animals such as fish and birds. The degree of internal exposure in these organisms determines whether toxicity is manifested in individuals. Se is first and foremost a reproductive toxicant (both a gonadotoxicantanda teratogen): the degree of reproductive damage determines whether populations are adversely affected. Adverse effects on reproduction usually occur at lower levels of exposure than acute mortality, but such effects can extirpate a population just as effectively as mortality in adults."

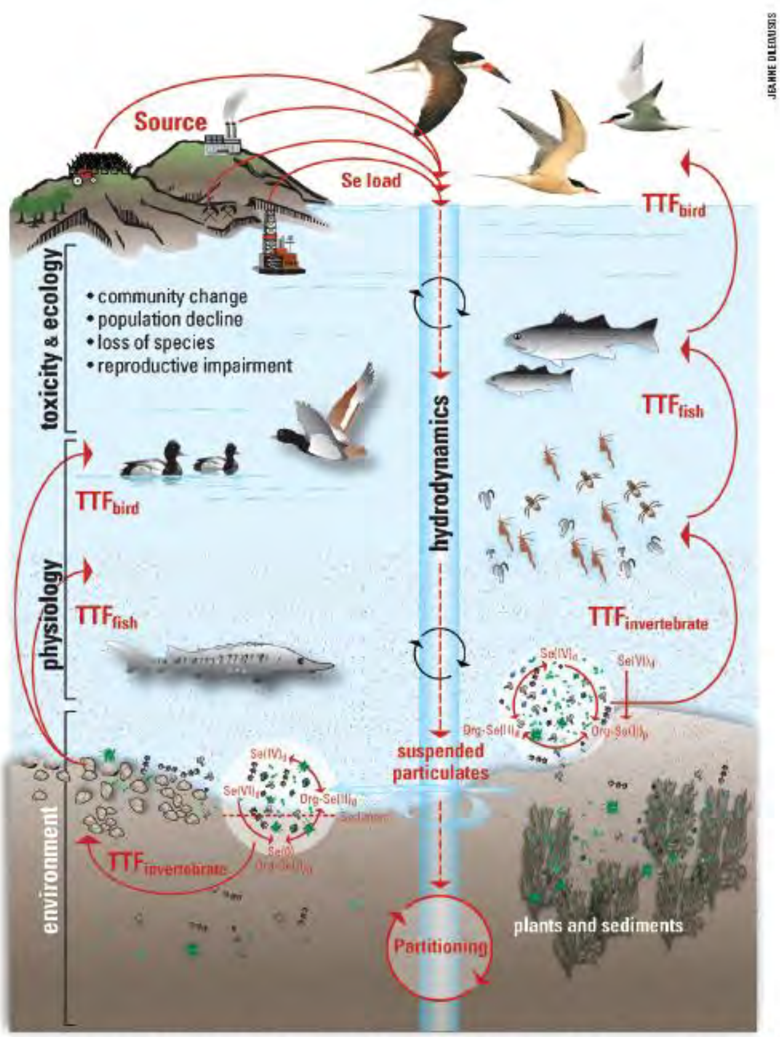

FIGURE 1. Conceptual model of Se fate and effects emphasizing the roles of speciation, biogeochemical transformation, and trophic transfer factors in modeling two aquatic food webs: a water column food web and a benthic food web. TTF = trophic transfer factor. Subscript d means dissolved, subscript p means particulate.

As of 2007 an estimated 222,025 cubic yards of sediment has accumulated in the San Luis Drain.[27] This is nearly a four-fold increase over the original 55,788 cubic yards of sediment that were recommended for removal at the beginning of the project, but never carried out.[28] Also contained in the USGS report on the Review of the Grassland Bypass Channel Project Monitoring Program is the following assessment of the entire monitoring program: “The original Monitoring Plan is not adequate because it does not account for all appropriate sources and sinks of selenium, salt, and boron within the GBCP area and because the sampling design does not adequately address temporal, width, and depth variability in chemical concentrations and loads.”[29] These contaminated sediments and suspended particulates in the water pose a toxic danger in the Drain, as well as, in Mud Slough and the San Joaquin River, that continue to grow and the proposed reductions in monitoring do not remedy these problems and shortcomings.

Conclusion: Continued Monitoring and a More Rigorous Approach are Necessary to Protect the Public Interest and Water Quality.

Rather than reduce monitoring, as proposed, we urge a substantial increase in the current 2001 monitoring plan to ensure compliance with state and federal law, while at the same time immediately initiating a comprehensive, peer-reviewed reevaluation of the monitoring program and the amounts of selenium being discharged under the current Total Maximum Daily Load (TMDL) and WDRs implementing the TMDLs. As noted in the November 3, 1995 agency letter, “There is no commitment, at this time, to approve long-term use of the Drain.”[30] Further in 2001 the Regional Board staff reported, “If monitoring demonstrates that the water quality objectives are not being met then additional load reductions or amendments to the TMDL will be required.”[31] As noted previously and documented in figures 3-5, discharges exceed federal and state water quality standards. The Waste Discharge Requirements and compliance monitoring need to be strengthened not relaxed.

Based on current science, the continued extension of discharges from the Grasslands Bypass Project make it more important than ever to ensure that a long-term monitoring and scientific assessment finally address the impacts of the Project and the realistic chances of future reductions in contamination. Please add us to any notifications regarding changes in the monitoring program or waste discharge requirements.

Sincerely,

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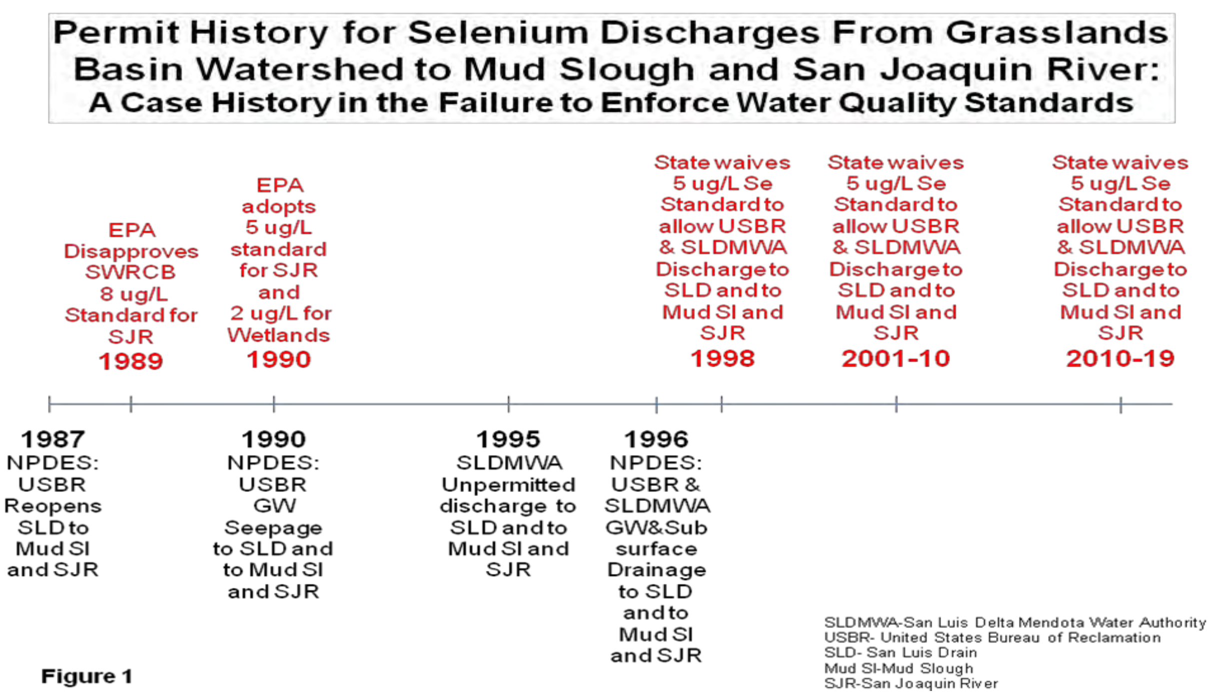

Figure 1

Attachment 2

Southern California Watershed Alliance

food&water watch

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Sierra Club California

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NORTH COAST RIVERS ALLIANCE

california water impact network

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PCFFA
STEWARDS OF THE FISHERIES

California Sportfishing Protection Alliance
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Since 1983

SalmonWaterNow
Working to make what is wrong, right again

AquAlliance
Defending Northern California Waters

September 7, 2011

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RE: Closure of Grassland Bypass Project (GBP) Data Collection and Review Team (DCRT) Meetings to Selected Members of the Public

Dear Commissioner Connor:

Late Friday, September 2, 2011, we were informed by Reclamation's Chair of the Grassland Bypass Project's Data Collection and Review Team (DCRT) that "outside observers" will be barred from the meetings of these public agencies who oversee the monitoring of the GBP. This action seems arbitrary and designed to exclude those most impacted by pollution caused by the GBP—the conservation, fishing and community groups advocating for water quality downstream from the discharge.

No rationale was provided as to why these meetings suddenly need to be held in secret, behind closed doors, excluding only selected members of the public, while others are granted access. For example, consultants for the dischargers, the San Francisco Estuary Institute, lawyers for the Grassland Drainers, and others, are given access.

The DCRT email indicates that "Policy documents developed by the DCRT relating to the program's implementation are subject to both scientific and public review prior to approval by the GBP Oversight Committee." We cannot find evidence in the public record to support this contention, especially with regard to critical monitoring changes made over the last decade. For example, monitoring changes recommended by the DCRT were implemented for several years without Oversight Committee approvals,[1] or at least no public record has yet been made available regarding such approvals.[2] The public record indicates that only one Oversight Committee meeting was held from 2000 to 2010.[3]

In October 2010,[4] at the hearing before the State Water Resources Control Board, where another decade-long pollution waiver was granted, commitments were made to allow interested parties access to the proceedings of these various technical and monitoring committees. Since that time, several members of the public have monitored the meetings. On August 2, 2011, the DCRT requested comments by August 12, 2011, regarding the proposed "Interim Water Quality Monitoring Program." We responded by the due date.[5] It appears that this critical look at the proposed monitoring program triggered a backlash, whereby, certain members of the public henceforth will be excluded from these meetings of public agencies. In particular, C-WIN's Tom Stokely, noted significant discrepancies in the proposed request for expending a half a million dollars on a Panoche Water District source canal lining project. The claim of reducing selenium by some 1000 lbs was later revised to 100 lbs. Clearly, in the public interest, these plans need this kind of careful scrutiny.

It appears that the DCRT wants to exclude downstream interests from observing these data collection and reporting meetings where, at least in the past, monitoring changes have been recommended and implemented without Oversight Committee review or approval. Closing the door to the public, and especially to those most impacted by the discharge of this pollution, is arbitrary and without merit. A double standard is created whereby those with interest in continuing the toxic discharges are allowed access, while those impacted are excluded.

As noted in our correspondence of August 12, 2011, we remain concerned that the toxic discharges of this project are neither adequately regulated nor monitored.[6] Some of the "proposed" reductions in monitoring are already being implemented. For example, selenium concentrations at various sites on the San Joaquin River, including its mouth at Vernalis, are no longer monitored. No one is charged with doing an integrated analysis of the consequences of this project on the San Joaquin River, source water and Bay-Delta Estuary. The establishment of the Oversight Committee[7] and this hierarchy committee structure amounts to a mirage of oversight and lacks the checks and balances promised. It appears that the dischargers of this toxic pollution have made a calculated bet that this "Hodge Podge" of consultants, miscellaneous reports, and volumes of uninterrupted raw data, will obscure the impacts. And, when damage occurs, they will have the concurrence of state and federal regulators to insulate them from the costs of clean up and damages. Barring the public from observing the process further creates a barrier to insulate these polluters.

New government studies[8] indicate that safe levels of selenium need to be up to 50 times less than the current water quality objectives sanctioned for the San Joaquin River flowing into the Bay Delta Estuary.[9] (See Attachment A) State regulators have determined almost all this toxic selenium comes from the west side of the San Joaquin Valley.[10] Recent federal reports document this toxic selenium pollution is showing up in source water below the federal export pumps at the terminus of the Delta Mendota Canal in the Mendota Pool at levels exceeding water quality objectives adopted to protect beneficial uses.[11]

We urge you to take action to ensure the Grassland Bypass Project "team meetings" are open to public observers, including both the Data Collection and Review Team and the Technical and Policy Review Team. Continuation of secret, closed door meetings, largely directed by the dischargers, creates a cozy regulatory environment where pollution impacts are thrust upon downstream users to treat and clean up, In the case of selenium this will cause irreparable harm because of its bio-magnification throughout the food web of the estuary or to fresh water supply exports.

Respectfully submitted,

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Zeke Grader
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Pacific Coast Federation of Fisherman's Federation Association Inc.

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Ren Lohoefener, USFWS, Regional Director
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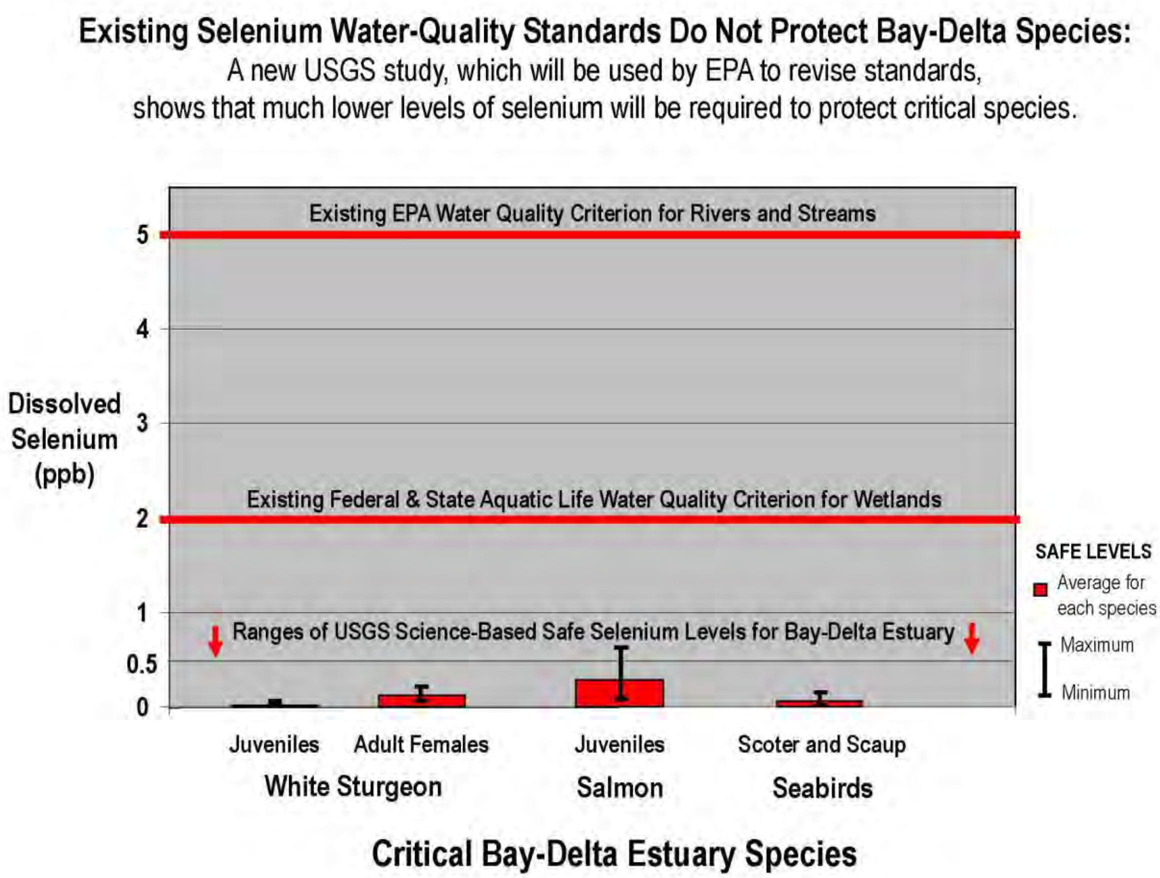
Charlton Bonham, California DFG, Director

Data Collection and Review Team

Interested Parties

Attachment A:



Since 2002, under the Clean Water Act, Section 303, and the Endangered Species Act, the United States Environmental Protection Agency (EPA) has been required to adopt acute and chronic aquatic life criteria for Selenium taking into account the bioaccumulation of this contaminant as it magnifies throughout the food chain often causing reproductive failure, teratogenic effects and death. The terms and conditions also included reevaluating and revising selenium criteria for the protection of semi-aquatic wildlife. The just released peer reviewed United States Geological Survey (USGS) study, also part of the terms and conditions, models the fate and transport of selenium in the San Francisco Bay-Delta Estuary and as agreed, the report will serve as the basis for revised water quality criteria for the protection of wildlife species. http://www.epa.gov/region9/water/ctr/

*** The above graph prepared by CSPA & CWIN is directly based on the results from the U.S. Geological Survey (USGS) study. http://www.epa.gov/region9/water/ctr/selenium-modeling_admin-report.pdf The USGS study evaluated a series of selenium exposure scenarios using a set of specific guidelines and modeling choices from the range of temporal hydrodynamic conditions, geographic locations, food webs, and allowable dissolved, particulate, and prey Se concentrations (which we have referred to as "safe levels"). According to the USGS, "The specificity of these scenarios demonstrates that enough is known about the biotransfer of Se and the interconnectedness of habitats and species to set a range of limits and establish an understanding of the conditions, biological responses, and ecological risks critical to management of the Bay-Delta".

The following scenarios were evaluated by USGS for a range of hydrologic conditions and residence times (See Tables 17, 18 and 19 in the USGS report):

- *Predicted allowed dissolved Se concentrations for Bay-Delta transects at different effect guidelines and associated levels of protection (USFWS, 2009b) for a suspended particulate material>C. amurensis>sturgeon food web.*
- *Predicted allowed dissolved Se concentrations for Bay-Delta transects at different effect guidelines and associated levels of protection (USFWS, 2009b) for a suspended particulate material>C. amurensis>clam-eating bird species food web.*
- *Predicted allowed dissolved Se concentrations for landward transects at different effect guidelines and associated levels of protection (USFWS, 2009b) for a suspended particulate material>aquatic insect>juvenile salmon food web.*

The CSPA-CWIN summary graphic of this data shows the results for critical Bay-Delta species, aggregated across all combinations of target tissues (eg. Whole body, eggs, or diets) that have known levels of concerns, as summarized by the U.S. Fish and Wildlife Service. Results are also combined across all hydrologic conditions for each species.

The ranges of "allowable" or safe levels of dissolved selenium clearly show that, although EPA will need to specify exact safety levels, flow conditions, and species, new standards for the Bay-Delta will need to be substantially less than 0.5 parts per billion dissolved selenium to be protective.

Endnotes:

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[1]http://www.swrcb.ca.gov/centralvalley/water_issues/swamp/water_quality_reports/gbp_04_05_wq_chptr.pdf

"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, and 2004). Prior to August 2003, nutrient samples were collected at Stations B and D as part of a research program external to the GBP water quality monitoring program. In an effort to minimize program costs, the DCRT agreed to incorporate that data into the water quality monitoring program. Frequently, due to reasons outside of the control of the DCRT, these data were unavailable. In August 2003, in an effort to prevent this loss of data, routine collection of nutrient samples at Stations B and D was assumed by the CVRWQCB.

DCRT Proposed monitoring changes in 2005:
http://swrcb2.swrcb.ca.gov/centralvalley/board_decisions/tentative_orders/0504/gbp/gbp-staff-report-3.pdf

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. See http://www.usbr.gov/mp/grassland/documents/monitoring_program_phase_2.pdf

[2] Sierra Club California, California Water Impact Network, Friends of the River, the Southern California Watershed Alliance and the California Sportfishing Protection Alliance filed A Freedom of Information Act request on August 3, 2011, for the times, places, agendas, meeting notes and attendees for the Grassland Project Oversight Committee meetings from 2000-2010. We were informed the request was "complex" and thus is in the "QUE" behind 18 other complex requests and likely will not adhere to the 20-day response period.

[3]http://legacy.sfei.org/grassland/reports/gbppdfs/AnnualReports/GBP%20Annual%20Report%200405.pdf

[4] http://calsport.org/cspa_files/CSPA_CWIN-SJR%20SeleniumCont.pdf

[5] http://www.pcl.org/files/GrasslandMonitoring.pdf

[6] *"In 2003, a series of events led to a worst-case scenario in one field within the SJRIP. A channel broke …. Water collected in one end of the field and remained for several weeks (late April through mid-May) during the nesting season. Eggs were collected, as they have been since 2001, but because there was standing water present, more nests were observed than had been in previous years. These eggs were found to have selenium at concentrations similar to egg concentrations found in Kesterson years earlier. Subsequent conversations with US Fish & Wildlife Service confirmed that at these concentrations, embryo viability would be severely compromised. A "take" had occurred."*
http://swrcb2.swrcb.ca.gov/centralvalley/board_decisions/tentative_orders/0504/gbp/gbp-staff-report-3.pdf
http://www.calsport.org/7-23-08.pdf

http://www.swrcb.ca.gov/rwqcb5/water_issues/grassland_bypass/usfws_att_d.pdf Deformed embryos found at the project in 2008 with selenium content of the egg greater than 70 ppm, greater than Kesterson levels.
High Selenium concentrations in eggs found 2003-2006
http://www.lloydgcarter.com/files_lgc/Drainage%20letter.pdf

[7] "*The GBP Oversight Committee (OC) consists of representatives from USBR, USFWS, CDFG, CVRWQCB, and USEPA. The role of the OC is to evaluate overall operations of the GBP, to assess monetary charges to SLDMWA for selenium loads exceeding those specified in the UA II, and to act on other issues brought to them by the Technical and Policy Review Team (TPRT) and/or the public. Specific charge or mission to the OC is found in the UA II.*"
http://www.usbr.gov/mp/grassland/documents/monitoring_program_phase_2.pdf

[8] http://www.epa.gov/region9/water/ctr/

[9] http://www.c-win.org/webfm_send/188

[10] http://swrcb2.swrcb.ca.gov/centralvalley/board_decisions/tentative_orders/0504/gbp/gbp-staff-report-3.pdf "*The WDRs for the project state "During water year 2000, releases from the (San Luis) Drain contributed 97% of the selenium, 55% of the boron, 36% of the salt and 13% of the volume of water discharged to the San Joaquin River from the Grassland Watershed*."

[11]https://www.c-win.org/selenium-press-room.html
http://www.c-win.org/webfm_send/187 & http://www.c-win.org/webfm_send/186

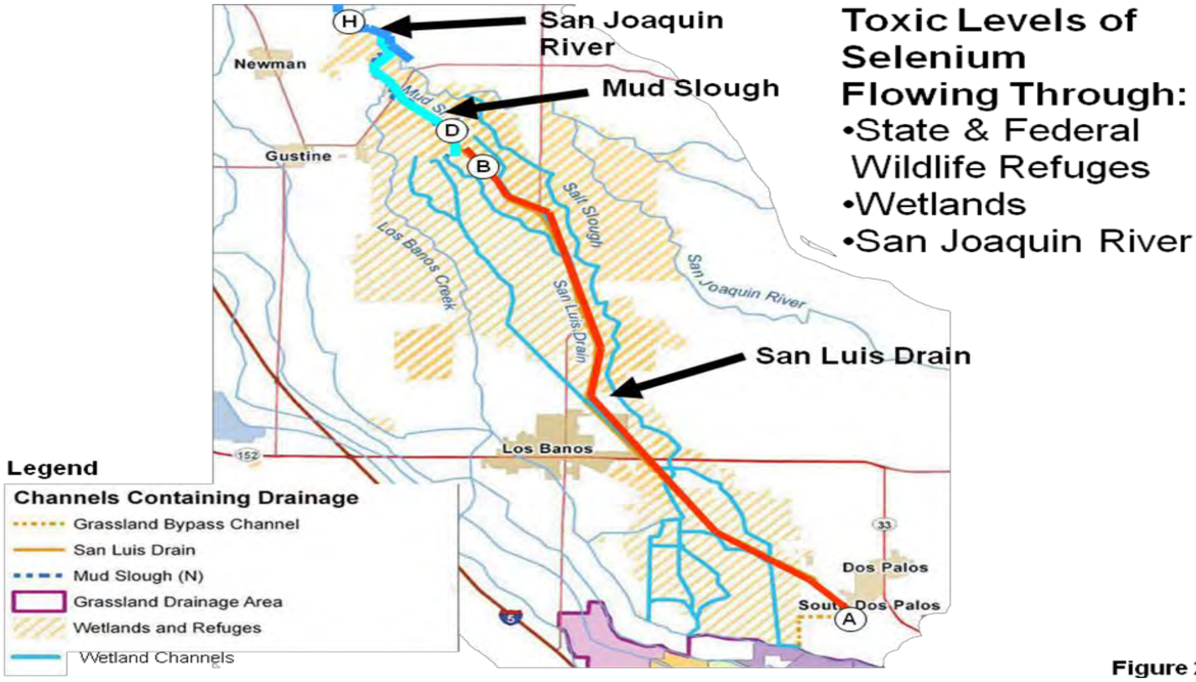


Figure 2

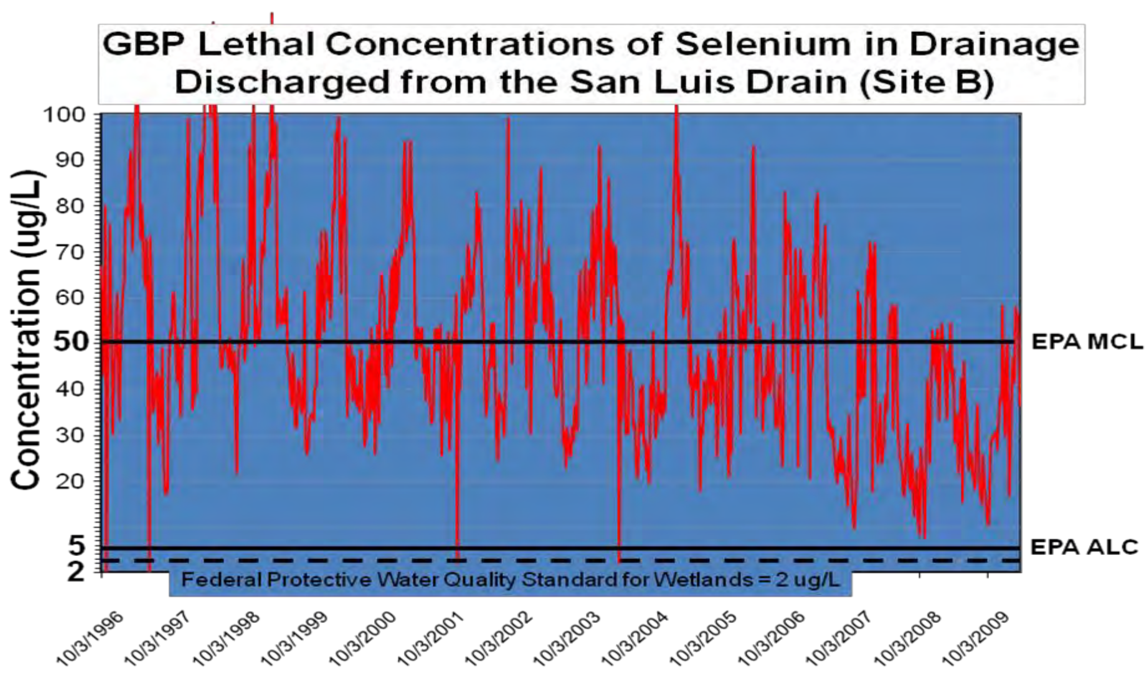


Figure 3

Data from USBR-Eacock MCL=Maximum Contaminant Level for Drinking Water ALC=Aquatic Life Criterion

GBP Lethal Concentrations of Selenium in Mud Slough (Site D) Through State and National Wildlife Refuges

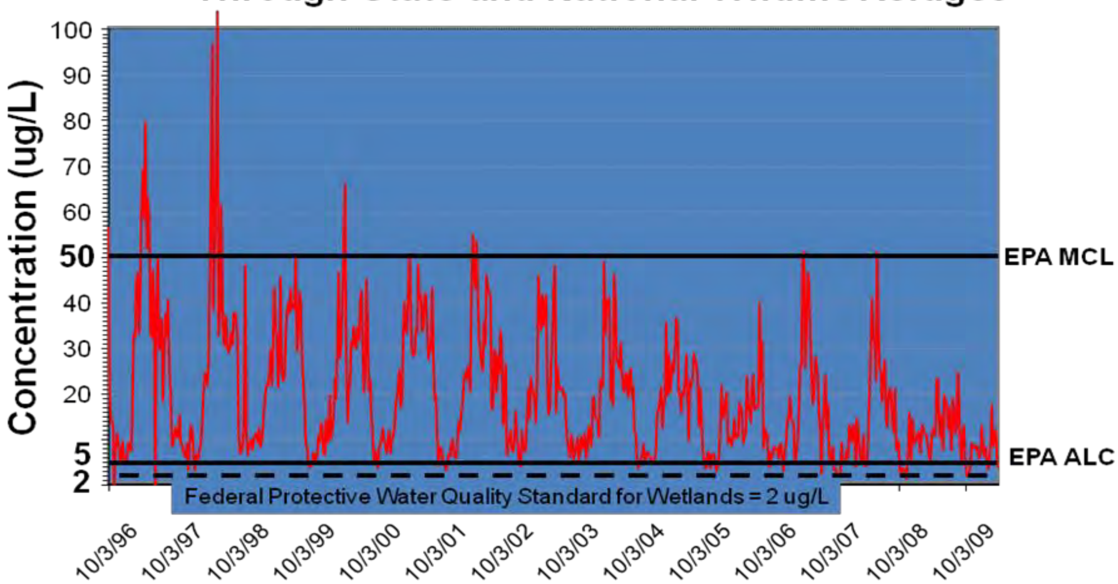


Figure 4

Data from USBR=Eacock MCL=Maximum Contaminant Level for Drinking Water ALC=Aquatic Life Criterion

GBP Lethal Concentrations of Selenium in San Joaquin River (Site H) Downstream of Mud Slough

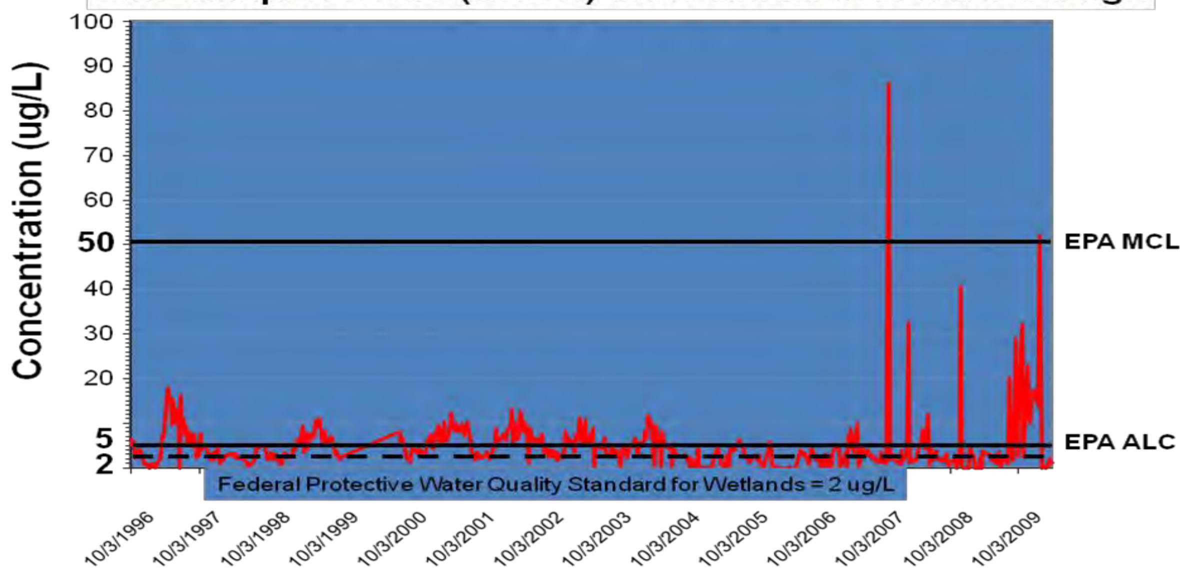
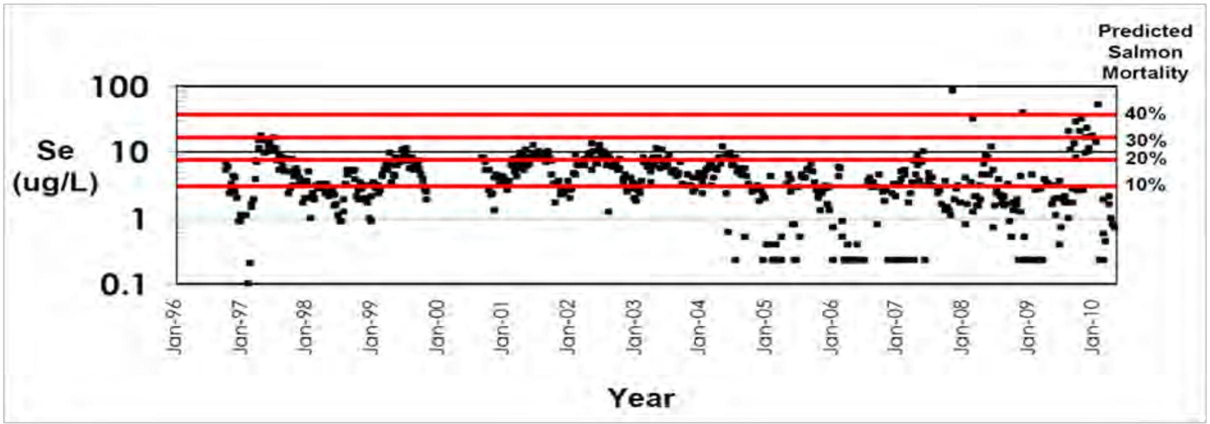


Figure 5

Data from USBR Eacock MCL=Maximum Contaminant Level for Drinking Water ALC=Aquatic Life Criterion

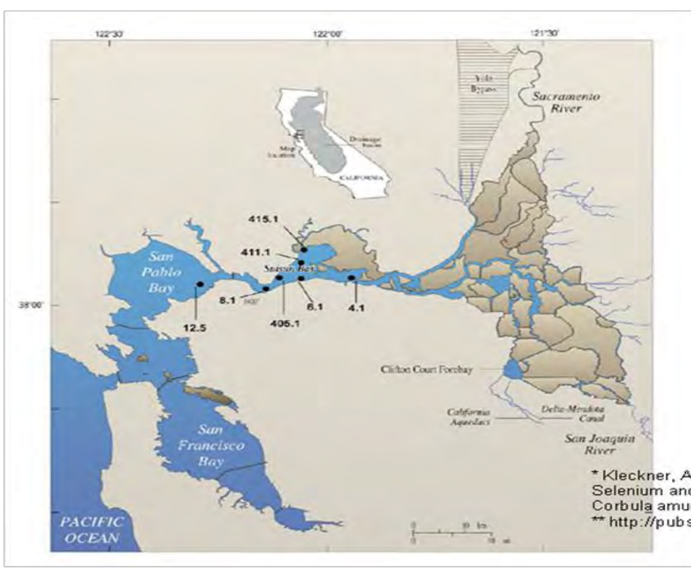
Selenium Levels in the San Joaquin River are not Safe for Salmon



Selenium concentrations measured in the San Joaquin River at Hills Ferry (data from USBR [Eacock]and USFWS [Maurer & Beckon])

Figure 6

Selenium Impacts in Bay-Delta



Unsafe levels of Selenium concentrations found in Suisun Bay and Northern San Francisco Bay 2 to 22 ppb.*

Selenium loads per day from Westside irrigators contribute approximately 10 to 30 times daily selenium load compared to the Sacramento and Oil refineries combined.**

* Kleckner, A.E., Stewart, A.R., Elrick, K., and Luoma, S.N., 2010, Selenium and stable isotopes of carbon and nitrogen in the benthic clam Corbula amurensis from Northern San Francisco Bay, California: May 1995b
** http://pubs.usgs.gov/pp/p1646/

Figure 7

ENDNOTES

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[1] Federal Defendants' Status Report of April 1, 2011. Case 1:88-cv-00634-OWW-DLB Document 864 Filed 04/01/11 page 6 & Glaser Third Declaration pg 6-7

[2] Ibid.

[3] http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4418 pg 26 of 66 FEIR/EIS Final EIS/EIR, Private/individual comments Part 2, Grassland Bypass 2010-2019

[4] Order No. 87-201 NPDES No. CA 0082171 Waste Discharge Requirements for United States Department of the Interior Bureau of Reclamation & Order No 90-027 NPDES NO CA 0082368 WDRs for USBR.

[5] Order No 96-0922 NPDES No. CA 0083917 Waste Discharge Requirements for USBR and San Luis Delta Mendota Water Authority adopted March 22, 1996.

[6]http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4413 "Tile drainage systems affect groundwater-flow in upper parts of the semi-confined aquifer. Seasonal changes in groundwater levels and drain flow indicate field conditions are affected by upslope irrigation activities. Furthermore, observation well data show that groundwater movement is upward towards the drainage systems from depths as great as 100 feet below land surface (Deverel and Fio, 1991; Fio, 1994)." Pg 236 of the PDF

[7] http://www.epa.gov/region9/nepa/letters/Grassland-Bypass-FEIS.pdf EPA March 30, 2009 Detailed EIS/EIR Comments RE Grassland Bypass Project Continued Use of San Luis Drain: *"Develop a comprehensive monitoring program that includes multiple contaminants and follow-up for detected biological effects…this program should cover biological as well as water quality and sediment components."*

http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4415 pg 15 -52 of PDF USFWS March 22, 2009 Comments RE Continuation of GBP 2009 to 2019 USFWS recommends… "*An evaluation of the environmental effects of continued acute spikes of selenium to the biota in the vicinity of the Grasslands wetland supply channels…Selenium bioaccumulates rapidly in aquatic organisms and a single pulse of selenium (>10 µg/L) into aquatic ecosystems could have lasting ramifications….Maier et al. found that the invetebrate food web was still contaminated at >4 µg/L 12 months after selenium treatment when the monitoring ended even though water concentrations were <1 µg/L."*

http://pubs.usgs.gov/pp/p1646/pdf/pp1646.pdf pg 26. ... "monitoring was not sufficiently frequent to accurately characterize loads during variable flows."…annual data are not available from individual farm-field sumps to help qualify source-area shallow groundwater conditions and determine long-term variability in selenium concentrations…compliance monitoring sites are 50 and 130 miles downstream from the agricultural discharge. Pg 118-119.

Grassland Bypass Project 1999-2000 Annual Report at page 4, "The Oversight Committee recommended that additional studies be undertaken to establish the sources of selenium."
http://openlibrary.org/books/OL23302134M/Grassland_bypass_project

Grassland Bypass Project 2001-2002 Annual Report at page 4, "The Oversight Committee recommended that additional studies be undertaken to establish the sources of selenium."
http://openlibrary.org/books/OL23302136M/Grassland_bypass_project

" A Review of the Grassland Bypass Channel Project Monitoring Program" Presser, Sylvester, Dubrovsky and Hoffman, December 1996
http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/Presser_etal_GBP_monitoring_plan_1996.pdf
http://www.swrcb.ca.gov/rwqcb5/water_issues/grassland_bypass/usfws_att_e.pdf Email From Tomas Mauer, Chief, Investigations and Prevention Branch Sacramento Fish and Wildlife Office, U.S. Fish and Wildlife Service to Shauna McDonald [USBR], 11-18-09: "*Site H is not as problematic a sampling site as it is described for monitoring selenium levels in this stretch of the San Joaquin River. Although the site is inappropriate to use for selenium load calculations, the historic data clearly shows that selenium concentrations here can reach high levels throughout much of the year regardless of Merced River influences. The highest selenium levels occur in the summer when Merced River flows through the side channel would not be influencing site H. Currently, sampling at site H is less frequent, and thus potential spikes of selenium may not be observed. A more detailed analysis of the data at this site may assess how well the current sampling regime would detect the highest selenium levels. Even the current reduced sampling effort shows concentrations over 9 µg/L. This is above the 20 percent mortality level and three times higher than the 10 percent mortality level for salmonids (attached chart includes more recent data for 2007)."*

[8] USFWS 2009 Biological Opinion for the Grasslands Bypass Project page 90.
http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4826 "It is notable that the geometric mean, egg-selenium concentration in recurvirostrid eggs collected at the SJRIP Phase I area in 2008 (50.9 µg/g) exceeded all geometric mean selenium concentrations in recurvirostrid eggs collected at Kesterson Reservoir from 1983 to 1985 (Ohlendorf and Hothem 1994)…"

[9] USBR 2001 Record of Decision page 6. http://www.usbr.gov/mp/grassland/documents/rod_final_09-28-01.pdf

[10] http://www.swrcb.ca.gov/rwqcb5/water_issues/grassland_bypass/usfws_com.pdf "*Selenium concentrations in the food-chain of these impacted waters have often reached levels that could impact or even kill a substantial proportion of young salmon (Beckon et al. 2008) if the salmon, on their downstream migration, are exposed to those selenium-laden food items for long enough for the salmon themselves to bioaccumulate selenium to toxic levels. Based on existing water quality data for selenium in specific reaches of the San Joaquin River, Beckon and Maurer (2008) concluded that there remains a substantial ongoing risk to migrating juvenile Chinook salmon and steelhead in the San Joaquin River as noted in Attachment E. The Service asks that the Regional Board consider the protection of Chinook salmon and steelhead in the San Joaquin River, including the reach between Sack Dam and the Merced River, in this Basin Plan Amendment."[page 6 of pdf]*

[11] http://calitics.com/tag/Selenium Napolitano, Garamendi, et al., November 26, 2010.
Personal Communication Rudy Schnagl to Ms Schifferle, 8-8-11 'Flow models document most of the San Joaquin River is diverted to the California Aqueduct, thus contaminants are likely captured and sent south.'

[12] Suisun Bay in the Delta is selenium impaired and agriculture is listed as a source in the 303(d) listing of this water body. Further, EPA is in the process of developing a site specific selenium objective for the Delta, so reduced monitoring of the GBP could further hinder compliance with this future objective.

[13] http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/san_joaquin_se/se_tmdl_rpt.pdf *"There would be effectively no allocation of selenium load in the absence of Merced River dilution flows. The source analysis has shown that subsurface agricultural return flows from the DPA are the primary source of selenium load in the lower SJR Basin." [page 14]* Also see 1994 Regional Board staff report, Total Maximum Monthly Load Model for the San Joaquin River (Karkoski, 1994),

[14] November 3, 1995, Letter to Karl Longley Central Valley Regional Water Quality Control Board from Dan Nelson, SLDMWA, Roger Patterson, USBR; Felicia Marcus, USEPA; Joel Medlin USFWS.
"A commitment to specific monthly and annual selenium load values which assure that within 2 years, the Water Authority will implement actions sufficient o reduce selenium loads to the River by at least 5 percent per year up through the end of the 5th year. …the parties agree that for the purpose of establishing selenium load reductions, the following water quality objectives are now applicable: (a) 5 ppb selenium, measured as a 4-day average, in the San Joaquin River and Mud Slough and (b) 2 ppb selenium, measured as a monthly mean, in Salt Slough and the wetland channels.

[15] 1994 Environmental Defense Fund, Terry Young and Chelsea Congdon "Plowing New Ground" pg 35.

[16] Ibid.

[17] http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/san_joaquin_se/se_tmdl_rpt.pdf pg 20 of the PDF

"Load allocations in this TMDL [for the SJR] are established for meeting the selenium water quality objective in the SJR downstream of the Merced River confluence. There would be effectively no allocation of selenium load in the absence of Merced River dilution flows. The source analysis has shown that subsurface agricultural return flows from the DPA are the primary source of selenium load in the lower SJR Basin….. Attainment of the selenium water quality objective upstream of the Merced River confluence may require significant changes to the DPA discharge, including the relocation of the discharge point."
http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/sjr_selenium/comments092210/susan_moore.pdf pg 2 of the PDF

[18] http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4418 pg 26 of 66 FEIR/EIS Final EIS/EIR, Private/individual comments Part 2, Grassland Bypass 2010-2019
http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=3513
Also see Appendix C of the December 17, 2009 Agreement for the Continued Use of the San Luis Drain Agreement No. 10-WC-20-3975. Predicted violations of CWA standards will continue with proposed loads approximately until years 9 and 10. They will be violated for those years unless "highly speculative treatment" is achieved. See http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4415 pg 4 of 40 of the PDF. EPA comments on the DEIS/EIR for Continued Use of the San Luis Drain for Discharge into Mud Slough and the San Joaquin River.

[19] http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=3513

[20]http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/303dlists2006/epa/state_usepa_combined.pdf
[21]http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/sjr_selenium/comments092210/susan_moore.pdf see page 2 of the PDF
[22]http://www.swrcb.ca.gov/rwqcb2/water_issues/programs/TMDLs/northsfbayselenium/Species_at_risk_FINAL.pdf, accessed 4/20/11.
[23] http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4415 see EPA comments pg 5 of 40 of the PDF.
[24] http://www.waterboards.ca.gov/centralvalley/water_issues/grassland_bypass/
http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/sjr_selenium/comments092210/susan_moore.pdf
[25]

http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/Presser_etal_GBP_monitoring_plan_1996.pdf and see USFWS comments and EPA comments RE USBR NEPA Document at
http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4415
[26] http://pubs.acs.org/doi/abs/10.1021/es900828h
[27] http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=4415 see USFWS comment pg 33 of 40 of the PDF.
[28]http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/Presser_etal_GBP_monitoring_plan_1996.pd @ pg 81 of the pdf.
[29]http://wwwrcamnl.wr.usgs.gov/Selenium/Library_articles/Presser_etal_GBP_monitoring_plan_1996.pdf @ pg 15 of the pdf
[30] November 3, 1995 Letter From USBOR, USFWS, US EPA and San Luis Delta Mendota Water Authority to Karl Longley, Chair of the Regional Water Quality Control Board: Re Basin Plan Amendment for the San Joaquin River. *"The Selenium load reductions proposed will not necessarily achieve these water quality objectives by the end of the 5th year, and thus a long-term implementation schedule will be required……It is understood that load reductions of this sort are only a first step and do not fully protect against the environmental impacts which may result from selenium discharges during months when water levels are low in the San Joaquin River*" at pages 3-4.
[31]http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/san_joaquin_se/se_tmdl_rpt.pdf *"Load allocations in this TMDL are established for meeting the selenium water quality objective in the San Joaquin River (SJR) downstream of the Merced River confluence. There would be effectively no allocation of selenium load in the absence of Merced River dilution flows. The source analysis has shown that subsurface agricultural return flows from the Drainage Project Area (DPA) are the primary source of selenium load in the lower SJR Basin….. Attainment of the selenium water quality objective upstream of the Merced River confluence may require significant changes to the DPA discharge, including the relocation of the discharge point."*

4.0 SEDIMENT APPLICATION

This section describes the management of dredged materials based on results of sediment sampling compared to the stated risk criteria as described in Section 3.0

4.1 HAZARDOUS MATERIAL DISPOSAL

If the concentration of selenium in the dredged material is equal to or greater than 100 µg Se /g, wet weight the sediment will be handled according to all applicable State and local regulations for hazardous materials and disposed in a licensed hazardous waste facility. The nearest facility to the Site which accepts hazardous material is Kettleman Hills Landfill, located in Kings County.

4.2 LAND APPLICATION

Dredged sediments that have selenium concentrations below 100 µg Se /g wet weight may be locally reused through land application. Although the human health standard for selenium is greater than the hazardous waste standard, as a precaution, the more stringent standard has been used in this plan to determine if land application is appropriate. Current proposals for land application of the sediments include agricultural lands adjacent to the Drain; however, other options for land application may include residential and industrial reuse and open space lands if such parcels become available. Table 3 summarizes the appropriate land application based on measured selenium concentrations within dredged sediments, as further discussed in the following sub-sections.

Table 3. Acceptable Concentrations of Selenium in Dredged Material by Land Use

Land Use	Acceptable Concentration of Se in Sediment
Residential development	< 100 µg Se /g, wet weight
Industrial development	< 100 µg Se /g, wet weight
Agriculture	< 10 µg Se /g, dry weight*
Open Space (Wetland and Upland)	< 2 µg Se /g, dry weight

Note: *Source: Zawislanski et al 2001. The 10 µg/g concentration is a general guideline recommended by the Lawrence Berkeley National Laboratory which if exceeded triggers certain monitoring as described in Section 4.2.2 below.

4.2.1 RESIDENTIAL/INDUSTRIAL REUSE

If selenium concentration less than 390 micrograms per gram dry weight with less than 97 percent moisture content (which would exceed hazardous material criteria), sediments may be applied on lands zoned for residential use. If the concentration of selenium is greater than 390 micrograms per gram, dry weight, but below hazardous material criteria, the sediments may only be applied on land areas zoned for industrial use.