5.F Selenium Analysis

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5.F.1 Introduction

Project-related changes in waterborne concentrations of selenium in the Sacramento–San Joaquin River Delta (Delta) may result in increased selenium bioaccumulation and/or toxicity to fish using the Delta. This appendix provides an analysis of the effects of selenium to NMFS species of concern (winter- and spring-run Chinook salmon [*Oncorhynchus tshawytscha*], steelhead [*O. mykiss*], and green sturgeon [*Acipenser medirostris*]) to support the California WaterFix Section 7 Biological Assessment (BA). It describes the approach used for the assessment; the sources of data and other information used in modeling or assessment of effects and in calibration of a selenium bioaccumulation model for estimating selenium concentrations in fish or their diet; analysis of the Proposed Action (PA) to evaluate the effects to ESA-listed species and their habitat; and interpretation of the results.

5.F.1.1 Report Organization

This appendix is organized following the Ecological Risk Assessment (ERA) framework recommended by USEPA (1998). Tables and figures are located at the end of this appendix.

- **Section 5.F.1 – Introduction.** Presents the purpose of the appendix and summarizes the organization, technical approach, and assumptions of the appendix.
- **Section 5.F.2 – Problem Formulation.** Presents the environmental setting, summarizes the available data, and establishes the ecological conceptual model (ECM).
- **Section 5.F.3 – Analysis.** Presents the technical evaluation of potential exposures and adverse effects through the exposure analysis and ecological effects analysis.
- **Section 5.F.4 – Risk Characterization.** Integrates the Problem Formulation and the Analysis to estimate the likelihood of impacts on threatened and endangered salmonids, green sturgeon, and designated critical habitat from exposure to selenium, and uses available lines of evidence to identify differences between the PA and baseline conditions (represented by the No Action Alternative [NAA]). It also presents uncertainties and limitations associated with the modeling, as well as uncertainties with the risk assessment data and methodology.
- **Section 5.F.5 – Conclusions.** Summarizes the overall conclusions of the selenium analysis.
- **Section 5.F.6 – References.** Provides a list of reference materials used to prepare this analysis.

5.F.1.2 Technical Approach

This analysis is consistent with the approach and structure provided by the U.S. Environmental Protection Agency *Guidelines for Ecological Risk Assessment* (USEPA 1998) and the National Research Council *Assessing Risks to Endangered and Threatened Species from Pesticides* (NRC

2013). It builds on the selenium assessment provided in the BDCP REIR/SEIS wherein potential effects of selenium were compared among various alternatives for upper trophic level fish (i.e., trophic level 4 [TL-4]) at representative locations throughout the Delta and for sturgeon at two western Delta locations (San Joaquin River at Antioch and Sacramento River at Mallard Island). It differs in that it focuses on the most sensitive life stage (juvenile salmonids, TL-3 fish) and species (green sturgeon) at higher risk of impacts from changes in selenium as a result of the project. Three additional locations (Delta Cross Channel (gates), San Joaquin River near San Andreas Landing, and Old River at Clifton Court Forebay Radial Gates (West Canal)) are included for assessment of risk to green sturgeon. The approach also incorporates information on the spatial and temporal impacts to habitat (i.e., the prey base) as a result of changes in selenium.

The analysis framework is shown in Figure 5.F-1 and includes the elements of Problem Formulation, Exposure Analysis, Effects Analysis, and Risk Characterization. Ultimately, this analysis serves to answer the following questions:

- Is implementation of the PA likely to jeopardize the continued existence of the species?
- Is implementation of the PA likely to adversely modify or destroy the designated critical habitat?

The overall approach included the following steps:

- Describing the Delta environmental setting, available data, and an ecological conceptual model for selenium (including sources of selenium, its behavior in the Delta, the importance of dietary exposure and bioaccumulation analysis for selenium assessment, and endpoints used for selenium effects (see Section 5.F.2).
- Using selenium concentrations for inflows to the Delta (reported in the BDCP REIR/SEIS) and the volumetric fingerprinting results from DSM2, computing selenium concentrations in the water column at the following locations for the 82-year DSM2 simulation period (Oct 1921 – Sept 2003) (Section 5.F.3.1):
    - Eleven representative locations for TL-3 fish analysis in the Delta interior, western Delta, and at major diversions
    - Five locations for green sturgeon analysis in the Delta where they occur most commonly (Radtke 1966 cited in USEPA 2008, 2012)
- Using the estimated annual average[1] selenium concentrations in the water column to estimate selenium concentrations in particulates, invertebrates, and whole-body TL-3 fish for the 82 years for which modeling is available. Used Model 3 from the BDCP REIR/SEIS (described in Section 5.F.3.1) to estimate water-to-tissue transfer of selenium for wet, above normal and below normal water year types[2] and Model 5 from the BDCP

[1] Annual average selenium concentration will be computed as average of monthly selenium concentrations in a water year - Oct-Sept

[2] Water year type is defined by the Sacramento Valley 40-30-30 Index Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030 under Q5 climate scenario.

REIR/SEIS to estimate water-to-tissue transfer of selenium for dry and critical water year types.

- Similarly, using the estimated annual average selenium concentrations at the five identified Delta locations to estimate the water-to-tissue transfer of selenium for green sturgeon and their diet (invertebrates) for the 82 years for which modeling is available, using the modeling parameters described in Section 5.F.3.1 (modified from BDCP REIR/SEIS).

- Using the environmentally relevant end-point threshold concentrations that are of concern for survival, growth, or reproduction of salmon and steelhead (as TL-3 fish) and of green sturgeon from the published literature, USEPA and NMFS, as identified in Section 5.F.3.2.

- Reporting the annual selenium concentrations in the water column, invertebrates (because dietary effects levels of concern are identified as an endpoint for fish), whole-body TL-3 fish, and whole-body green sturgeon as exceedance curves (i.e., frequency of exceedance of particular concentrations by modeled concentrations) for each location (Section 5.F.4.1).

- Comparing the estimated annual selenium concentrations at each Delta location under the NAA and PA with the relevant endpoints and reporting the change in the probability of exceedance under the PA in comparison to the NAA for each endpoint of interest (Section 5.F.4.1).

- Reporting the estimated annual selenium concentrations at each Delta location as a water-year type average (Section 5.F.4.1).

- Qualitatively describing how the expected changes in selenium under the PA compared to the NAA would affect the listed NMFS fish species when they are present in the Delta (Section 5.F.4.2), describing the potential effects on different life stages for which the endpoint information is available (Section 5.F.4.2), describing potential effects to habitat of ESA-listed species (i.e., effects to the prey base) (Section 5.F.4.2), and identifying uncertainties associated with modeling parameters and endpoint threshold values used in the assessment (Section 5.F.4.3).

5.F.1.3 Model Methods and Assumptions

This assessment was completed under the following assumptions and constraints, which are specific to the Delta environment and the species considered in the assessment or are typical of current practice for selenium assessment (Hodson et al. 2010; Janz et al. 2010; Stewart et al. 2010; Young et al. 2010):

- The juvenile life stages and assessment endpoints for survival and growth of salmonids are included in the analyses due to the timing in which juveniles occur and feed within the proposed action area. While adults migrate through the Delta, their exposure is likely to be less than exposure for juveniles, which spend most of their time feeding and foraging for food in the Delta.

- Exposures of all life stages of green sturgeon are important, so potential effects on reproduction (for which threshold effects benchmarks are lower than for other endpoints; see Section 5.F.3.2 for a description of the effects thresholds) are the appropriate assessment endpoint.

- Measured and modeled selenium concentrations in water, particulates, invertebrates, and whole-body fish are representative of actual selenium concentrations in the project area.

- Toxicological information used includes information currently available from literature and database searches, and it reflects appropriate effects concentration benchmarks for selenium assessment.

- To estimate bioaccumulation in the salmonids, Model 3 (as described in Section 5.F.3.1.2) was used to calculate particulate/water ratios (K_ds) or “enrichment factors” for the wet, above normal, and below normal years and Model 5 (as described in Section 5.F.3.1.2) was used to calculate K_ds for the dry and critical years.

- A trophic transfer factor (TTF) of 2.8 was used in the Delta-wide model for salmonids. This is the average of the TTFs reported for aquatic insect species with similar bioaccumulative potential (Presser and Luoma 2010a, 2010b, 2013), and is assumed to be representative of the salmonid insect prey base.

- For green sturgeon, uptake from water was calculated using K_d = 3,000 for wet, above normal, and below normal water years, and K_d = 6,000 for dry and critical water year types. These values are approximations of the K_ds used by Presser and Luoma (2013) for “average” and “low flow” conditions and are assumed to be appropriate for modeling in this assessment.

- At the two western Delta locations evaluated, green sturgeon diet was assumed to include 50 percent *Corbula amurensis* and 50 percent other crustaceans, based on Presser and Luoma (2013). A diet of 50 percent amphipods and mysids and 50 percent insects was assumed for the other locations based on a 1960s-era study (Radtke 1966, as presented in USFWS 2008).

- For green sturgeon, a TTF from particulates to invertebrates of 9.2 (from Presser and Luoma 2013) was used at the western Delta locations. At all other locations, a TTF of 1.9 was used (as a composite of TTFs for amphipods [0-6 – 0.9], mysids [1.3], and insects [2.8]; from Presser and Luoma 2010a, 2013).

- A TTF from invertebrates to fish of 1.3 (Presser and Luoma 2010a, 2013) was used for both salmonids and green sturgeon.

5.F.2 Problem Formulation

Problem Formulation integrates available information to focus the analysis provided in subsequent sections. It includes a description of the environmental setting, a summary of the available data, and development of the ECM.

5.F.2.1 Environmental Setting/Baseline

This selenium analysis focuses on various representative locations in the Delta because the PA may affect any waterway in the Delta or Suisun Marsh. The Delta is where California's largest rivers, the Sacramento River and the San Joaquin River, meet. The fresh water from these major rivers comingles with salt water from the Pacific Ocean in the Delta's several channels. Despite its name, the Sacramento–San Joaquin River Delta is not simply the merging of two river deltas, but is instead an elongated and complex network of deltas and flood basins with flow sources that include Cache Creek, Putah Creek, Sacramento River, Mokelumne River, San Joaquin River, and other streams. Water diversions in the watershed (e.g., irrigation and dams) have altered the natural seasonal high flows during the winter and spring and the low flows during the fall (Contra Costa Water District 2010). These developments have accentuated the natural salinity intrusions into the Delta during drought periods.

Selenium is identified as one of the pollutants in San Francisco Bay and the western Delta on the Clean Water Act Section 303(d) List (State Water Resources Control Board 2011). Although selenium is essential for human and other animal nutrition, high concentrations of selenium are a concern because of bioaccumulation and potential reproductive effects on fish or other aquatic life. Endangered steelhead and salmon and threatened green sturgeon are exposed to selenium in the Delta when they migrate there from the Sacramento River to grow and mature. In the Delta, these species consume aquatic insects, crustaceans, or clams (e.g., *Corbula amurensis*) that consume plankton that have bioaccumulated selenium.

There is a gradient of low to high pH and salinity within the Delta, such that pH and salinity are higher downstream and they decrease with distance upstream. Selenium concentrations vary across the Delta as well, and tend to increase nearer the mouth of the San Joaquin River. Expansion of salinity intrusion farther upstream is of concern because it could result in an expansion of the range for *Corbula amurensis. Corbula amurensis* bioaccumulates selenium at a higher rate than aquatic insects, so fish that feed on this clam (e.g., green sturgeon) may be exposed to higher concentrations of selenium in their diet as the salinity intrusions into the Delta increase. Presser and Luoma (2010b, 2013) conducted site-specific modeling for the Bay-Delta that includes derivation of salinity-specific operationally defined factors for partitioning of selenium between water and suspended particulate material (K_ds), and also described the much greater bioaccumulation of selenium by *Corbula amurensis* than is typical for other common items in the prey base for salmonids and sturgeon.

A more detailed description of the Environmental Setting, including the biology of salmonids and green sturgeon in the Delta, is provided in Chapter 4 of the main text.

5.F.2.2 Summary of Available Data

Dissolved or total selenium concentration data for the following six inflows to the Delta (Table 5.F-1) and the volumetric fingerprinting results from DSM2 modeling (described below) were used to compute selenium concentrations in the water column at the locations identified in Section 5.F.3.1.1 for the 82-year DSM2 simulation period (Oct 1921 – Sep 2003):

- Sacramento River below Knights Landing
- Sacramento River at Freeport
- Mildred Island, Center
- Mokelumne, Calaveras, and Cosumnes Rivers
- San Joaquin River at Vernalis (Airport Way)
- San Joaquin River near Mallard Island

Both dissolved and total selenium data were considered suitable for purposes of the modeling conducted for the Delta, because they typically do not differ greatly. Statements related to waterborne selenium concentrations in this appendix would be applicable to either dissolved or total concentrations.

Whole-body largemouth bass (*Micropterus salmoides*) data for selenium available from the following DSM2 output locations (Foe 2010) were used to calibrate a bioaccumulation model for trophic level four (TL-4) fish across the Delta (described in Section 5.F.3.1.2 and Attachment 5.F-1):

- Big Break
- Cache Slough Ryer
- Franks Tract
- Middle River Bullfrog
- Old River Near Paradise Cut
- Sacramento River Mile (RM) 44
- San Joaquin River Potato Slough

Largemouth bass data also were available from the Veterans Bridge on the Sacramento River and from Vernalis on the San Joaquin River (Foe 2010), but DSM2 data were not available for those locations; therefore, historical data for selenium concentrations in water collected nearby (Table 5.F-1) were used to represent quarterly averages for those locations. The geometric mean of total selenium concentrations in water collected from the Sacramento River below Knights Landing in years 2004, 2007, and 2008 (California DWR Website 2009) were used to represent quarterly averages of selenium concentrations in water for Veterans Bridge in all years.

The geometric means of selenium concentrations (total or dissolved was not specified) in water collected from years 1999–2000, 2004-2005, and 2006-2007 (SWAMP 2009) were used to represent quarterly averages for selenium concentrations in water at Vernalis during 2000, 2005, and 2007, respectively. Implementation of the Grassland Bypass Project (GBP) has led to a 60 percent decrease in selenium loads from the Grassland Drainage Area in comparison to pre-project conditions (Tetra Tech 2008). These changes are reflected in data for the San Joaquin River at Vernalis, where water quality is monitored frequently because the river is a primary source of selenium to the Delta. Vernalis water data for two years (1999-2000, 2004-2005, and 2006-2007) were used for each year when fish data were available because of the GBP-related changes and because the lag time for selenium bioaccumulation in the piscivorous largemouth bass, the species for which the Delta-wide bioaccumulation model was calibrated, may be more than one year (Beckon 2014).

5.F.2.3 Ecological Conceptual Model

The ECM is a written and visual presentation of predicted relationships among stressors, exposure pathways, and assessment endpoints. The ECM describes the sources of selenium as well as transport and fate mechanisms, evaluates potential exposure pathways, and outlines important resources to be protected (referred to as assessment endpoints) and the means by which the assessment endpoints are evaluated (measures of exposure and effects). Additionally, the representative species that were used to assess potential ecological risk are identified in the ECM. The ECM is depicted in Figure 5.F-2.

5.F.2.3.1 Source Evaluation

Within the Delta, there are multiple sources of selenium. Presser and Luoma (2013) identify oil refinery wastewaters from processing crude oils at North Bay refineries and irrigation drainage from agricultural lands in the western San Joaquin Valley (mainly via the San Joaquin River) as the two primary sources. Agricultural drainage in the Sacramento Valley (e.g., drains and west-side creeks in the Yolo Bypass and non-oil industries and wastewater treatment effluents are minor sources of selenium in the Delta.

5.F.2.3.2 Selenium Transport and Fate

Selenium in agricultural drainage waters typically enters a stream primarily as selenate, whereas refinery discharges are predominantly selenite (Presser and Luoma 2013). If the stream flows into a wetland and the water is retained there with sufficient residence time, recycling of selenium may occur. This results in generation of particulate selenium and conversion to more bioaccumulative selenite and organo-selenium from the less-bioaccumulative dissolved selenate. Residence time of selenium is usually the most influential factor on the conditions in the receiving water environment. Short water residence times (e.g., in streams and rivers) limit partitioning of selenium into particulate material and subsequent bioaccumulation. Conversely, longer residence times (e.g., sloughs, lakes, estuaries) allow greater uptake by plants, algae, and microorganisms and their consumers (i.e., invertebrates and fish). Furthermore, environments in downstream portions of a watershed can receive cumulative contributions of upstream recycling in a hydrologic system.

5.F.2.3.3 Exposure Pathways

The primary exposure pathway for fish and other aquatic organisms to selenium is through their diet (Presser and Luoma 2010a, 2010b, 2013; Stewart et al. 2010). TL-3 fish, represented by endangered steelhead and salmon, and threatened green sturgeon are the focus of this selenium analysis in the Delta. For steelhead and salmon species selenium exposure in the Delta occurs when juveniles migrate from major rivers to the ocean. Before reaching the ocean they grow, mature, and adapt from freshwater to saltwater in the Delta. Because adult salmon and steelhead do not forage extensively while in the Delta before spawning upstream in the rivers (Sasaki 1966), their exposure is likely to be less than exposure for juveniles, which spend most of their time feeding and foraging for food in the Delta. Thus, exposures that may affect survival and growth of juvenile salmonids were included in the analyses of potential selenium effects, due to the timing in which those juveniles occur and feed within the proposed action area. Green sturgeon migrate from major rivers to the Delta and reside within the Delta or in the Pacific Ocean (USFWS 2008). Therefore, all life stages of sturgeon are exposed to selenium in the Delta.

5.F.2.3.4 Assessment Endpoints

Assessment endpoints are expressions of the important ecological values that should be protected in the assessment area (Suter 1990, 1993; USEPA 1998; Suter et al. 2000). Assessment endpoints are developed based on known information concerning the contaminants present, the study area, the ECM, and risk hypotheses. There are three components to each assessment endpoint: an *entity* (e.g., special-status fish), an *attribute* of that entity (e.g., individual survival or growth), and a *measure* (e.g., a measurable value, such as an effect level). Measures are described following the general description of assessment endpoints (USEPA 1998; Suter et al. 2000).

The assessment endpoint entities for this assessment were selected based on the following principal criteria (USEPA 1998):

- Ecological relevance
- Societal value
- Relevance to policy goals
- Susceptibility (or high exposure) to selenium in the Delta

In this case, fish that may be exposed to selenium in the Delta were selected as the entity. Specifically, these are the NMFS species of concern winter- and spring-run Chinook salmon, steelhead, and green sturgeon. As species of concern, the attributes of individual-level survival or growth (all species) and reproduction (sturgeon only) were selected. Adult salmon and steelhead pass through the Delta without extensive feeding (Sasaki 1966), so selenium exposure within the Delta is limited for adults and not likely to affect reproduction. Therefore, survival and growth are important characteristics for juvenile salmon and steelhead. In contrast, sturgeon remain in the Delta throughout their life-cycle such that survival, growth, and reproduction are important characteristics for green sturgeon. Green sturgeon are primarily found in freshwater habitat during the first 4 years of their life (Allen et al. 2009) and then revisit it intermittently after they become more marine-oriented subadults and adults (Lindley et al. 2011). Some subadults may return to the Delta for foraging or to make mock spawning runs (entrainment hypothesis), and adults may utilize it for a few months when they return to spawn every 2-4 years (Heublein et al. 2009; Lindley et al. 2011). The assessment endpoints were defined as follows:

- Survival and growth of individual juvenile salmon or steelhead potentially exposed to selenium in surface water and prey items within the Delta.
- Survival, growth, and reproduction of individual green sturgeon potentially exposed to selenium in surface water and prey items within the Delta.

5.F.2.3.5 Measures of Exposure and Effects

Measures are measurable attributes used to evaluate the risk hypotheses and are predictive of effects on the assessment endpoints (USEPA 1998). The three categories of measures include the following:

- Measures of exposure are quantitative or qualitative indicators of an analyte's occurrence and movement in the environment in a way that results in contact with the assessment endpoint. Measured and estimated selenium concentrations in surface water and in prey items of the Delta serve as measures of exposure to salmon, steelhead, and sturgeon that may use the Delta.
- Measures of effects are measurable adverse changes in an attribute of an assessment endpoint (or its surrogate) in response to an analyte to which it is exposed. In this case, published toxicity benchmarks for survival and growth of salmonids and survival, growth and reproduction of green sturgeon were selected as measures of effects.
- Measures of ecosystem and receptor characteristics are used to evaluate the ecosystem characteristics that influence the assessment endpoints, the distribution of stressors, and the characteristics of the assessment endpoints that may affect exposure or response to the stressor. Measures of ecosystem and receptor characteristics include site-specific studies of the diversity and abundance of receptors and/or quantitative or qualitative evaluations of the habitat quality and functioning in the project area.

For this analysis, measures of exposure and effects were the primary measures used, with measures of ecosystem and receptor characteristics implicitly incorporated as effects on critical habitat (specifically, as effects on the invertebrate prey base) into the assessment approach and consideration of applicable life stages in selection of the measures of exposure and effects.

5.F.3 Analysis

The Analysis step in the ERA links information from the ECM and Problem Formulation to quantify potential exposures to the selected endpoint species and to characterize the potential ecological effects from selenium to the selected species in the Delta. The Analysis phase includes the Exposure Analysis and the Ecological Effects Analysis. These two components are used to evaluate the relationships among species of concern and habitat, potential exposures, and potential effects. The results provide the information necessary to estimate potential risks to the representative species under the PA in comparison to the NAA.

5.F.3.1 Exposure Analysis

The Exposure Analysis is used to evaluate the relationship between species of concern and habitat and potential stressors (i.e., selenium). Exposure is defined as the co-occurrence of a stressor (e.g., selenium) and a receptor in both space and time. The methods used to estimate exposure, including exposure areas; receptor-specific exposure models, exposure factors, and assumptions; and calculation of exposure point concentrations (EPCs) are described in this section.

5.F.3.1.1 Exposure Areas

The areas evaluated for selenium exposure in this analysis were the same as those used for the selenium assessment in the BDCP REIR/SEIS, with the addition of three locations in the Delta for green sturgeon analysis based on NMFS recommendations. The additional locations represent a gradient of low to high salinity through the Delta, along with shifts in pH and selenium concentrations. They also represent changes in mixing zones and areas where clams represent varying composition of the benthic community. Areas invaded by *Corbula amurensis* clams that bioaccumulate selenium and are eaten by green sturgeon are represented, mainly by the two western Delta locations. The following three locations were added to those included in the BDCP REIR/SEIS:

1. Delta Cross Channel (gates) at the Head of the Sacramento River – The channel connects the interior Delta with the Sacramento River. The gates control the amount of fresh water in the Delta. At this location water is diverted, tidally influenced, and assumed to contain low concentrations of selenium (similar to the Sacramento River). This area is heavily studied and data for this location are available.

2. San Joaquin River near San Andreas Landing – Historically, green sturgeon were found at San Andreas Shoals. The San Joaquin River near San Andreas Landing is the modeling node nearest to San Andreas Shoals.

3. Old River at Clifton Court Forebay Radial Gates (West Canal) – This location reflects selenium coming in from agricultural sources on the San Joaquin River, and taken up at the export pumps.

The following locations were included in this assessment and are shown on Figure 5.F-3:

- Locations for TL-3 fish (salmonids) analysis in the Delta:

- Delta Interior
  - Mokelumne River (South Fork) at Staten Island
  - San Joaquin River at Buckley Cove
  - Franks Tract
  - Old River at Rock Slough
- Western Delta
  - Sacramento River at Emmaton
  - San Joaquin River at Antioch
  - Sacramento River at Mallard Island
- Major Diversions
  - North Bay Aqueduct at Barker Slough Pumping Plant
  - Contra Costa Pumping Plant #1
  - Banks Pumping Plant
  - Jones Pumping Plant

- Locations for green sturgeon analysis in the Delta:
  - Sacramento River upstream of Delta Cross Channel
  - San Joaquin River near San Andreas Landing
  - Old River at Clifton Court Forebay Radial Gates (West Canal)
  - San Joaquin River at Antioch
  - Sacramento River at Mallard Island

5.F.3.1.2 Exposure Models

The exposure models describe the relationships and equations used to estimate how much of a given analyte in a given medium may be taken up by the receptor through a given exposure route. These relationships can be simple or complex, depending on the receptor involved and the number of exposure routes being evaluated. In this analysis, selenium concentrations in the water column were estimated for each assessment location using DSM2 modeling results over the 82 years for which modeling is available, as described below. Exposures were divided into two types: those for wet, above normal and below normal water year types[3] and those for dry and critical water year types.

Then tissue-based exposure models using the estimated annual average[4] selenium concentrations in the water column (over the 82 years for which modeling is available) were used to estimate selenium concentrations in particulates, invertebrates (as fish diet), and whole-body TL-3 fish for salmon and steelhead and from water to invertebrates (as diet) and whole-body fish for green sturgeon. Similar to waterborne selenium concentrations, exposures for fish were divided into two types: those for wet, above normal and below normal water year types and those for dry and critical water year types. The exposure models and parameters for salmon and steelhead and for green sturgeon are described below.

Selenium concentrations in whole-body TL-3 fish were calculated using ecosystem-scale models developed by Presser and Luoma (2010a, 2010b, 2013). The models were based on biogeochemical and physiological factors from laboratory and field studies; loading rates, chemical speciation, and transformation to particulate material; bioavailability; bioaccumulation in invertebrates; and trophic transfer to predators. Important components of the methodology included (1) empirically determined environmental partitioning factors between water and particulate material that quantify the effects of dissolved speciation and phase transformation; (2) concentrations of selenium in living and non-living particulates at the base of the food web that determine selenium bioavailability to invertebrates; and (3) selenium biodynamic food web transfer factors that quantify the physiological potential for bioaccumulation from particulate matter to consumer organisms and from prey to their predators.

5.F.3.1.2.1 Selenium Concentration in Water

For DSM2 output locations, the geometric mean selenium concentrations from the inflow locations were combined with the modeled quarterly average percent inflow for each DSM2 output location to estimate waterborne selenium concentrations at those locations. The quarterly average mix of water from the six inflow sources (Table 5.F-1) was calculated from daily percent inflows provided by the DSM2 model output for the DSM2 output locations for which fish data were available. The quarterly waterborne selenium concentrations at DSM2 locations were calculated using the following equation:

$$C_{water\,quarterly} = \frac{(I_1 \bullet C_1) + (I_2 \bullet C_2) + (I_3 \bullet C_3) + (I_4 \bullet C_4) + (I_5 \bullet C_5) + (I_6 \bullet C_6)}{100} \quad \text{[Eq.1]}$$

Where:

$C_{water\ quarterly}$ = quarterly average selenium concentration in water (micrograms/liter [µg/L]) at a DSM2 output location

[3] Water year type is defined by the Sacramento Valley 40-30-30 Index Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030 under Q5 climate scenario.

[4] Annual average selenium concentration was computed as average of monthly selenium concentrations in a water year - Oct-Sep

$I_{1\text{-}6}$ = modeled quarterly inflow from each of the six sources of water to the Delta for each DSM2 output location (percentage)

$C_{1\text{-}6}$ = selenium concentration in water (µg/L) from each of the six inflow sources to the Delta (1-6)

Example Calculation: Modeled Selenium Concentration at Franks Tract Year 2000, First Quarter:

(43.94 [% inflow from Sacramento River water source at Franks Tract] × 0.09 µg/L [selenium concentration at Sacramento River at Freeport]) + (11.56 [% inflow from East Delta Tributaries water source at Franks Tract] × 0.10 µg/L [selenium concentration at Mokelumne, Calaveras, and Cosumnes Rivers]) + (15.79 [% inflow from San Joaquin River water source at Franks Tract] × 0.83 µg/L [selenium concentration at San Joaquin River at Vernalis]) + (0.02 [% inflow from Martinez/Suisun Bay water source at Franks Tract] × 0.10 µg/L [selenium concentration at San Joaquin River near Mallard Island]) + (0.32 [% inflow from Yolo Bypass water source at Franks Tract] × 0.23 µg/L [selenium concentration at Sacramento River below Knights Landing]) + (5.06 [% inflow from Delta Agriculture water source at Franks Tract] × 0.11 µg/L [selenium concentration at Mildred Island, Center])/100 = 0.19 µg/L

The quarterly and average annual waterborne selenium concentrations for the DSM2 output locations are shown in Attachment 5.F-1[Attachment Table 5.F-1 (Year 2000), Attachment Table 5.F-2 (Year 2005), and Attachment Table 5.F-3 (Year 2007).

5.F.3.1.2.2 Selenium Concentration in Particulates

Phase transformation reactions from dissolved to particulate selenium are the primary form by which selenium enters the food web. Presser and Luoma (2010a, 2010b, 2013) used field observations to quantify the relationship between particulate material and dissolved selenium as provided below.

$$C_{particulate} = K_d \bullet C_{watercolumn} \qquad \text{[Eq. 2]}$$

Where:

$C_{particulate}$ = selenium concentration in particulate material (micrograms/kilogram, dry weight [µg/kg dw])

$C_{water\ column}$ = selenium concentration in water column (µg/L)

K_d = particulate/water ratio

The K_d (which is also called an "enrichment factor") describes the particulate/water ratio at the moment the sample was taken and should not be interpreted as an equilibrium constant (as it sometimes is mistaken to be). It can vary widely among hydrologic environments and potentially among seasons (Presser and Luoma 2010a, 2010b, 2013; Young et al. 2010). In addition, other factors such as speciation, residence time, and particle type affect K_d. As previously described (Section 5.F.2.3.2), selenium typically enters a stream primarily as selenate. If the stream flows into a wetland and the water is retained there with sufficient residence time, recycling of selenium may occur. This results in generation of particulate selenium and conversion to more bioaccumulative selenite and organo-selenium from the less-bioaccumulative dissolved selenate. Residence time of selenium is usually the most influential factor on the conditions in the receiving water environment. Short water residence times (e.g., streams and rivers) limit partitioning of selenium into particulate material. Conversely, longer residence times (e.g., sloughs, lakes, estuaries) allow greater uptake by plants, algae, and microorganisms. Furthermore, environments in downstream portions of a watershed can receive cumulative contributions of upstream recycling in a hydrologic system. Due to its high variability, K_d is a large source of uncertainty in any selenium model where extrapolations from selenium concentrations in the water column to those in aquatic organism tissues, or from tissue to waterborne concentrations, are necessary.

Whole-body tissue concentrations for largemouth bass were available from areas near DSM2 locations (Foe 2010). Therefore, these tissue data were used to develop and calibrate a water-to-tissue model for bass (as TL-4 fish), and the model was adapted to include juvenile salmonids (as TL-3 fish) by not including the final trophic transfer from a fish diet to a predatory fish. In calibrating the Delta-wide bioaccumulation model for bass, the particulate selenium concentration initially was estimated using Equation 2 and a default K_d of 1,000 (Presser and Luoma 2010a). Because the K_d is typically much more variable than other steps in the bioaccumulation model, the K_d was then adjusted to calibrate the model so that the modeled concentrations for fish approximated the measured concentrations in bass for normal and wet years (2000 and 2005) and for dry years (2007). Figures and tables supporting model development are provided in Attachment 5.F-1.

Presser and Luoma (2013) determined K_d values for San Francisco Bay (including Carquinez Strait – Suisun Bay) during “low flow” conditions (5,986) and “average” conditions (3,317). Approximations of these values were used to model selenium concentrations in particulates and in bioaccumulation modeling for sturgeon under dry and critical water years (K_d = 6,000) and under wet, above normal, and below normal water years (K_d = 3,000).

5.F.3.1.2.3 Selenium Concentrations in Invertebrates

Species-specific TTFs for transfer of selenium from particulates to prey and to predators were developed using data from laboratory experiments and field studies (Presser and Luoma 2010a, 2010b, 2013). TTFs are species-specific, but the range of TTFs for freshwater invertebrates was found to be similar to TTFs for marine invertebrates determined in laboratory experiments.

TTFs for estimating selenium concentrations in invertebrates were calculated using the following equation:

$$TTF_{invertebrate} = \frac{C_{invertebrate}}{C_{particulate}} \qquad \text{[Eq. 3]}$$

Where:

$TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrate

$C_{invertebrate}$ = concentration of selenium in invertebrate (µg/g dw)

$C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)

An average aquatic insect TTF was calculated from TTFs for aquatic insect species with similar bioaccumulative potential, including mayfly (Baetidae; Heptageniidae; Ephemerellidae), caddisfly (Rhyacophilidae; Hydropsychidae), crane fly (Tipulidae), stonefly (Perlodidae/Perlidae; Chloroperlidae), damselfly (Coenagrionidae), corixid (*Cenocorixa* sp.), and chironomid (*Chironomus* sp.) aquatic life stages. Species-specific TTFs ranged from 2.1 to 3.2 (Presser and Luoma 2010a); the average TTF of 2.8 was used in the Delta-wide model for salmonids.

Sturgeon in the western Delta, Carquinez Strait, and Suisun Bay typically prey on a mix of clams (including *Corbula amurensis*, which is known to be an efficient bioaccumulator of selenium; Stewart et al. 2010) and crustaceans. Presser and Luoma (2013) assumed a sturgeon diet of 50 percent clams and 50 percent other crustaceans in their model. Based on this diet, the authors reported a TTF of 9.2 (identified as TTF_{prey} in Table 1 of Presser and Luoma [2013]). Consistent with the BDCP REIR/SEIS, this TTF was used to calculate concentrations in sturgeon invertebrate prey for the two western Delta locations (San Joaquin River at Antioch and Sacramento River at Mallard Island). At the other locations, a diet of 50 percent amphipods and mysids (based on a 1960s-era study [Radtke 1966, cited in USFWS 2008]) was used. The other 50 percent of the diet was represented by insects (which have a higher TTF than amphipods and mysids) to conservatively include the possibility of insects being more important than reflected in the 1960s diet information. Therefore, a TTF of 1.9 was used for the three new locations, which is a blend of TTFs for amphipods (0.6 – 0.9), mysids (1.3), and insects (2.8) from Presser and Luoma (2010a, 2013).

5.F.3.1.2.4 Selenium Concentrations in Whole-body Fish

The mechanistic equation for modeling of selenium bioaccumulation in fish tissue is similar to that for invertebrates if whole-body concentrations are the endpoint (Presser and Luoma 2010a, 2010b, 2013), as follows:

$$TTF_{fish} = \frac{C_{fish}}{C_{invertebrate}}$$

$$where:$$

$$C_{invertebrate} = C_{particulate} \bullet TTF_{invertebrate}$$

$$therefore:$$

$$C_{fish} = C_{particulate} \bullet TTF_{invertebrate} \bullet TTF_{fish} \quad \text{[Eq. 4]}$$

Where:

C_{fish} = concentration of selenium in fish (µg/g dw)

$C_{invertebrate}$ = concentration of selenium in invertebrate (µg/g dw)

$C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)

$TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrate

TTF_{fish} = trophic transfer factor from invertebrate to fish

Modeling selenium bioaccumulation into a particular fish species considers organism physiology and its preferred foods. However, variability in fish tissue concentrations of selenium for present modeling purposes is driven more by dietary choices and their respective levels of bioaccumulation (i.e., $TTF_{invertebrate}$) than by differences in fish physiology or the dietary transfer to the fish (TTF_{fish}). A diet of mixed prey (including invertebrates or other fish) can be modeled as follows:

$$C_{fish} = TTF_{fish} \bullet \left[(C_1 \bullet F_1) + (C_2 \bullet F_2) + (C_3 \bullet F_3) \right] \quad \text{[Eq. 5]}$$

Where:

C_{fish} = concentration of selenium in fish (µg/g dw)

TTF_{fish} = trophic transfer factor for fish species

$C_{1\text{-}3}$ = concentration of selenium in invertebrate or fish prey items 1, 2, and 3 (µg/g dw)

$F_{1\text{-}3}$ = fraction of diet composed of prey items 1, 2, and 3

In this analysis, the following equation was used to model whole-body tissue concentrations in TL-3 fish and green sturgeon:

$$C_{fish} = C_{particulate} \bullet TTF_{inverterbrate} \bullet TTF_{foragefish} \quad \text{[Eq. 6]}$$

Where:

C_{fish} = concentration of selenium in fish (µg/g dw)

$TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrate

$C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)

$TTF_{forage\ fish}$ = trophic transfer factor for invertebrates to foraging fish species

The fish TTFs reported in Presser and Luoma (2010a) ranged from 0.5 to 1.6, so the average fish TTF of 1.1 was used for all TL-3 fish in the Delta-wide model. A TTF of 1.3 was reported for sturgeon in Presser and Luoma (2013) and was used to calculate concentrations of selenium in green sturgeon.

Several models were evaluated and refined to estimate selenium uptake in fish from waters throughout the Delta, as described in Attachment 5.F-1. Input parameters were varied among the models as refinements were made. Data for largemouth bass collected in the Delta from areas near DSM2 output locations (Foe 2010) were used to calibrate the model so the estimated selenium concentration in fish approximated the measured selenium in whole-body bass. For this assessment of bioaccumulation in salmonids, the first steps of the calibrated bass models (up to TL-3 fish) were used. Although Model 3 tends to slightly overestimate selenium bioaccumulation (Attachment Table 5.F-5 and Attachment Figure 5.F-1), it was used for estimating selenium concentrations in whole-body fish to compare the PA to the NAA in this analysis for "wet, above normal, and below normal" years, and Model 5 (Attachment Table 5.F-6 and Attachment Figure 5.F-1) was used for "dry and critical" years.

Modeling for sturgeon did not require refinement because it relied on recent data provided by Presser and Luoma (2013), as described above.

5.F.3.1.2.5 Exposure Point Concentrations

Selenium concentrations in the water column at various locations in the Delta were estimated based on the monthly averaged sourcewater volumetric fingerprinting results simulated using DSM2. Appendix 5B provides an overview of the DSM2 modeling performed for the BA. As described in Section 5.B.2.2.2.2 *Delta Sourcewater Fingerprinting*, DSM2 QUAL model was used to estimate the volume fraction of various Delta inflow sources at a given location in the Delta at a given time, over the 82-year (WY 1922 – 2003) period. Selenium concentrations in the water column for each month in a water year were averaged to compute the annual selenium concentration in the water column for each of the 82-years.

5.F.3.2 Effects Analysis

The Ecological Effects Analysis consists of evaluating available toxicity or other effects information that can be used to relate the exposure estimates to a level of adverse effect. As previously identified, effects measures for salmonids relate to survival and growth, whereas those for sturgeon relate to survival, growth, and reproduction. Dietary and whole-body benchmarks for effects were developed from the literature as follows (all concentrations are reported on a dry-weight basis):

- Salmonids
    - Survival: **18.2 mg/kg diet** and **10.4 mg/kg whole-body** selenium represent no-effect levels for survival of juvenile Chinook salmon fed a selenomethionine-dosed diet (USEPA 2015, based on study by Hamilton et al. 1990)
    - Growth: **7.36 mg/kg whole-body** selenium represents an effect level for reduced growth of salmon fed a selenomethionine-dosed diet (USEPA 2015, based on study by Hamilton et al. 1990)

- Green sturgeon
  - Survival and growth: No benchmarks were identified for evaluating these endpoints because they are much higher (i.e., 28.9 mg/kg and 16.4 mg/kg, respectively; USEPA 2015, based on study by De Riu et al. 2014) than those for reproduction.
  - Reproduction: **8.2 mg/kg diet** and **3.3 mg/kg whole body** represented as EC_{05} concentrations for reproductive effects (USFWS 2012, based on Linville 2006 and Linares-Casenave et al. 2010).

In addition to the dietary and whole-body tissue benchmarks, water quality benchmarks were used to evaluate selenium concentrations in surface water. The USEPA (2012) recommended criterion for protection of freshwater aquatic life is 5 µg/L total recoverable selenium, which represents the continuous concentration (4-day average). The Grassland Bypass Project (Beckon et al. 2013) used a level of 2 µg/L total recoverable selenium as a Level of Concern. Both of these benchmarks were used to evaluate waterborne selenium concentrations.

5.F.4 Risk Characterization

In the Risk Characterization, exposure and effects data are integrated to draw conclusions concerning the presence, nature, and magnitude of effects that may exist in the Delta. This section outlines the methodology by which exposure and effects data were integrated to estimate risk. The three main components of the Risk Characterization are the Risk Estimation, Risk Description, and Uncertainty and Limitations Analysis. These three components are used together in the following sections to identify differences in risk under the PA in comparison to the NAA.

5.F.4.1 Risk Estimation

Risk Estimation focuses primarily on quantitative methods to evaluate the potential for risk. The risk estimates are derived from the combinations of assessment endpoint levels, representative receptors, exposure media, EPCs, and benchmarks developed in the Problem Formulation and Analysis components.

The results of the quantitative risk estimation are presented as a series of exceedance curves for water, invertebrate (diet), and whole-body fish selenium concentrations for each location selected for either salmonids or green sturgeon. These curves show the probability that the water quality, dietary, or whole-body benchmark will be exceeded in any one year based on the 82-year simulation period for the waterborne selenium concentrations. Additionally, the particulates, which have no benchmarks, are shown to illustrate the linkage between waterborne concentration and bioaccumulation based on K_d. The NAA and PA probability exceedances are graphed together for comparison. Discussion of the NAA (Appendix 5A, Section 5.A.5, CalSim II Modeling Assumptions) provides a baseline for risks in the project area to which the risks associated with the PA can be compared to determine the potential effect of the PA. However, the NAA risk levels are not a criterion for determination in the BA.

Probability of exceedance curves for TL-3 fish (salmon and steelhead) are shown in Figures 5.F-4 through 5.F-14 and those for green sturgeon are shown in Figures 5.F-15 through 5.F-19. Results are discussed by receptor below.

5.F.4.1.1 TL-3 Fish (Salmon and Steelhead)

At all Delta locations analyzed for TL-3 fish, selenium concentrations in water under the PA are similar or slightly greater than concentrations under the NAA (Tables 5.F-2 through 5.F-12). However, these differences are very small at all locations (< 0.067 µg/L increase) and estimated waterborne concentrations under both scenarios are well below the lowest water quality benchmark of 2 µg/L (see Panel A on Figures 5.F-4 through 5.F-14). It should also be noted that waterborne selenium concentrations at all these locations are below the draft water quality criterion for lentic systems of 1.2 µg/L (USEPA 2015).

No differences in estimated particulate selenium concentrations were observed between the PA in comparison to the NAA at any Delta location (see Panel B on Figures 5.F-4 through 5.F-14). As shown in Tables 5.F-2 through 5.F-12, there is no difference (i.e., 0% difference) between the particulate selenium concentrations estimated under the PA and NAA. Similarly, no differences (i.e., 0% difference; Tables 5.F-2 through 5.F-12) in estimated dietary and whole-body concentrations between the PA in comparison to the NAA were observed (see Panels C and D on Figures 5.F-4 through 5.F-14). Additionally, dietary and whole-body tissue concentrations were well below benchmarks at all locations.

These results also are shown in Tables 5.F-2 through 5.F-12 and are discussed further in the Risk Description (Section 5.F.4.2).

5.F.4.1.2 Green Sturgeon

At all Delta locations analyzed for green sturgeon, selenium concentrations in water under the PA are slightly greater than those under the NAA (Tables 5.F-13 through 5.F-17). However, these differences are very small at all locations (< 0.072 µg/L increase); estimated waterborne selenium concentrations under both scenarios are well below the lowest water quality benchmark of 2 µg/L (see Panel A on Figures 5.F-15 through 5.F-19) and would not result in increased impacts to sturgeon. It should also be noted that waterborne selenium concentrations at all these locations are below the draft water quality criterion for lentic systems of 1.2 µg/L (USEPA 2015).

For green sturgeon, patterns of uptake and exceedance probabilities differed across the Delta. Results by location are as follows:

- Sacramento River upstream of Delta Cross Channel – No differences (i.e., 0% difference; Table 5.F-13) in estimated particulate selenium concentrations were observed between the PA in comparison to the NAA (see also Panel B on Figure 5.F-15). Similarly, no differences in estimated dietary or whole-body concentrations between the PA in comparison to the NAA were observed (see Panels C and D on Figure 5.F-15). As shown in Tables 5.F-13, there is no difference (i.e., 0% difference) between the dietary and whole-body selenium concentrations estimated under the PA and NAA. Additionally, dietary and whole-body tissue concentrations are well below benchmarks for reproduction at this location.

- San Joaquin River near San Andreas Landing – Estimated selenium concentrations in particulates, diet, and whole-body sturgeon were slightly greater (a 15% increase over the full 82-year simulation period) under the PA compared to the NAA (see Table 5.F-14 and Panels B, C, and D on Figure 5.F-16). All concentrations under the PA and NAA were below the dietary and whole-body thresholds for sturgeon.

- Old River at Clifton Court Forebay Radial Gates (West Canal) – Estimated selenium concentrations in particulates, diet, and whole-body sturgeon were slightly greater (a 15% increase over the full 82-year simulation period) under the PA in comparison to the NAA (Table 5.F-15 and Figure 5.F-17). However, dietary concentrations were well below the benchmark for reproduction at this location. Whole-body selenium concentrations in sturgeon exceeded the benchmark up to 20 percent of the time for both the PA and the NAA. As shown in Table 5.F-15, whole-body selenium concentrations estimated for the PA and NAA exceeded the 3.3 mg/kg benchmark only during dry years.

- San Joaquin River at Antioch – Estimated selenium concentrations in particulates, diet, and whole-body sturgeon were slightly greater (a 13% increase over the full 82-year simulation period) under the PA compared to the NAA (Table 5.F-16 and Figure 5.F-18). However, dietary selenium concentrations were well below benchmarks for reproduction at this location except for a low incidence of <1 percent for the PA. In contrast, both the PA and NAA had a high frequency of exceedance of the whole-body benchmark for reproductive effects (virtually 100%), although there was little difference between the PA and NAA. Over the 82-year simulation period, average whole-body concentrations in green sturgeon are predicted to increase by 0.7 mg/kg (from 5.4 to 6.2 mg/kg; Table 5.F-16). Estimated whole-body sturgeon concentrations for both PA and NAA were greatest during the dry and critical years.

- Sacramento River at Mallard Slough – Estimated selenium concentrations in particulates, diet, and whole-body sturgeon were slightly greater (an 8% increase over the full 82-year simulation period) under the PA compared to the NAA (Table 5.F-17 and Figure 5.F-19). However, dietary selenium concentrations were well below the benchmark for effects on reproduction at this location. In contrast, both the PA and NAA had a high frequency of exceedance (virtually 100%) of the whole-body benchmark for reproductive effects, although there was little difference between the PA and NAA. Over the 82-year simulation period, average whole-body selenium concentrations in green sturgeon are predicted to increase by 0.4 mg/kg (from 5.3 to 5.7 mg/kg; Table 5.F-17). Estimated whole-body sturgeon concentrations were greatest during the dry and critical years.

These results are discussed further in the Risk Description (Section 5.F.4.2).

5.F.4.2 Risk Description

The Risk Description incorporates results of Risk Estimation along with other information to describe how the expected changes in selenium would affect the listed NMFS fish species when they are present in the Delta. The risk descriptions for TL-3 fish (salmon and steelhead) and green sturgeon are provided below. Disparities between smaller changes predicted for TL-3 fish and larger changes estimated for sturgeon described below are attributable largely to differences in modeling approaches for these species (as described in Attachment 5.F-1) and differences in the thresholds for effects (Section 5.F.3.2). The model for TL-3 fish was calibrated to encompass the varying concentration-dependent uptake from waterborne selenium concentrations (expressed as the K_d) that was exhibited in data for fish from locations across the Delta used to calibrate the bioaccumulation model. In contrast, the modeling for sturgeon could not be similarly calibrated and used "fixed" literature-derived uptake factors and trophic transfer factors. In some instances, the Hazard Quotient (HQ; estimated diet or whole-body fish concentration/benchmark) is provided for the risk description.

5.F.4.2.1 TL-3 Fish (Salmon and Steelhead)

Slightly higher selenium concentrations are predicted in water under the PA compared to the NAA. However, these differences are very small at all locations (< 0.067 µg/L increase under the PA) and estimated waterborne concentrations under both scenarios are well below the lowest water quality benchmark of 2 µg/L. Therefore, no adverse effects to water quality are predicted based on the slight increase in estimated waterborne concentrations under the PA.

At the Mokelumne River (South Fork) at Staten Island, selenium concentrations in particulates were very similar for the NAA and the PA (Table 5.F-2 and Panel B of Figure 5.F-4). This is due to the use of the log-log K_d models and the concentration-related nature of the K_d. In calibration of the bioaccumulation model for fish in the Delta it was found that the K_d increases with low water concentrations and decreases with high water concentrations (see Attachment 5.F-1). The step down in particulate concentrations (just before 40% probability exceedance on the x-axis of the figure) indicates the difference between the dry and critical years (K_d calculated using Model 5) and the wet, above normal, and below normal years (K_d calculated using Model 3). Panel C of Figure 5.F-4 shows the same pattern but with higher selenium concentrations in the TL-3 fish diet than in particulates due to the TTF of 2.8 from particulates to invertebrates. However, estimated concentrations for both the PA and NAA are well below the dietary benchmark of 18.2 mg/kg. Similarly, estimated concentrations of whole-body TL-3 fish tissue were slightly higher than dietary concentrations (TTF of 1.1 from diet to fish), but were also well below the benchmarks for growth (7.36 mg/kg) and survival (10.4 mg/kg) (see Panel D of Figure 5.F-4). As a result of the project, slight increases in waterborne selenium are predicted, as are some increases in the prey base and whole-body tissue for juvenile salmon and steelhead. These same increases are predicted in the absence of the project (0% difference between PA and NAA; Table 5.F-2). Although some locations are expected to have slightly higher selenium concentrations in water, this pattern of results for TL-3 fish was the same at all 11 locations within the Delta (Tables 5.F-2 through 5.F-12 and Figures 5.F-4 through 5.F-14). The similarity in risk patterns among sites in the Delta is due to the use of the log-log K_d models and the concentration-related nature of the K_d (i.e., K_d increases with low water concentrations and decreases with high water concentrations).

The dietary and whole-body benchmarks for survival of salmonids are based on no effect concentrations and the whole-body benchmark for growth is based on an effect concentration for 10 percent of the test group (EC_{10}). HQs for the maximum estimated concentrations in diet and whole-body TL-3 fish at all locations are only 0.1 and 0.3, respectively. Given that K_d fluctuates with waterborne selenium concentration such that estimated diet and whole-body fish concentrations are essentially the same (about 2 mg/kg in the diet and 2.2 mg/kg in whole-body fish) over an 82-year timeframe, no adverse effects to individual juvenile salmon and steelhead or populations of these receptor species due to the proposed action are predicted.

5.F.4.2.2 Green Sturgeon

Slightly higher selenium concentrations are predicted in water under the PA compared to the NAA at all sturgeon locations. However, these differences are very small (< 0.072 µg/L increase under the PA), and estimated waterborne concentrations under both scenarios are well below the lowest water quality benchmark of 2 µg/L (Tables 5.F-13 through 5.F-17 and Figures 5.F-15 through 5.F-19). Therefore, no adverse effects to water quality are predicted based on the slight increase in estimated waterborne concentrations under the PA.

K_ds used in the green sturgeon model were fixed, with 3,000 used for wet, above normal, and below normal years and 6,000 used for dry and critical years. As a result, the pattern of concentrations in particulates, diet, and whole-body sturgeon is similar to the pattern in water (i.e., selenium concentrations under the PA are slightly greater than under the NAA). The one exception is the Sacramento River upstream of Delta Cross Channel location, where estimated particulates, diet, and whole-body fish selenium concentrations do not appear to differ between the PA and the NAA (Panels B, C, and D on Figure 5.F-15). As presented in Table 5.F-13, there is no (i.e., 0%) difference between the PA and the NAA for these estimated concentrations at the Sacramento River upstream of Delta Cross Channel location. This location shows a different pattern because the estimated waterborne selenium concentrations over the 82-year period differ so little (range from 0.09003 to 0.09010 µg/L). The difference in K_d also accounts for the higher concentrations during the dry and critical years when bioaccumulation is greater.

Unlike the salmonids, exceedance results for green sturgeon differed across the Delta. These differences were mainly due to the different diets assumed for the two western Delta locations (including 50% of diet as *Corbula amurensis*) compared to the other locations. For example, estimated concentrations in the diet and whole-body sturgeon at the Sacramento River upstream of Delta Cross Channel (Figure 5.F-15; Table 5.F-13) and the San Joaquin River near San Andreas Landing (Figure 5.F-16; Table 5.F-14) were well below reproductive thresholds (8.2 mg/kg in diet and 3.3 mg/kg whole-body fish). At these locations, the sturgeon diet is assumed to be a mixture of amphipods, mysids, and insects with a TTF of 1.9 used to estimate dietary concentration from particulate concentration. As a result of the project, slight increases in waterborne selenium are predicted, as are some increases in the prey base and whole-body tissue concentrations for green sturgeon at the San Joaquin River near San Andreas Landing location. At the Sacramento River upstream of Delta Cross Channel location, the very small increase in waterborne selenium concentrations under the PA results in no increase (i.e., 0% difference) in the dietary and whole-body estimated concentrations under the PA compared to the NAA. The HQs for the maximum estimated concentrations in diet (0.1) and whole-body green sturgeon (0.4) at the Sacramento River upstream of Delta Cross Channel location are the same for the PA and the NAA. At the San Joaquin River near San Andreas Landing, HQs are 0.2 and 0.5 under the PA compared to 0.1 and 0.4 under the NAA. Based on these results (i.e., all HQs are well below 1), no adverse effects to individual green sturgeon or populations of this receptor species at the Sacramento River upstream of Delta Cross Channel and the San Joaquin River near San Andreas Landing locations are predicted due to the proposed action.

At the Old River at Clifton Court Forebay Radial Gates (West Canal) location, a TTF from particulates to invertebrates of 1.9 was used (Figure 5.F-17). The estimated dietary concentrations at this location were well below the reproductive threshold. However, about 20 percent or less of the estimated whole-body concentrations exceeded the reproductive threshold for both the NAA and the PA, but there was very little difference between scenarios (Table 5.F-15). As a result of the project, slight increases in waterborne selenium (< 0.072 µg/L) are predicted at this location, as are some increases in the prey base and whole-body tissue selenium concentrations for green sturgeon. The HQs for the maximum estimated concentrations in diet and whole-body green sturgeon under the NAA are 0.3 and 1.04, respectively. For the PA, these values are 0.4 and 1.2. Based on these results (i.e., all HQs are well below 1), there is no risk of adverse effects from the diet. However, there is low risk of adverse effects (HQs < 1.5) based on whole-body tissue under both the NAA and PA. Whole-body exceedances of the reproductive threshold were limited to dry and critical years (i.e., all estimated whole-body fish concentrations for wet, above normal, and below normal years were less than the reproductive threshold; Table 5.F-15). In fact, over the 82-year simulation period, average whole-body concentrations in green sturgeon are predicted to increase by only 0.4 mg/kg (from 2.5 to 2.9 mg/kg; Table 5.F-15) under the PA, but remain under the 3.3 mg/kg benchmark. The higher estimated concentrations of selenium in water under the NAA and PA during dry and critical years were the driver for exceedances and increased HQs in this area of the Delta.

In the western Delta where sturgeon are known to forage on *Corbula amurensis* and on crustaceans, a conservative TTF of 9.2 (from Presser and Luoma 2013) was used to estimate dietary concentrations from particulates. This resulted in greater dietary concentrations at these locations, though there were no exceedances of the dietary benchmark under the NAA or PA at the Sacramento River at Mallard Island location (Figure 5.F-19) and no exceedances, except for rare occurrences (<1%) under the PA at the San Joaquin River at Antioch location (Figure 5.F-18). However, as a consequence of these greater dietary concentrations and the very low whole-body benchmark, all estimated concentrations in whole-body sturgeon tissue at these two locations exceeded the reproductive threshold under both the PA and NAA, though there is a relatively small difference between scenarios (Tables 5.F-16 and 5.F-17). For example, at the San Joaquin River at Antioch location, estimated whole-body concentrations are about 7.4 mg/kg (PA) compared to 7.0 mg/kg (NAA) at the 20 percent exceedance probability and about 5.6 mg/kg (PA) compared to 4.6 mg/kg (NAA) at the 60 percent exceedance probability (Table 5.F-16; Figure F.5-18). The differences between the NAA and the PA are even smaller (< 0.2 mg/kg different at 20% probability and < 0.7 mg/kg different at 60% probability) at the Sacramento River at Mallard Island location (Table 5.F-17; Figure 5.F-19). HQs for the maximum whole-body concentrations were 2.2 for the NAA and 2.4 for the PA at the San Joaquin River at Antioch location and 2.2 compared to 2.3 at the Sacramento River at Mallard Island location. Detection of small changes in whole-body sturgeon such as those estimated for the western Delta would require very large sample sizes because of the inherent variability in fish tissue selenium concentrations.

It should also be noted that the whole-body benchmark of 3.3 mg/kg is a literature-derived benchmark for reproductive effects that is based on an effect concentration for 5 percent of the test group (EC_{05}). Given that it is difficult to distinguish natural variation from the effects of a stressor at this low effect level, the whole-body benchmark is likely conservative (i.e., similar to the "background" level for areas unaffected by releases of selenium to the environment). For the two western Delta locations that had 100 percent exceedance of this whole-body benchmark, this means that 5 percent of individuals may be expected to have a decrease in reproduction under both the PA and NAA, which may translate into a decrease in reproduction of the green sturgeon population. At the Old River at Clifton Court Forebay Radial Gates (West Canal) location, there is an even lower probability of exceedance (20% of estimated whole-body concentrations exceed the benchmark) and thus a lower risk of adverse effects to individuals (1 in 100 individuals [5% of the 20% of exceedances]) and green sturgeon populations.

Presser and Luoma (2013) use a low benchmark of 5 mg/kg to evaluate possible effects to sturgeon. This value was derived to provide additional protection to special-status species (Skorupa et al. 2004, Skorupa 2008). All estimated whole-body green sturgeon concentrations at the Old River at Clifton Court Forebay Radial Gates (West Canal) location under both the PA and NAA were less than this threshold (Table 5.F-15), suggesting that green sturgeon in this area may not be at risk.

At the two western Delta locations, about 70 percent (San Joaquin River at Antioch) or 60 percent (Sacramento River at Mallard Island) of whole-body fish concentrations exceeded the 5 mg/kg threshold under the PA compared to about 50 percent at both locations under the NAA. Therefore, increased risk of adverse effects to individual green sturgeon in these areas under the PA cannot be excluded. However, risks of adverse effects under the PA are likely low given the low magnitude of exceedance of the 5 mg/kg threshold at both locations (HQ of 1.6 for San Joaquin River at Antioch and 1.5 for Sacramento River at Mallard Island under the PA compared to HQ of 1.4 under the NAA at both locations). Exceedances under both the PA and NAA at the Sacramento River at Mallard Island location were limited to dry and critical years (i.e., all estimated whole-body fish concentrations for wet, above normal, and below normal years were less than the reproductive threshold; Table 5.F-17). At the San Joaquin River at Antioch location, all exceedances under the NAA were limited to dry and critical years (Table 5.F-16). Exceedances under the PA were predicted for wet years as well as critical and dry years, but not for above normal or below normal years (Table 5.F-16).

Based on the selenium analysis for reproductive effects in green sturgeon (the most sensitive life-stage), no risks of adverse effects to individual green sturgeon or populations are predicted at two locations (Sacramento River upstream of Delta Cross Channel and San Joaquin River near San Andreas Landing). Adverse effects at the Old River at Clifton Court Forebay Radial Gates (West Canal) location are considered unlikely (i.e., all dietary concentrations below benchmark of 8.2 mg/kg and some exceedances of the whole-body benchmark of 3.3 mg/kg, but no exceedances of the 5 mg/kg benchmark). Additionally, average whole-body concentrations in green sturgeon predicted over the 82-year simulation period (2.5 mg/kg for the NAA and 2.9 mg/kg for the PA; Table 5.F-15) are less than the 3.3 mg/kg benchmark and risks of adverse effects from the diet are not predicted (i.e., HQs < 1). These findings further support a conclusion of low risk of adverse effects to green sturgeon at this location.

Although modeled whole-body concentrations at the two western Delta locations may present a risk of adverse effects to sturgeon, these risks are based on a conservative TTF from particulates to *Corbula amurensis* and a conservative reproductive effects threshold. For these locations, there is a higher predicted frequency of exceedances of the less-conservative threshold of 5 mg/kg under the PA (60% for Sacramento River at Mallard Island and 70% for San Joaquin River at Antioch) than under the NAA (about 50% at both locations), but there is very little difference in predicted tissue concentrations ($\leq$ 1 mg/kg) between the NAA and the PA, and whole-body HQs using the 5 mg/kg threshold are low (< 2). Risks of adverse effects from the diet are not predicted (i.e., HQs < 1, except for rare cases [< 1%] at San Joaquin River at Antioch). Based on these results, risk of adverse effects to individual green sturgeon or populations of green sturgeon are low. Although the PA slightly increases these risks, risk of adverse effects remains low under the PA, and – because of the inherent variability in fish tissue selenium concentrations and their effects – the differences likely would not be measurable by sampling or monitoring for effects.

5.F.4.2.3 Critical Habitat

This section describes the potential effects of the PA on critical habitat of ESA-listed species, by considering the potential effects to the invertebrate prey base. In its derivation of the current draft ambient water quality criteria for selenium, USEPA (2015) concluded that the relative insensitivity of invertebrates, when compared with the fish whole-body concentrations, demonstrates that invertebrates are generally protected by selenium criterion values derived from fish. This conclusion was supported by Janz et al. (2010) based on their analysis of the toxicity of selenium to aquatic organisms. Therefore, invertebrates are considered implicitly in the analyses of juvenile salmon and steelhead and adult green sturgeon, and it is unlikely that prey availability for salmonids or green sturgeon would be affected to a greater degree than the effects on fish themselves. Namely, no adverse effects to critical habitat are expected because invertebrates are considered less sensitive than fish to the effects of selenium (Janz et al. 2010; USEPA 2015), and no (juvenile salmon and steelhead, as well as green sturgeon at some locations) or low (green sturgeon at the western Delta locations) risk of adverse effects to ESA-listed fish are predicted.

5.F.4.3 Uncertainty and Limitations Analysis

Uncertainties and limitations are inherent in all aspects of risk analysis. The nature and magnitude of uncertainties depend on the amount and quality of the data available, the degree of knowledge concerning site conditions, and the assumptions made to assess the risk. Uncertainties and limitations for this selenium analysis in the Delta are provided below, in no particular order.

Modeling was used to estimate waterborne selenium concentrations at the DSM2 locations. Limitations of this model are detailed in Appendix 5.B (Section 5.B.1.2). Briefly, the DSM2 model is one-dimensional with inherent limitations in simulating hydrodynamic and transport processes in a complex estuarine environment such as the Delta. Despite the calibration of the DSM2 model using measured data, it is not possible to identify whether concentrations are over- or under-estimated. However, the modeled data are useful for making comparisons between the PA and NAA.

Modeling was used to estimate waterborne selenium concentrations over the 82-year period. Limitations and appropriate use of the 82-year water model (CalSim II) are detailed in Appendix

5.A (Section 5.A.1.1). The model assumes that facilities, land use, water supply contracts, and regulatory requirements are constant over 82 years, representing a fixed level of development. Because it is simulating hypothetical conditions, CalSim II is not calibrated and cannot be used in a real-time predictive manner. CalSim II results are intended to be used in a comparative manner, which allows for assessing the changes in incremental effects between two scenarios. The model should be used with caution when absolute results are needed in instances such as determining effects based on a threshold. This modeling may under- or over-estimate risk, but it is useful for making comparisons between the PA and NAA.

Exposure estimates required the calculation of particulate selenium concentrations from waterborne selenium concentrations using the K_d. As discussed in Section 5.F.3.1.2, K_d is a large source of uncertainty when extrapolating from waterborne selenium to aquatic organisms due to its high variability. Uncertainties associated with K_ds are as follows:

- For juvenile salmonids, whole-body tissue concentrations in largemouth bass collected in the Delta were used to develop a water-to-tissue model. Log-log regression relations of K_d to waterborne selenium were developed for all years, normal/wet years, and dry years based on the available data. Use of these log-log regressions may over- or under-estimate selenium transfer to particulates. However, the model was calibrated using measured data, so the effect of this uncertainty on the risk conclusions is low.

- For green sturgeon, fixed K_ds that are approximations of K_d values reported in Presser and Luoma (2013) for low-flow and normal-flow conditions were used. These fixed values do not allow for changes in K_d related to changes in waterborne selenium concentrations as occurs in the log-log regression model for salmonids. Therefore, uptake to particulates may be over- or under-estimated.

Estimated dietary concentrations for juvenile salmonids and green sturgeon rely on invertebrate TTFs that were derived from literature sources. Uncertainties with these invertebrate TTFs are as follows:

- For salmonids, a TTF from particulates to invertebrates of 2.8 was selected based on data provided in Presser and Luoma (2010a, 2010b, 2013). This is the average TTF (range 2.1 to 3.2) for aquatic life stages of insects that are likely to be in the salmonid diet (mayfly, caddisfly, crane fly, stonefly, damselfly, corixid, and chironomid). TTFs differ between species and may also differ with location within the Delta. Additionally, the range of TTFs is limited to aquatic insects that have been measured and may not include all insects represented in the actual diet of juvenile salmonids foraging in the Delta. It should also be noted that some TTFs were based on laboratory studies (Presser and Luoma 2010a), which may not fully represent conditions in the Delta. Therefore, use of the selected TTF may under- or over-estimate exposure, and therefore risk, to juvenile salmonids in this analysis.

- The invertebrate TTF for green sturgeon in the western Delta (Carquinez Strait and Suisun Bay) of 9.2 is the average of the average TTF for uptake from particulates to *Corbula amurensis* (17) and the average TTF for benthic crustaceans (1.4). It is unknown whether use of this TTF will under- or over-predict exposure and risks to green sturgeon in the western Delta because the composition of their diet is not well documented.

- The invertebrate TTFs for green sturgeon in other locations of the Delta (1.9) is the average of TTFs for amphipods (0.6-0.9), mysids (1.3), and insects (2.8) from Presser and Luoma (2010a, 2013). A diet of 50 percent amphipods and mysids (assumed based on a 1960s-era report [see USFWS 2008]) and 50 percent insects was assumed. TTFs differ among species and may also differ with location within the Delta. Additionally, the range of TTFs is limited to amphipods, mysids, and aquatic insects that have been measured and may not include all items represented in the actual diet of green sturgeon foraging in the Delta. Moreover, dietary information for green sturgeon is based on a study from the 1960s and may not represent current dietary composition of green sturgeon. It should also be noted that some TTFs were based on laboratory studies (Presser and Luoma 2010a), which may not fully represent conditions in the Delta. Therefore, use of the selected TTF may under- or over-estimate exposure, and therefore risk, to green sturgeon in this analysis.

Estimated whole-body concentrations for juvenile salmonid and green sturgeon rely on fish TTFs that were derived from literature sources. Uncertainties with these fish TTFs are as follows:

- Laboratory- and field-derived TTFs for fish reported in Presser and Luoma (2010a) varied from 0.5 to 1.6 and the average of the available data (1.1) was selected for use in the tissue modeling for juvenile salmonids. As discussed for invertebrate TTFs, differences among species, among locations within the Delta, and between laboratory and actual field conditions are sources of uncertainty for this fish TTF. Therefore, use of the selected TTF may under- or over-estimate exposure, and therefore risk, to juvenile salmonids in this analysis.

- The fish TTF used for green sturgeon (1.3) is based on a field measured TTF for white sturgeon assumed to eat a diet of clams (Presser and Luoma 2010a). This is likely a good approximation for the green sturgeon; however, there may be differences between the two species and the TTF is based on a diet of 100 percent clams and may not represent TTFs for other prey items (e.g., amphipods, mysids, and insects). Although this TTF may under- or over-estimate exposure and risk to green sturgeon, the effect is likely very minor.

Literature-derived toxicity data from laboratory studies were the only toxicity data used to evaluate risk to juvenile salmonids and green sturgeon. Uncertainties with these studies are as follows:

- Effects data for salmonids are based on survival and growth studies using Chinook salmon (Hamilton et al. 1990 as reported in USEPA 2015). Effects observed in this species were assumed to be indicative of effects that would occur in other salmonids. The suitability of this assumption is unknown and may result in either over- or under-estimation of risk. However, the magnitude of this effect is considered to be low.

- Effects data for green sturgeon are based on reproduction studies using white and green sturgeon. The white sturgeon study (Linville 2006) reported EC_{05} and EC_{10} dietary and whole-body concentrations associated with mortality of larvae exposed to selenium via microinjection and with larval abnormalities for white sturgeon exposed to selenium via maternal diet. Linares-Casenave et al. (2010) completed similar larval microinjection studies on green sturgeon, but did not include maternal dietary exposures. Therefore, maternal diet effect levels for green sturgeon used in this selenium analysis (8.2 mg/kg diet and 3.3 mg/kg whole body) were calculated from the white sturgeon maternal dietary exposure effect levels by adjusting for relative species sensitivity using the ratio of EC_{10}s from the white and green sturgeon microinjection studies (see USFWS 2012). Because injection of chemicals is not an accurate representation of dietary uptake, the suitability of using the white-to-green sturgeon ratio calculated from the microinjection studies to calculate a dietary effect level is unknown. As a consequence, risk may be over- or under-estimated.

- Available references do not give benchmarks for physiological, behavioral, or other sublethal effects to salmonids or green sturgeon. For the issue of such effects specifically to green sturgeon, USFWS (2012) said "Until data on sublethal reproductive and behavioral effects such as these are published, to the best of our knowledge, the data used here [referring to the benchmarks for survival, growth, and reproduction as used in this appendix] are the best available for the most sensitive endpoint currently known for these fish."

5.F.5 Conclusions

This analysis of the effects of selenium on NMFS species of concern (winter- and spring-run Chinook salmon, steelhead, and green sturgeon) and their habitat was completed to support the California WaterFix Section 7 BA evaluating the effects of the PA. The conclusions of this analysis are summarized in Table 5.F-18 and as follows:

- For both juvenile salmonids (salmon and steelhead) and green sturgeon, slightly higher selenium concentrations are predicted in water under the PA compared to the NAA. However, these differences are very small at all locations (< 0.072 µg/L increase under the PA) and estimated waterborne concentrations under both scenarios are well below the lowest water quality benchmark of 2 µg/L (Note: all estimated waterborne concentrations are also well below the draft water quality criterion for lentic systems of 1.2 µg/L developed by USEPA [2015]) Therefore, no adverse effects to water quality are predicted based on the slight increase in estimated waterborne concentrations under the PA. Because these benchmarks are developed to be protective of invertebrates (salmonid and green sturgeon diet), no effects on prey availability are expected under the PA.

- For juvenile salmon and steelhead, there is no (i.e., 0%) difference between the PA and NAA, and estimates of dietary and tissue selenium concentrations are below survival or growth effect thresholds. Therefore, no effects to individual juvenile salmon and steelhead or to populations of these salmonids are predicted.

- Based on the selenium analysis for reproductive effects in green sturgeon (the most sensitive life-stage), no risks of adverse effects to individual green sturgeon or populations are predicted at two locations (Sacramento River upstream of Delta Cross Channel and San Joaquin River near San Andreas Landing).

- Risks of adverse effects to green sturgeon (individuals and populations) at the Old River at Clifton Court Forebay Radial Gates (West Canal) location are possible, but are considered to be *de minimis*. Specifically, all dietary concentrations at this location are below the benchmark of 8.2 mg/kg; although there were some exceedances of the whole-body benchmark of 3.3 mg/kg (maximum HQ of 1.2), these exceedances would affect only a small portion of individuals (5% of the 20% probability of exceedance or 1 in 100) and there were no exceedances of the 5 mg/kg benchmark. Additionally, average whole-body concentrations in green sturgeon predicted over the 82-year simulation period (2.5 mg/kg for the NAA and 2.9 mg/kg for the PA) are less than the 3.3 mg/kg benchmark.

- Modeled green sturgeon whole-body concentrations at the two western Delta locations may present a risk of effects to sturgeon (i.e., virtually all whole-body concentrations exceeded the 3.3 mg/kg threshold and 50 to 70 percent of whole-body concentrations exceeded the less conservative 5 mg/kg threshold). The 3.3 mg/kg threshold is an EC_{05} and the 5 mg/kg threshold is an EC_{10}, which suggests 5 to 10 percent of individuals may experience reproductive effects that could translate into a population effect. However, there are several issues that suggest that risks of adverse effects at these two locations are low. Namely, these risks are based on a conservative TTF from particulates to *Corbula amurensis* that may over-estimate exposure and risk and risks of adverse effects from the diet are not predicted (i.e., HQs < 1, except for rare cases [< 1%] at San Joaquin River at Antioch). Additionally, there is very little difference in predicted tissue concentrations (≤ 1 mg/kg) between the NAA and the PA, and whole-body HQs using the 5 mg/kg threshold are low (< 2). Although the PA slightly increases these risks, risk of adverse effects remains low under the PA, and – because of the inherent variability in fish tissue selenium concentrations and their effects – the differences likely would not be measurable by sampling or monitoring for effects.

- Possible risks identified for green sturgeon would be most likely to occur during dry or critical years.

As discussed in the Technical Approach (Section 5.F.1.2), this selenium analysis serves to support a determination for the following questions:

- Is implementation of the PA likely to adversely affect the continued existence of the species?

- Is implementation of the PA likely to adversely modify or destroy the designated critical habitat?

No selenium-based risks to juvenile salmonids were predicted. Low risks of effects to green sturgeon reproduction were identified in some areas of the Delta (primarily in the western Delta), but there was little difference between the PA and the NAA (e.g., there is a < 1 mg/kg difference in predicted whole-body green sturgeon tissue concentrations between the NAA and the PA; such a difference is difficult to discern given the inherent variability in fish tissue selenium concentrations and their effects). Therefore, the PA is unlikely to adversely affect the continued existence of juvenile salmonids and green sturgeon in the Delta when compared to the NAA.

Given the minimal difference in waterborne selenium concentrations under the PA and the NAA, adverse effects to the critical habitat for juvenile salmonids and green sturgeon from the PA are not likely when compared to the NAA. Specifically, results of the analysis indicate that the very small increase in waterborne selenium concentrations predicted for the PA (< 0.072 µg/L increase under the PA across all locations and for salmonid and sturgeon receptors) will have little effect on water quality (i.e., all concentrations are below the lowest water quality benchmark of 2 µg/L as well as the draft water quality criterion for lentic systems of 1.2 µg/L developed by USEPA [2015]). In its derivation of the current draft ambient water quality criterion for selenium, USEPA (2015) concluded that the relative insensitivity of invertebrates, when compared with the fish whole-body concentrations demonstrates that invertebrates are generally protected by selenium criterion values derived from fish. This conclusion is supported by another comprehensive evaluation of selenium toxicity to aquatic organisms (Janz et al. 2010). Therefore, invertebrates are considered implicitly in the analyses above, and it is unlikely that prey availability for salmonids or green sturgeon would be affected to a greater degree than the effects on fish themselves. Because invertebrates are considered less sensitive than fish to the effects of selenium (Janz et al. 2010; USEPA 2015), and no (juvenile salmon and steelhead, as well as green sturgeon at some locations) or low (green sturgeon at the western Delta locations) risk of adverse effects to ESA-listed fish are predicted, no effects on habitat quality are expected.

5.F.6 References

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5.F.7 Tables

Table 5.F-1. Selenium Concentrations in Water at Inflow Sources to the Delta

Delta Sources	Representative Inflow Site	GM Se Concentration in Water (µg/L)[a]	Years	Source
Delta Agriculture	Mildred Island, Center	0.11	2000	Lucas and Stewart 2007
East Delta Tributaries	Mokelumne, Calaveras, and Cosumnes Rivers	0.10[b]	None	None
Martinez/Suisun Bay	San Joaquin River near Mallard Island	0.10	02/2000–08/2008	SFEI Website 2014
Sacramento River	Sacramento River at Freeport	0.09	11/2007–07/2014	USGS Website 2014
San Joaquin River	San Joaquin River at Vernalis (Airport Way)	0.45[c]	11/2007-08/2014	USGS Website 2014
San Joaquin River	San Joaquin River at Vernalis (Airport Way)	0.83[d]	1999-2000	SWAMP Website 2009
		0.85[d]	2004-2005	SWAMP Website 2009
		0.58[d]	2006-2007	SWAMP Website 2009
Yolo Bypass	Sacramento River below Knights Landing	0.23[e]	2004, 2007, 2008	DWR Website 2009

Notes:

[a] Selenium concentrations are in dissolved fraction unless otherwise noted.

[b] Dissolved selenium concentration is assumed to be 0.1 µg/L due to lack of available data and lack of sources that would be expected to result in concentrations greater than 0.1 µg/L.

[c] Data used to represent current/baseline conditions for comparison of alternatives.

[illegible]
2004-2005 for bass in 2005; and data for 2006-2007 for bass in 2007.

[e] Total selenium concentration in water.

µg/L = microgram(s) per liter

GM = geometric mean

Se = selenium

Table 5.F-2. Mokelumne River (South Fork) at Staten Island – TL3 Fish

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - TL3 Fish Model 3 or 5[e] (mg/kg)				Invertebrates - TL3 Fish Diet, Model 3 or 5[e] (mg/kg)				Whole Body TL3 Fish, Model 3 or 5[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.0947	0.0955	0.001	1%	0.7256	0.7255	0.000	0%	2.0316	2.0315	0.000	0%	2.2347	2.2347	0.000	0%
20%	0.0942	0.0952	0.001	1%	0.7255	0.7255	0.000	0%	2.0314	2.0313	0.000	0%	2.2346	2.2344	0.000	0%
30%	0.0940	0.0947	0.001	1%	0.7254	0.7254	0.000	0%	2.0313	2.0311	0.000	0%	2.2344	2.2342	0.000	0%
40%	0.0936	0.0942	0.001	1%	0.5377	0.5377	0.000	0%	1.5056	1.5056	0.000	0%	1.6562	1.6561	0.000	0%
50%	0.0935	0.0940	0.001	1%	0.5374	0.5374	0.000	0%	1.5048	1.5047	0.000	0%	1.6552	1.6552	0.000	0%
60%	0.0931	0.0935	0.000	0%	0.5374	0.5374	0.000	0%	1.5047	1.5046	0.000	0%	1.6552	1.6551	0.000	0%
70%	0.0930	0.0932	0.000	0%	0.5374	0.5373	0.000	0%	1.5047	1.5045	0.000	0%	1.6551	1.6550	0.000	0%
80%	0.0927	0.0929	0.000	0%	0.5374	0.5373	0.000	0%	1.5046	1.5045	0.000	0%	1.6550	1.6549	0.000	0%
90%	0.0924	0.0927	0.000	0%	0.5373	0.5373	0.000	0%	1.5045	1.5044	0.000	0%	1.6550	1.6548	0.000	0%
Long Term																
Full Simulation Period[b]	0.0934	0.0940	0.001	1%	0.6108	0.6108	0.000	0%	1.7102	1.7101	0.000	0%	1.8812	1.8811	0.000	0%
Water Year Types[c d]																
Wet (32%)	0.0943	0.0952	0.001	1%	0.5373	0.5373	0.000	0%	1.5046	1.5044	0.000	0%	1.6550	1.6549	0.000	0%
Above Normal (16%)	0.0935	0.0941	0.001	1%	0.5374	0.5374	0.000	0%	1.5047	1.5046	0.000	0%	1.6552	1.6551	0.000	0%
Below Normal (13%)	0.0926	0.0930	0.000	0%	0.5374	0.5374	0.000	0%	1.5049	1.5048	0.000	0%	1.6553	1.6553	0.000	0%
Dry (24%)	0.0930	0.0934	0.000	0%	0.7255	0.7254	0.000	0%	2.0314	2.0312	0.000	0%	2.2345	2.2343	0.000	0%
Critical (15%)	0.0927	0.0929	0.000	0%	0.7255	0.7255	0.000	0%	2.0315	2.0314	0.000	0%	2.2346	2.2346	0.000	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Table 5.F-3. San Joaquin River at Buckley Cove – TL3 Fish

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - TL3 Fish Model 3 or 5[e] (mg/kg)				Invertebrates - TL3 Fish Diet, Model 3 or 5[e] (mg/kg)				Whole Body TL3 Fish, Model 3 or 5[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.4126	0.4176	0.005	1%	0.7056	0.7050	-0.001	0%	1.9757	1.9741	-0.002	0%	2.1733	2.1715	-0.002	0%
20%	0.4099	0.4163	0.006	2%	0.7051	0.7045	-0.001	0%	1.9743	1.9727	-0.002	0%	2.1717	2.1700	-0.002	0%
30%	0.4063	0.4135	0.007	2%	0.7047	0.7043	0.000	0%	1.9733	1.9721	-0.001	0%	2.1706	2.1693	-0.001	0%
40%	0.4020	0.4095	0.008	2%	0.5301	0.5297	0.000	0%	1.4842	1.4832	-0.001	0%	1.6326	1.6315	-0.001	0%
50%	0.3975	0.4067	0.009	2%	0.5297	0.5296	0.000	0%	1.4833	1.4828	0.000	0%	1.6316	1.6311	0.000	0%
60%	0.3951	0.4055	0.010	3%	0.5296	0.5296	0.000	0%	1.4830	1.4827	0.000	0%	1.6313	1.6310	0.000	0%
70%	0.3878	0.4026	0.015	4%	0.5296	0.5295	0.000	0%	1.4829	1.4826	0.000	0%	1.6312	1.6308	0.000	0%
80%	0.3803	0.3968	0.016	4%	0.5295	0.5294	0.000	0%	1.4827	1.4824	0.000	0%	1.6310	1.6307	0.000	0%
90%	0.3689	0.3884	0.020	5%	0.5295	0.5294	0.000	0%	1.4825	1.4824	0.000	0%	1.6308	1.6306	0.000	0%
Long Term																
Full Simulation Period[b]	0.3944	0.4058	0.011	3%	0.5982	0.5979	0.000	0%	1.6749	1.6740	-0.001	0%	1.8423	1.8414	-0.001	0%
Water Year Types[c d]																
Wet (32%)	0.4072	0.4125	0.005	1%	0.5295	0.5295	0.000	0%	1.4827	1.4825	0.000	0%	1.6310	1.6308	0.000	0%
Above Normal (16%)	0.3993	0.4100	0.011	3%	0.5296	0.5295	0.000	0%	1.4830	1.4826	0.000	0%	1.6313	1.6309	0.000	0%
Below Normal (13%)	0.3915	0.4055	0.014	4%	0.5298	0.5296	0.000	0%	1.4833	1.4828	-0.001	0%	1.6316	1.6311	-0.001	0%
Dry (24%)	0.3869	0.4026	0.016	4%	0.7051	0.7045	-0.001	0%	1.9743	1.9727	-0.002	0%	2.1717	2.1700	-0.002	0%
Critical (15%)	0.3763	0.3920	0.016	4%	0.7055	0.7049	-0.001	0%	1.9754	1.9738	-0.002	0%	2.1730	2.1712	-0.002	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Table 5.F-4. Franks Tract – TL3 Fish

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - TL3 Fish Model 3 or 5[e] (mg/kg)				Invertebrates - TL3 Fish Diet, Model 3 or 5[e] (mg/kg)				Whole Body TL3 Fish, Model 3 or 5[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.1696	0.2132	0.044	26%	0.7250	0.7237	-0.001	0%	2.0299	2.0264	-0.003	0%	2.2329	2.2291	-0.004	0%
20%	0.1523	0.1948	0.043	28%	0.7247	0.7230	-0.002	0%	2.0292	2.0244	-0.005	0%	2.2321	2.2268	-0.005	0%
30%	0.1327	0.1760	0.043	33%	0.7241	0.7212	-0.003	0%	2.0276	2.0193	-0.008	0%	2.2304	2.2213	-0.009	0%
40%	0.1214	0.1591	0.038	31%	0.5372	0.5364	-0.001	0%	1.5042	1.5018	-0.002	0%	1.6546	1.6520	-0.003	0%
50%	0.1080	0.1358	0.028	26%	0.5368	0.5355	-0.001	0%	1.5029	1.4994	-0.004	0%	1.6532	1.6494	-0.004	0%
60%	0.1029	0.1299	0.027	26%	0.5362	0.5346	-0.002	0%	1.5014	1.4970	-0.004	0%	1.6515	1.6467	-0.005	0%
70%	0.1000	0.1178	0.018	18%	0.5357	0.5341	-0.002	0%	1.5001	1.4955	-0.005	0%	1.6501	1.6451	-0.005	0%
80%	0.0976	0.1105	0.013	13%	0.5350	0.5335	-0.002	0%	1.4979	1.4937	-0.004	0%	1.6477	1.6431	-0.005	0%
90%	0.0963	0.1050	0.009	9%	0.5342	0.5330	-0.001	0%	1.4958	1.4923	-0.003	0%	1.6453	1.6416	-0.004	0%
Long Term																
Full Simulation Period[b]	0.1244	0.1541	0.030	24%	0.6091	0.6076	-0.002	0%	1.7055	1.7012	-0.004	0%	1.8761	1.8713	-0.005	0%
Water Year Types[c d]																
Wet (32%)	0.1585	0.2060	0.047	30%	0.5347	0.5333	-0.001	0%	1.4972	1.4931	-0.004	0%	1.6469	1.6425	-0.004	0%
Above Normal (16%)	0.1233	0.1576	0.034	28%	0.5360	0.5347	-0.001	0%	1.5008	1.4971	-0.004	0%	1.6509	1.6468	-0.004	0%
Below Normal (13%)	0.1095	0.1370	0.028	25%	0.5366	0.5354	-0.001	0%	1.5024	1.4991	-0.003	0%	1.6527	1.6490	-0.004	0%
Dry (24%)	0.1043	0.1218	0.018	17%	0.7240	0.7218	-0.002	0%	2.0271	2.0210	-0.006	0%	2.2298	2.2231	-0.007	0%
Critical (15%)	0.0986	0.1076	0.009	9%	0.7247	0.7234	-0.001	0%	2.0290	2.0255	-0.003	0%	2.2319	2.2281	-0.004	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Table 5.F-5. Old River at Rock Slough – TL3 Fish

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - TL3 Fish Model 3 or 5[e] (mg/kg)				Invertebrates - TL3 Fish Diet, Model 3 or 5[e] (mg/kg)				Whole Body TL3 Fish, Model 3 or 5[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.2017	0.2678	0.066	33%	0.7242	0.7221	-0.002	0%	2.0276	2.0220	-0.006	0%	2.2304	2.2242	-0.006	0%
20%	0.1823	0.2400	0.058	32%	0.7236	0.7211	-0.002	0%	2.0260	2.0192	-0.007	0%	2.2286	2.2211	-0.007	0%
30%	0.1642	0.2199	0.056	34%	0.7227	0.7189	-0.004	-1%	2.0235	2.0129	-0.011	-1%	2.2258	2.2142	-0.012	-1%
40%	0.1492	0.1960	0.047	31%	0.5370	0.5355	-0.002	0%	1.5037	1.4995	-0.004	0%	1.6541	1.6494	-0.005	0%
50%	0.1244	0.1659	0.042	33%	0.5362	0.5345	-0.002	0%	1.5015	1.4965	-0.005	0%	1.6516	1.6461	-0.005	0%
60%	0.1129	0.1562	0.043	38%	0.5352	0.5335	-0.002	0%	1.4985	1.4939	-0.005	0%	1.6484	1.6433	-0.005	0%
70%	0.1085	0.1363	0.028	26%	0.5346	0.5328	-0.002	0%	1.4968	1.4920	-0.005	0%	1.6465	1.6412	-0.005	0%
80%	0.1035	0.1257	0.022	21%	0.5340	0.5324	-0.002	0%	1.4951	1.4906	-0.004	0%	1.6446	1.6396	-0.005	0%
90%	0.1015	0.1173	0.016	16%	0.5333	0.5318	-0.002	0%	1.4932	1.4890	-0.004	0%	1.6425	1.6378	-0.005	0%
Long Term																
Full Simulation Period[b]	0.1438	0.1844	0.041	28%	0.6081	0.6062	-0.002	0%	1.7027	1.6973	-0.005	0%	1.8730	1.8671	-0.006	0%
Water Year Types[c d]																
Wet (32%)	0.1910	0.2500	0.059	31%	0.5337	0.5322	-0.001	0%	1.4944	1.4902	-0.004	0%	1.6438	1.6392	-0.005	0%
Above Normal (16%)	0.1451	0.1948	0.050	34%	0.5352	0.5335	-0.002	0%	1.4985	1.4939	-0.005	0%	1.6483	1.6433	-0.005	0%
Below Normal (13%)	0.1238	0.1640	0.040	32%	0.5360	0.5345	-0.001	0%	1.5007	1.4965	-0.004	0%	1.6508	1.6462	-0.005	0%
Dry (24%)	0.1148	0.1410	0.026	23%	0.7227	0.7197	-0.003	0%	2.0235	2.0153	-0.008	0%	2.2259	2.2168	-0.009	0%
Critical (15%)	0.1067	0.1216	0.015	14%	0.7235	0.7217	-0.002	0%	2.0259	2.0206	-0.005	0%	2.2285	2.2227	-0.006	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Table 5.F-6. Sacramento River at Emmaton – TL3 Fish

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - TL3 Fish Model 3 or 5[e] (mg/kg)				Invertebrates - TL3 Fish Diet, Model 3 or 5[e] (mg/kg)				Whole Body TL3 Fish, Model 3 or 5[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.1157	0.1301	0.014	12%	0.7251	0.7246	-0.001	0%	2.0302	2.0288	-0.001	0%	2.2332	2.2316	-0.002	0%
20%	0.1116	0.1250	0.013	12%	0.7249	0.7244	0.000	0%	2.0298	2.0285	-0.001	0%	2.2328	2.2313	-0.001	0%
30%	0.1070	0.1177	0.011	10%	0.7246	0.7237	-0.001	0%	2.0289	2.0263	-0.003	0%	2.2318	2.2290	-0.003	0%
40%	0.1032	0.1147	0.012	11%	0.5374	0.5371	0.000	0%	1.5046	1.5039	-0.001	0%	1.6551	1.6543	-0.001	0%
50%	0.1007	0.1091	0.008	8%	0.5371	0.5367	0.000	0%	1.5038	1.5026	-0.001	0%	1.6542	1.6529	-0.001	0%
60%	0.0991	0.1068	0.008	8%	0.5369	0.5364	-0.001	0%	1.5033	1.5019	-0.001	0%	1.6536	1.6520	-0.002	0%
70%	0.0975	0.1026	0.005	5%	0.5367	0.5362	-0.001	0%	1.5028	1.5013	-0.002	0%	1.6531	1.6514	-0.002	0%
80%	0.0964	0.0997	0.003	3%	0.5364	0.5358	-0.001	0%	1.5020	1.5003	-0.002	0%	1.6523	1.6504	-0.002	0%
90%	0.0952	0.0989	0.004	4%	0.5363	0.5356	-0.001	0%	1.5015	1.4997	-0.002	0%	1.6517	1.6497	-0.002	0%
Long Term																
Full Simulation Period[b]	0.1036	0.1123	0.009	8%	0.6101	0.6095	-0.001	0%	1.7082	1.7066	-0.002	0%	1.8791	1.8773	-0.002	0%
Water Year Types[c d]																
Wet (32%)	0.1121	0.1255	0.013	12%	0.5364	0.5358	-0.001	0%	1.5020	1.5003	-0.002	0%	1.6522	1.6504	-0.002	0%
Above Normal (16%)	0.1053	0.1148	0.009	9%	0.5368	0.5363	0.000	0%	1.5029	1.5016	-0.001	0%	1.6532	1.6518	-0.001	0%
Below Normal (13%)	0.0989	0.1074	0.008	9%	0.5371	0.5367	0.000	0%	1.5039	1.5026	-0.001	0%	1.6543	1.6529	-0.001	0%
Dry (24%)	0.0982	0.1040	0.006	6%	0.7247	0.7239	-0.001	0%	2.0292	2.0269	-0.002	0%	2.2321	2.2296	-0.002	0%
Critical (15%)	0.0964	0.0994	0.003	3%	0.7250	0.7245	0.000	0%	2.0299	2.0287	-0.001	0%	2.2329	2.2315	-0.001	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Table 5.F-7. San Joaquin River at Antioch – TL3 Fish

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - TL3 Fish Model 3 or 5[e] (mg/kg)				Invertebrates - TL3 Fish Diet, Model 3 or 5[e] (mg/kg)				Whole Body TL3 Fish, Model 3 or 5[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.1406	0.1687	0.028	20%	0.7249	0.7243	-0.001	0%	2.0298	2.0281	-0.002	0%	2.2328	2.2309	-0.002	0%
20%	0.1291	0.1589	0.030	23%	0.7248	0.7240	-0.001	0%	2.0294	2.0273	-0.002	0%	2.2324	2.2301	-0.002	0%
30%	0.1160	0.1393	0.023	20%	0.7244	0.7230	-0.001	0%	2.0284	2.0244	-0.004	0%	2.2312	2.2269	-0.004	0%
40%	0.1104	0.1344	0.024	22%	0.5373	0.5369	0.000	0%	1.5044	1.5033	-0.001	0%	1.6548	1.6536	-0.001	0%
50%	0.1034	0.1183	0.015	14%	0.5370	0.5363	-0.001	0%	1.5036	1.5016	-0.002	0%	1.6540	1.6518	-0.002	0%
60%	0.1001	0.1137	0.014	14%	0.5367	0.5356	-0.001	0%	1.5026	1.4996	-0.003	0%	1.6529	1.6496	-0.003	0%
70%	0.0986	0.1067	0.008	8%	0.5363	0.5354	-0.001	0%	1.5017	1.4990	-0.003	0%	1.6518	1.6489	-0.003	0%
80%	0.0973	0.1026	0.005	6%	0.5357	0.5346	-0.001	0%	1.5000	1.4967	-0.003	0%	1.6500	1.6464	-0.004	0%
90%	0.0965	0.1009	0.004	4%	0.5352	0.5342	-0.001	0%	1.4986	1.4958	-0.003	0%	1.6484	1.6454	-0.003	0%
Long Term																
Full Simulation Period[b]	0.1129	0.1301	0.017	15%	0.6096	0.6087	-0.001	0%	1.7069	1.7043	-0.003	0%	1.8776	1.8747	-0.003	0%
Water Year Types[c d]																
Wet (32%)	0.1331	0.1626	0.030	22%	0.5356	0.5345	-0.001	0%	1.4996	1.4966	-0.003	0%	1.6496	1.6463	-0.003	0%
Above Normal (16%)	0.1128	0.1322	0.019	17%	0.5364	0.5356	-0.001	0%	1.5020	1.4996	-0.002	0%	1.6522	1.6496	-0.003	0%
Below Normal (13%)	0.1029	0.1176	0.015	14%	0.5369	0.5362	-0.001	0%	1.5033	1.5013	-0.002	0%	1.6536	1.6515	-0.002	0%
Dry (24%)	0.1012	0.1103	0.009	9%	0.7243	0.7231	-0.001	0%	2.0281	2.0247	-0.003	0%	2.2309	2.2272	-0.004	0%
Critical (15%)	0.0976	0.1015	0.004	4%	0.7248	0.7242	-0.001	0%	2.0294	2.0278	-0.002	0%	2.2324	2.2306	-0.002	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Table 5.F-8. Sacramento River at Mallard Island – TL3 Fish

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - TL3 Fish Model 3 or 5[e] (mg/kg)				Invertebrates - TL3 Fish Diet, Model 3 or 5[e] (mg/kg)				Whole Body TL3 Fish, Model 3 or 5[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.1263	0.1450	0.019	15%	0.7248	0.7244	0.000	0%	2.0293	2.0283	-0.001	0%	2.2323	2.2311	-0.001	0%
20%	0.1200	0.1366	0.017	14%	0.7246	0.7242	0.000	0%	2.0289	2.0279	-0.001	0%	2.2318	2.2307	-0.001	0%
30%	0.1110	0.1247	0.014	12%	0.7243	0.7236	-0.001	0%	2.0281	2.0260	-0.002	0%	2.2309	2.2286	-0.002	0%
40%	0.1065	0.1227	0.016	15%	0.5372	0.5370	0.000	0%	1.5042	1.5036	-0.001	0%	1.6547	1.6539	-0.001	0%
50%	0.1031	0.1122	0.009	9%	0.5370	0.5366	0.000	0%	1.5035	1.5024	-0.001	0%	1.6539	1.6526	-0.001	0%
60%	0.1009	0.1081	0.007	7%	0.5367	0.5360	-0.001	0%	1.5028	1.5009	-0.002	0%	1.6531	1.6510	-0.002	0%
70%	0.0996	0.1037	0.004	4%	0.5365	0.5359	-0.001	0%	1.5023	1.5004	-0.002	0%	1.6525	1.6505	-0.002	0%
80%	0.0985	0.1012	0.003	3%	0.5361	0.5354	-0.001	0%	1.5011	1.4990	-0.002	0%	1.6512	1.6489	-0.002	0%
90%	0.0977	0.1004	0.003	3%	0.5358	0.5350	-0.001	0%	1.5002	1.4981	-0.002	0%	1.6502	1.6479	-0.002	0%
Long Term																
Full Simulation Period[b]	0.1084	0.1190	0.011	10%	0.6098	0.6092	-0.001	0%	1.7073	1.7056	-0.002	0%	1.8781	1.8762	-0.002	0%
Water Year Types[c d]																
Wet (32%)	0.1210	0.1394	0.018	15%	0.5360	0.5353	-0.001	0%	1.5009	1.4988	-0.002	0%	1.6510	1.6487	-0.002	0%
Above Normal (16%)	0.1093	0.1212	0.012	11%	0.5366	0.5360	-0.001	0%	1.5024	1.5009	-0.002	0%	1.6526	1.6510	-0.002	0%
Below Normal (13%)	0.1016	0.1107	0.009	9%	0.5370	0.5365	0.000	0%	1.5035	1.5022	-0.001	0%	1.6538	1.6524	-0.001	0%
Dry (24%)	0.1011	0.1066	0.006	5%	0.7243	0.7236	-0.001	0%	2.0280	2.0260	-0.002	0%	2.2308	2.2286	-0.002	0%
Critical (15%)	0.0985	0.1007	0.002	2%	0.7247	0.7243	0.000	0%	2.0290	2.0282	-0.001	0%	2.2319	2.2310	-0.001	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Table 5.F-9. North Bay Aqueduct at Barker Slough Pumping Plant – TL3 Fish

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - TL3 Fish Model 3 or 5[e] (mg/kg)				Invertebrates - TL3 Fish Diet, Model 3 or 5[e] (mg/kg)				Whole Body TL3 Fish, Model 3 or 5[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.1224	0.1244	0.002	2%	0.7249	0.7249	0.000	0%	2.0298	2.0297	0.000	0%	2.2328	2.2326	0.000	0%
20%	0.1179	0.1198	0.002	2%	0.7244	0.7244	0.000	0%	2.0284	2.0282	0.000	0%	2.2313	2.2310	0.000	0%
30%	0.1133	0.1149	0.002	1%	0.7241	0.7241	0.000	0%	2.0275	2.0274	0.000	0%	2.2303	2.2301	0.000	0%
40%	0.1091	0.1117	0.003	2%	0.5373	0.5372	0.000	0%	1.5044	1.5042	0.000	0%	1.6548	1.6546	0.000	0%
50%	0.1050	0.1058	0.001	1%	0.5369	0.5368	0.000	0%	1.5033	1.5030	0.000	0%	1.6536	1.6533	0.000	0%
60%	0.1022	0.1028	0.001	1%	0.5366	0.5365	0.000	0%	1.5025	1.5022	0.000	0%	1.6527	1.6525	0.000	0%
70%	0.1005	0.1014	0.001	1%	0.5364	0.5363	0.000	0%	1.5018	1.5016	0.000	0%	1.6520	1.6518	0.000	0%
80%	0.0987	0.0994	0.001	1%	0.5361	0.5361	0.000	0%	1.5012	1.5010	0.000	0%	1.6513	1.6511	0.000	0%
90%	0.0963	0.0968	0.001	1%	0.5359	0.5359	0.000	0%	1.5006	1.5004	0.000	0%	1.6507	1.6505	0.000	0%
Long Term																
Full Simulation Period[b]	0.1080	0.1094	0.001	1%	0.6098	0.6097	0.000	0%	1.7074	1.7071	0.000	0%	1.8781	1.8778	0.000	0%
Water Year Types[c d]																
Wet (32%)	0.1195	0.1216	0.002	2%	0.5361	0.5360	0.000	0%	1.5010	1.5008	0.000	0%	1.6511	1.6509	0.000	0%
Above Normal (16%)	0.1110	0.1126	0.002	1%	0.5365	0.5364	0.000	0%	1.5021	1.5019	0.000	0%	1.6524	1.6521	0.000	0%
Below Normal (13%)	0.1008	0.1020	0.001	1%	0.5370	0.5369	0.000	0%	1.5036	1.5034	0.000	0%	1.6539	1.6537	0.000	0%
Dry (24%)	0.1008	0.1020	0.001	1%	0.7243	0.7242	0.000	0%	2.0281	2.0277	0.000	0%	2.2309	2.2304	-0.001	0%
Critical (15%)	0.0983	0.0984	0.000	0%	0.7247	0.7247	0.000	0%	2.0291	2.0291	0.000	0%	2.2320	2.2320	0.000	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Table 5.F-10. Contra Costa Pumping Plant #1 – TL3 Fish

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - TL3 Fish Model 3 or 5[e] (mg/kg)				Invertebrates - TL3 Fish Diet, Model 3 or 5[e] (mg/kg)				Whole Body TL3 Fish, Model 3 or 5[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.1837	0.2438	0.060	33%	0.7240	0.7218	-0.002	0%	2.0272	2.0212	-0.006	0%	2.2299	2.2233	-0.007	0%
20%	0.1649	0.2212	0.056	34%	0.7233	0.7208	-0.003	0%	2.0254	2.0183	-0.007	0%	2.2279	2.2201	-0.008	0%
30%	0.1526	0.2053	0.053	35%	0.7226	0.7188	-0.004	-1%	2.0232	2.0127	-0.010	-1%	2.2255	2.2139	-0.012	-1%
40%	0.1426	0.1874	0.045	31%	0.5368	0.5355	-0.001	0%	1.5032	1.4994	-0.004	0%	1.6535	1.6494	-0.004	0%
50%	0.1247	0.1649	0.040	32%	0.5362	0.5345	-0.002	0%	1.5013	1.4966	-0.005	0%	1.6515	1.6463	-0.005	0%
60%	0.1139	0.1533	0.039	35%	0.5353	0.5338	-0.001	0%	1.4989	1.4947	-0.004	0%	1.6488	1.6442	-0.005	0%
70%	0.1101	0.1377	0.028	25%	0.5349	0.5332	-0.002	0%	1.4976	1.4930	-0.005	0%	1.6474	1.6423	-0.005	0%
80%	0.1068	0.1285	0.022	20%	0.5344	0.5328	-0.002	0%	1.4962	1.4918	-0.004	0%	1.6458	1.6410	-0.005	0%
90%	0.1028	0.1196	0.017	16%	0.5338	0.5323	-0.002	0%	1.4946	1.4904	-0.004	0%	1.6440	1.6394	-0.005	0%
Long Term																
Full Simulation Period[b]	0.1375	0.1767	0.039	29%	0.6082	0.6063	-0.002	0%	1.7031	1.6977	-0.005	0%	1.8734	1.8675	-0.006	0%
Water Year Types[c d]																
Wet (32%)	0.1725	0.2302	0.058	33%	0.5342	0.5326	-0.002	0%	1.4958	1.4914	-0.004	0%	1.6454	1.6405	-0.005	0%
Above Normal (16%)	0.1409	0.1850	0.044	31%	0.5353	0.5338	-0.001	0%	1.4988	1.4947	-0.004	0%	1.6487	1.6441	-0.005	0%
Below Normal (13%)	0.1241	0.1641	0.040	32%	0.5359	0.5344	-0.001	0%	1.5006	1.4965	-0.004	0%	1.6507	1.6461	-0.005	0%
Dry (24%)	0.1146	0.1405	0.026	23%	0.7226	0.7197	-0.003	0%	2.0234	2.0153	-0.008	0%	2.2258	2.2168	-0.009	0%
Critical (15%)	0.1085	0.1238	0.015	14%	0.7233	0.7214	-0.002	0%	2.0252	2.0199	-0.005	0%	2.2277	2.2219	-0.006	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Table 5.F-11. Banks Pumping Plant – TL3 Fish

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - TL3 Fish Model 3 or 5[e] (mg/kg)				Invertebrates - TL3 Fish Diet, Model 3 or 5[e] (mg/kg)				Whole Body TL3 Fish, Model 3 or 5[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.2695	0.3090	0.039	15%	0.7188	0.7169	-0.002	0%	2.0127	2.0072	-0.005	0%	2.2140	2.2080	-0.006	0%
20%	0.2520	0.2911	0.039	16%	0.7176	0.7154	-0.002	0%	2.0094	2.0031	-0.006	0%	2.2103	2.2034	-0.007	0%
30%	0.2306	0.2747	0.044	19%	0.7161	0.7144	-0.002	0%	2.0052	2.0004	-0.005	0%	2.2057	2.2004	-0.005	0%
40%	0.2201	0.2576	0.038	17%	0.5347	0.5341	-0.001	0%	1.4971	1.4955	-0.002	0%	1.6468	1.6450	-0.002	0%
50%	0.1933	0.2281	0.035	18%	0.5337	0.5329	-0.001	0%	1.4944	1.4921	-0.002	0%	1.6438	1.6413	-0.003	0%
60%	0.1800	0.2074	0.027	15%	0.5331	0.5323	-0.001	0%	1.4927	1.4905	-0.002	0%	1.6419	1.6396	-0.002	0%
70%	0.1728	0.1922	0.019	11%	0.5326	0.5317	-0.001	0%	1.4912	1.4886	-0.003	0%	1.6403	1.6375	-0.003	0%
80%	0.1577	0.1843	0.027	17%	0.5321	0.5313	-0.001	0%	1.4899	1.4878	-0.002	0%	1.6389	1.6365	-0.002	0%
90%	0.1475	0.1691	0.022	15%	0.5317	0.5310	-0.001	0%	1.4889	1.4868	-0.002	0%	1.6377	1.6355	-0.002	0%
Long Term																
Full Simulation Period[b]	0.2051	0.2370	0.032	16%	0.6048	0.6035	-0.001	0%	1.6933	1.6897	-0.004	0%	1.8627	1.8587	-0.004	0%
Water Year Types[c d]																
Wet (32%)	0.2569	0.2968	0.040	16%	0.5321	0.5313	-0.001	0%	1.4898	1.4875	-0.002	0%	1.6387	1.6363	-0.002	0%
Above Normal (16%)	0.2112	0.2456	0.034	16%	0.5331	0.5323	-0.001	0%	1.4927	1.4905	-0.002	0%	1.6419	1.6395	-0.002	0%
Below Normal (13%)	0.1923	0.2215	0.029	15%	0.5336	0.5328	-0.001	0%	1.4940	1.4919	-0.002	0%	1.6434	1.6411	-0.002	0%
Dry (24%)	0.1688	0.1995	0.031	18%	0.7171	0.7147	-0.002	0%	2.0078	2.0011	-0.007	0%	2.2086	2.2012	-0.007	0%
Critical (15%)	0.1582	0.1749	0.017	11%	0.7179	0.7165	-0.001	0%	2.0102	2.0061	-0.004	0%	2.2113	2.2067	-0.005	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Table 5.F-12. Jones Pumping Plant – TL3 Fish

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - TL3 Fish Model 3 or 5[e] (mg/kg)				Invertebrates - TL3 Fish Diet, Model 3 or 5[e] (mg/kg)				Whole Body TL3 Fish, Model 3 or 5[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.3259	0.3579	0.032	10%	0.7117	0.7121	0.000	0%	1.9928	1.9939	0.001	0%	2.1921	2.1933	0.001	0%
20%	0.3059	0.3367	0.031	10%	0.7110	0.7114	0.000	0%	1.9908	1.9920	0.001	0%	2.1899	2.1912	0.001	0%
30%	0.2943	0.3205	0.026	9%	0.7102	0.7097	0.000	0%	1.9885	1.9873	-0.001	0%	2.1873	2.1860	-0.001	0%
40%	0.2861	0.3115	0.025	9%	0.5324	0.5330	0.001	0%	1.4906	1.4924	0.002	0%	1.6397	1.6416	0.002	0%
50%	0.2725	0.2987	0.026	10%	0.5319	0.5313	-0.001	0%	1.4893	1.4876	-0.002	0%	1.6382	1.6364	-0.002	0%
60%	0.2664	0.2845	0.018	7%	0.5315	0.5311	0.000	0%	1.4883	1.4871	-0.001	0%	1.6371	1.6358	-0.001	0%
70%	0.2566	0.2632	0.007	3%	0.5313	0.5309	0.000	0%	1.4876	1.4864	-0.001	0%	1.6364	1.6350	-0.001	0%
80%	0.2503	0.2441	-0.006	-2%	0.5311	0.5306	-0.001	0%	1.4871	1.4856	-0.001	0%	1.6358	1.6342	-0.002	0%
90%	0.2398	0.2308	-0.009	-4%	0.5307	0.5302	0.000	0%	1.4860	1.4846	-0.001	0%	1.6346	1.6331	-0.002	0%
Long Term																
Full Simulation Period[b]	0.2793	0.2948	0.016	6%	0.6014	0.6012	0.000	0%	1.6840	1.6833	-0.001	0%	1.8524	1.8516	-0.001	0%
Water Year Types[c d]																
Wet (32%)	0.3136	0.3314	0.018	6%	0.5310	0.5307	0.000	0%	1.4867	1.4859	-0.001	0%	1.6354	1.6345	-0.001	0%
Above Normal (16%)	0.2793	0.3126	0.033	12%	0.5316	0.5310	-0.001	0%	1.4884	1.4867	-0.002	0%	1.6372	1.6354	-0.002	0%
Below Normal (13%)	0.2694	0.2998	0.030	11%	0.5317	0.5312	-0.001	0%	1.4889	1.4873	-0.002	0%	1.6378	1.6360	-0.002	0%
Dry (24%)	0.2568	0.2668	0.010	4%	0.7109	0.7105	0.000	0%	1.9906	1.9893	-0.001	0%	2.1897	2.1882	-0.001	0%
Critical (15%)	0.2515	0.2382	-0.013	-5%	0.7112	0.7120	0.001	0%	1.9915	1.9936	0.002	0%	2.1906	2.1930	0.002	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Table 5.F-13. Sacramento River upstream of Delta Cross Channel – Green Sturgeon

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - Green Sturgeon[e] (mg/kg)				Invertebrates - Green Sturgeon Diet [e f] (mg/kg)				Whole Body Green Sturgeon[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.0901	0.0901	0.000	0%	0.5405	0.5405	0.000	0%	1.0269	1.0269	0.000	0%	1.3350	1.3350	0.000	0%
20%	0.0901	0.0901	0.000	0%	0.5404	0.5404	0.000	0%	1.0268	1.0268	0.000	0%	1.3348	1.3349	0.000	0%
30%	0.0901	0.0901	0.000	0%	0.5404	0.5404	0.000	0%	1.0267	1.0267	0.000	0%	1.3347	1.3348	0.000	0%
40%	0.0901	0.0901	0.000	0%	0.2702	0.2702	0.000	0%	0.5134	0.5134	0.000	0%	0.6675	0.6675	0.000	0%
50%	0.0901	0.0901	0.000	0%	0.2702	0.2702	0.000	0%	0.5134	0.5134	0.000	0%	0.6674	0.6674	0.000	0%
60%	0.0901	0.0901	0.000	0%	0.2702	0.2702	0.000	0%	0.5133	0.5133	0.000	0%	0.6673	0.6673	0.000	0%
70%	0.0900	0.0901	0.000	0%	0.2701	0.2702	0.000	0%	0.5133	0.5133	0.000	0%	0.6673	0.6673	0.000	0%
80%	0.0900	0.0900	0.000	0%	0.2701	0.2701	0.000	0%	0.5133	0.5133	0.000	0%	0.6672	0.6673	0.000	0%
90%	0.0900	0.0900	0.000	0%	0.2701	0.2701	0.000	0%	0.5132	0.5133	0.000	0%	0.6672	0.6672	0.000	0%
Long Term																
Full Simulation Period[b]	0.0901	0.0901	0.000	0%	0.3756	0.3756	0.000	0%	0.7137	0.7137	0.000	0%	0.9278	0.9278	0.000	0%
Water Year Types[c d]																
Wet (32%)	0.0900	0.0901	0.000	0%	0.2701	0.2702	0.000	0%	0.5133	0.5133	0.000	0%	0.6673	0.6673	0.000	0%
Above Normal (16%)	0.0901	0.0901	0.000	0%	0.2702	0.2702	0.000	0%	0.5133	0.5133	0.000	0%	0.6673	0.6673	0.000	0%
Below Normal (13%)	0.0901	0.0901	0.000	0%	0.2702	0.2702	0.000	0%	0.5133	0.5134	0.000	0%	0.6673	0.6674	0.000	0%
Dry (24%)	0.0901	0.0901	0.000	0%	0.5404	0.5404	0.000	0%	1.0268	1.0268	0.000	0%	1.3348	1.3348	0.000	0%
Critical (15%)	0.0901	0.0901	0.000	0%	0.5405	0.5405	0.000	0%	1.0269	1.0269	0.000	0%	1.3350	1.3350	0.000	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e The Kd value for wet, above normal, and below normal years was 3,000 and for dry and critical years was 6,000.

f The TTF for invertabrates was 9.2 (see text).

Table 5.F-14. San Joaquin River near San Andreas Landing – Green Sturgeon

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - Green Sturgeon[e] (mg/kg)				Invertebrates - Green Sturgeon Diet [e f] (mg/kg)				Whole Body Green Sturgeon[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.1256	0.1471	0.022	17%	0.5835	0.6644	0.081	14%	1.1086	1.2624	0.154	14%	1.4412	1.6412	0.200	14%
20%	0.1159	0.1413	0.025	22%	0.5706	0.6219	0.051	9%	1.0841	1.1815	0.097	9%	1.4093	1.5360	0.127	9%
30%	0.1105	0.1360	0.025	23%	0.5652	0.6003	0.035	6%	1.0740	1.1406	0.067	6%	1.3962	1.4828	0.087	6%
40%	0.1070	0.1279	0.021	20%	0.4404	0.5439	0.104	24%	0.8367	1.0335	0.197	24%	1.0878	1.3435	0.256	24%
50%	0.1015	0.1204	0.019	19%	0.3740	0.4390	0.065	17%	0.7107	0.8340	0.123	17%	0.9239	1.0842	0.160	17%
60%	0.0979	0.1150	0.017	17%	0.3437	0.4220	0.078	23%	0.6530	0.8017	0.149	23%	0.8490	1.0423	0.193	23%
70%	0.0963	0.1073	0.011	11%	0.3282	0.4046	0.076	23%	0.6236	0.7687	0.145	23%	0.8107	0.9993	0.189	23%
80%	0.0950	0.1046	0.010	10%	0.3114	0.3761	0.065	21%	0.5916	0.7145	0.123	21%	0.7691	0.9289	0.160	21%
90%	0.0941	0.1002	0.006	6%	0.2952	0.3502	0.055	19%	0.5609	0.6654	0.104	19%	0.7291	0.8650	0.136	19%
Long Term																
Full Simulation Period[b]	0.1060	0.1237	0.018	17%	0.4326	0.4975	0.065	15%	0.8219	0.9453	0.123	15%	1.0685	1.2289	0.160	15%
Water Year Types[c d]																
Wet (32%)	0.1173	0.1430	0.026	22%	0.3520	0.4290	0.077	22%	0.6687	0.8151	0.146	22%	0.8694	1.0597	0.190	22%
Above Normal (16%)	0.1076	0.1275	0.020	18%	0.3228	0.3824	0.060	18%	0.6132	0.7265	0.113	18%	0.7972	0.9445	0.147	18%
Below Normal (13%)	0.1014	0.1199	0.019	18%	0.3041	0.3598	0.056	18%	0.5778	0.6836	0.106	18%	0.7511	0.8887	0.138	18%
Dry (24%)	0.0989	0.1110	0.012	12%	0.5935	0.6662	0.073	12%	1.1276	1.2657	0.138	12%	1.4659	1.6455	0.180	12%
Critical (15%)	0.0960	0.1026	0.007	7%	0.5758	0.6159	0.040	7%	1.0940	1.1702	0.076	7%	1.4222	1.5212	0.099	7%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e The Kd value for wet, above normal, and below normal years was 3,000 and for dry and critical years was 6,000.

f The TTF for invertabrates was 9.2 (see text).

Table 5.F-15. Old River at Clifton Court Forebay Radial Gates (West Canal) – Green Sturgeon

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - Green Sturgeon[e] (mg/kg)				Invertebrates - Green Sturgeon Diet [e f] (mg/kg)				Whole Body Green Sturgeon[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.2922	0.3631	0.071	24%	1.3937	1.5575	0.164	12%	2.6481	2.9592	0.311	12%	3.4426	3.8469	0.404	12%
20%	0.2813	0.3513	0.070	25%	1.3278	1.3889	0.061	5%	2.5228	2.6389	0.116	5%	3.2797	3.4305	0.151	5%
30%	0.2657	0.3362	0.070	27%	1.2279	1.3081	0.080	7%	2.3331	2.4853	0.152	7%	3.0330	3.2309	0.198	7%
40%	0.2560	0.3188	0.063	24%	1.0654	1.1940	0.129	12%	2.0243	2.2685	0.244	12%	2.6316	2.9491	0.317	12%
50%	0.2450	0.2936	0.049	20%	0.8761	1.0890	0.213	24%	1.6646	2.0692	0.405	24%	2.1640	2.6899	0.526	24%
60%	0.2339	0.2741	0.040	17%	0.8336	1.0513	0.218	26%	1.5838	1.9975	0.414	26%	2.0589	2.5968	0.538	26%
70%	0.2262	0.2591	0.033	15%	0.7872	1.0083	0.221	28%	1.4957	1.9158	0.420	28%	1.9445	2.4905	0.546	28%
80%	0.2204	0.2378	0.017	8%	0.7577	0.9517	0.194	26%	1.4396	1.8082	0.369	26%	1.8715	2.3506	0.479	26%
90%	0.2047	0.2202	0.016	8%	0.6993	0.8564	0.157	22%	1.3287	1.6271	0.298	22%	1.7273	2.1153	0.388	22%
Long Term																
Full Simulation Period[b]	0.2499	0.2952	0.045	18%	1.0128	1.1682	0.155	15%	1.9243	2.2195	0.295	15%	2.5015	2.8853	0.384	15%
Water Year Types[c d]																
Wet (32%)	0.2861	0.3567	0.071	25%	0.8582	1.0701	0.212	25%	1.6306	2.0331	0.403	25%	2.1198	2.6431	0.523	25%
Above Normal (16%)	0.2510	0.3107	0.060	24%	0.7529	0.9320	0.179	24%	1.4304	1.7708	0.340	24%	1.8596	2.3020	0.442	24%
Below Normal (13%)	0.2360	0.2887	0.053	22%	0.7079	0.8662	0.158	22%	1.3450	1.6458	0.301	22%	1.7485	2.1396	0.391	22%
Dry (24%)	0.2270	0.2534	0.026	12%	1.3623	1.5201	0.158	12%	2.5883	2.8883	0.300	12%	3.3648	3.7547	0.390	12%
Critical (15%)	0.2210	0.2211	0.000	0%	1.3261	1.3267	0.001	0%	2.5197	2.5207	0.001	0%	3.2756	3.2769	0.001	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e The Kd value for wet, above normal, and below normal years was 3,000 and for dry and critical years was 6,000.

f The TTF for invertabrates was 9.2 (see text).

Table 5.F-16. San Joaquin River at Antioch – Green Sturgeon

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - Green Sturgeon[e] (mg/kg)				Invertebrates - Green Sturgeon Diet [e f] (mg/kg)				Whole Body Green Sturgeon[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.1406	0.1687	0.028	20%	0.6002	0.6558	0.056	9%	5.5222	6.0333	0.511	9%	7.1788	7.8433	0.664	9%
20%	0.1291	0.1589	0.030	23%	0.5847	0.6180	0.033	6%	5.3795	5.6856	0.306	6%	6.9934	7.3912	0.398	6%
30%	0.1160	0.1393	0.023	20%	0.5794	0.6056	0.026	5%	5.3303	5.5719	0.242	5%	6.9295	7.2435	0.314	5%
40%	0.1104	0.1344	0.024	22%	0.5534	0.5868	0.033	6%	5.0913	5.3986	0.307	6%	6.6187	7.0181	0.399	6%
50%	0.1034	0.1183	0.015	14%	0.4207	0.5051	0.084	20%	3.8706	4.6466	0.776	20%	5.0318	6.0406	1.009	20%
60%	0.1001	0.1137	0.014	14%	0.3814	0.4714	0.090	24%	3.5089	4.3366	0.828	24%	4.5615	5.6376	1.076	24%
70%	0.0986	0.1067	0.008	8%	0.3423	0.4102	0.068	20%	3.1488	3.7741	0.625	20%	4.0934	4.9063	0.813	20%
80%	0.0973	0.1026	0.005	6%	0.3206	0.3924	0.072	22%	2.9497	3.6097	0.660	22%	3.8346	4.6927	0.858	22%
90%	0.0965	0.1009	0.004	4%	0.3005	0.3436	0.043	14%	2.7643	3.1611	0.397	14%	3.5936	4.1094	0.516	14%
Long Term																
Full Simulation Period[b]	0.1129	0.1301	0.017	15%	0.4555	0.5155	0.060	13%	4.1909	4.7423	0.551	13%	5.4482	6.1649	0.717	13%
Water Year Types[c d]																
Wet (32%)	0.1331	0.1626	0.030	22%	0.3994	0.4879	0.089	22%	3.6741	4.4890	0.815	22%	4.7764	5.8357	1.059	22%
Above Normal (16%)	0.1128	0.1322	0.019	17%	0.3385	0.3966	0.058	17%	3.1138	3.6485	0.535	17%	4.0480	4.7431	0.695	17%
Below Normal (13%)	0.1029	0.1176	0.015	14%	0.3088	0.3528	0.044	14%	2.8411	3.2459	0.405	14%	3.6935	4.2196	0.526	14%
Dry (24%)	0.1012	0.1103	0.009	9%	0.6074	0.6618	0.054	9%	5.5881	6.0885	0.500	9%	7.2645	7.9151	0.651	9%
Critical (15%)	0.0976	0.1015	0.004	4%	0.5855	0.6091	0.024	4%	5.3862	5.6037	0.217	4%	7.0021	7.2848	0.283	4%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e The Kd value for wet, above normal, and below normal years was 3,000 and for dry and critical years was 6,000.

f The TTF for invertabrates was 9.2 (see text).

Table 5.F-17. Sacramento River at Mallard Island – Green Sturgeon

Statistic	Selenium Concentration															
	Water (µg/L)				Particulates - Green Sturgeon[e] (mg/kg)				Invertebrates - Green Sturgeon Diet [e f] (mg/kg)				Whole Body Green Sturgeon[e] (mg/kg)			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																
10%	0.1263	0.1450	0.019	15%	0.6007	0.6290	0.028	5%	5.5260	5.7866	0.261	5%	7.1838	7.5226	0.339	5%
20%	0.1200	0.1366	0.017	14%	0.5926	0.6075	0.015	3%	5.4520	5.5888	0.137	3%	7.0876	7.2654	0.178	3%
30%	0.1110	0.1247	0.014	12%	0.5858	0.6019	0.016	3%	5.3894	5.5378	0.148	3%	7.0062	7.1992	0.193	3%
40%	0.1065	0.1227	0.016	15%	0.4644	0.5568	0.092	20%	4.2726	5.1227	0.850	20%	5.5544	6.6595	1.105	20%
50%	0.1031	0.1122	0.009	9%	0.3788	0.4339	0.055	15%	3.4850	3.9920	0.507	15%	4.5305	5.1896	0.659	15%
60%	0.1009	0.1081	0.007	7%	0.3537	0.4089	0.055	16%	3.2543	3.7614	0.507	16%	4.2306	4.8899	0.659	16%
70%	0.0996	0.1037	0.004	4%	0.3276	0.3709	0.043	13%	3.0139	3.4123	0.398	13%	3.9180	4.4359	0.518	13%
80%	0.0985	0.1012	0.003	3%	0.3174	0.3611	0.044	14%	2.9202	3.3220	0.402	14%	3.7962	4.3186	0.522	14%
90%	0.0977	0.1004	0.003	3%	0.3029	0.3276	0.025	8%	2.7865	3.0135	0.227	8%	3.6225	3.9176	0.295	8%
Long Term																
Full Simulation Period[b]	0.1084	0.1190	0.011	10%	0.4424	0.4792	0.037	8%	4.0700	4.4089	0.339	8%	5.2910	5.7316	0.441	8%
Water Year Types[c d]																
Wet (32%)	0.1210	0.1394	0.018	15%	0.3630	0.4183	0.055	15%	3.3392	3.8488	0.510	15%	4.3410	5.0034	0.662	15%
Above Normal (16%)	0.1093	0.1212	0.012	11%	0.3279	0.3635	0.036	11%	3.0166	3.3438	0.327	11%	3.9216	4.3469	0.425	11%
Below Normal (13%)	0.1016	0.1107	0.009	9%	0.3049	0.3321	0.027	9%	2.8048	3.0556	0.251	9%	3.6462	3.9723	0.326	9%
Dry (24%)	0.1011	0.1066	0.006	5%	0.6065	0.6396	0.033	5%	5.5796	5.8842	0.305	5%	7.2535	7.6494	0.396	5%
Critical (15%)	0.0985	0.1007	0.002	2%	0.5911	0.6042	0.013	2%	5.4385	5.5583	0.120	2%	7.0701	7.2257	0.156	2%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CalSim II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

e The Kd value for wet, above normal, and below normal years was 3,000 and for dry and critical years was 6,000.

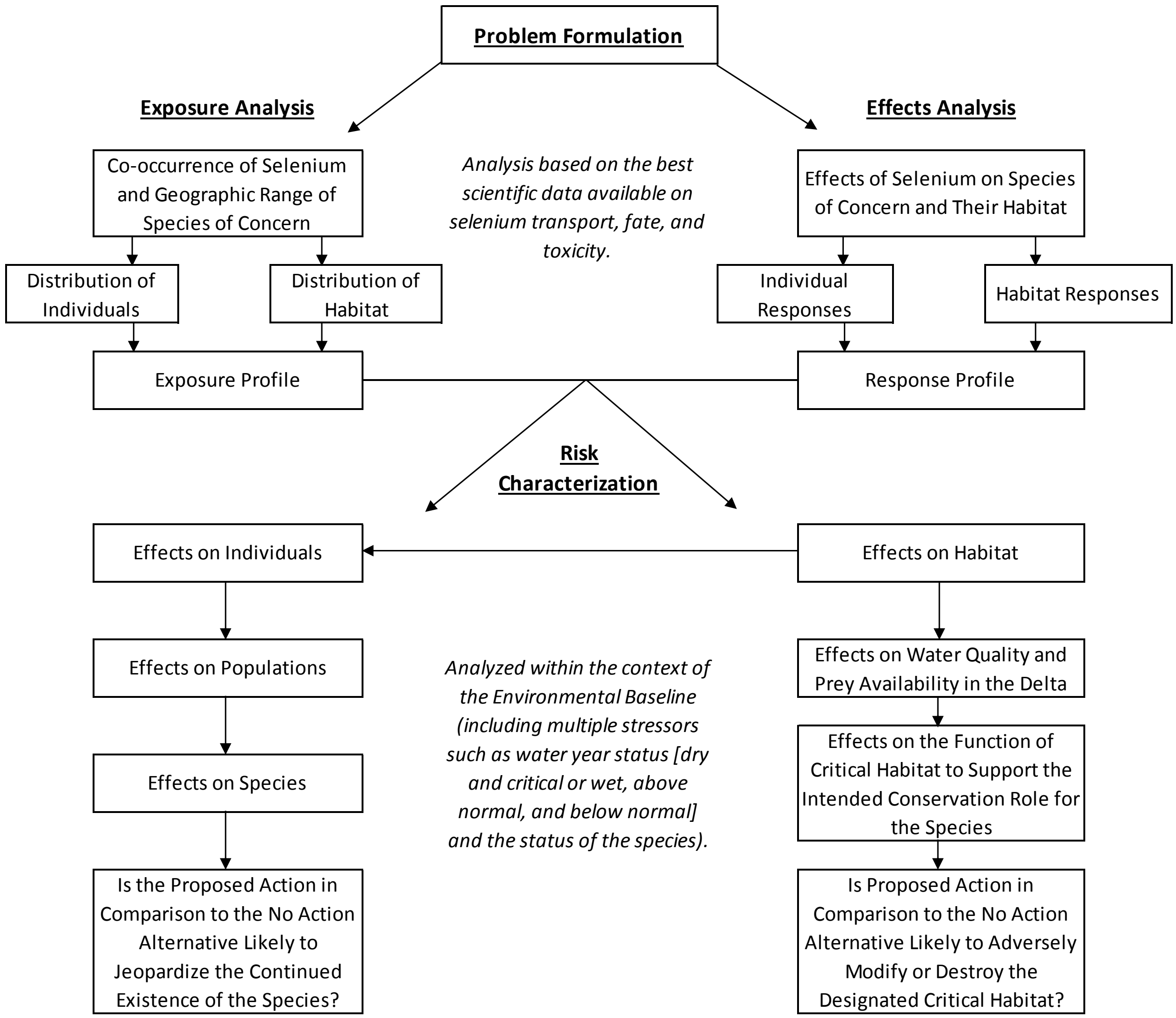
f The TTF for invertabrates was 9.2 (see text).

Table 5.F-18. Summary of Risk Conclusions

Delta Locations	Exceedance of Water Threshold[a]	Exceedance of Dietary Threshold[b]	Exceedances of Whole-body Fish Threshold[c]	Conclusions
Salmonids				
Mokelumne River (South Fork) at Staten Island	No	No	No	No difference (i.e., 0%) between PA and NAA for juvenile salmon and steelhead; predicted water concentrations below water quality benchmarks; dietary and tissue estimates below survival and growth thresholds. No risk of adverse effects to critical habitat (i.e., prey base), individuals, or populations predicted.
San Joaquin River at Buckley Cove	No	No	No	
Franks Tract	No	No	No	
Old River at Rock Slough	No	No	No	
Sacramento River at Emmaton	No	No	No	
San Joaquin River at Antioch	No	No	No	
Sacramento River at Mallard Island	No	No	No	
North Bay Aqueduct at Barker Slough Pumping Plant	No	No	No	
Contra Costa Pumping Plant #1	No	No	No	
Banks Pumping Plant	No	No	No	
Jones Pumping Plant	No	No	No	
Green Sturgeon				
Sacramento River upstream of Delta Cross Channel	No	No	No	No significant difference between PA and NAA for green sturgeon; predicted water concentrations below water quality benchmarks; dietary and tissue estimates below reproductive thresholds. No risk of adverse effects to critical habitat (i.e., prey base), individuals, or populations predicted.
San Joaquin River near San Andreas Landing	No	No	No	
Old River at Clifton Court Forebay Radial Gates (West Canal)	No	No	Yes for PA and NAA (up to 20% frequency)	There is little difference between PA in comparison to the NAA. Predicted water concentrations below water quality benchmarks. Some exceedances of whole-body reproductive threshold for green sturgeon, but all dietary concentrations below reproductive threshold and only a small percentage of individuals (1 in 100) are at risk. No exceedance of less conservative low threshold (5 mg/kg; Presser and Luoma 2013) under PA and NAA and average whole-body concentrations predicted over the 82-year simulation are

Delta Locations	Exceedance of Water Threshold[a]	Exceedance of Dietary Threshold[b]	Exceedances of Whole-body Fish Threshold[c]	Conclusions
				below 3.3 mg/kg. No effects to critical habitat (i.e., prey base) and risks of adverse effects to individual green sturgeon or populations are considered de minimis.
San Joaquin River at Antioch	No	No for NAA Yes for PA (<1% frequency)	Yes for PA and NAA (100% frequency)	There is little difference between PA in comparison to the NAA. Predicted water concentrations below water quality benchmarks. Lower frequency of exceedance under both the PA and NAA when using the less conservative threshold (5 mg/kg) and low magnitude of exceedance (HQs < 2). Risks are based on a conservative TTF from particulates to Corbula amurensis. Risks of adverse effects from diet not predicted (i.e., HQs < 1, except for rare cases [< 1%] at San Joaquin River at Antioch). Slight difference in predicted tissue concentrations (< 1 mg/kg) between the NAA and the PA not likely to be measurable in the field due to inherent natural variability. No risk of adverse effects to critical habitat (i.e., prey base). Risks to individual green sturgeon or populations cannot be excluded, but risks are low under both the NAA and PA.
Sacramento River at Mallard Island	No	No	Yes for PA and NAA (100% frequency)	
Notes:				
[a]Lowest value is 2 µg/L from the Grassland Bypass Project (Beckon et al. 2013).				
[b] Salmonids: 18.2 mg/kg diet (USEPA 2015) Green sturgeon: 8.2 mg/kg diet for reproduction (USFWS 2012)				
[c] Salmonids: 10.4 mg/kg whole-body for survival and 7.36 mg/kg whole-body for growth (USEPA 2015) Green sturgeon: 3.3 mg/kg whole-body for reproduction (USFWS 2012)				
µg/L = microgram(s) per liter				
NAA = no action alternative				
PA = proposed action				

5.F.8 Figures



*Adapted from NRC (2013) and USEPA (1998)

Figure 5.F-1: Analysis Framework – Selenium Analysis

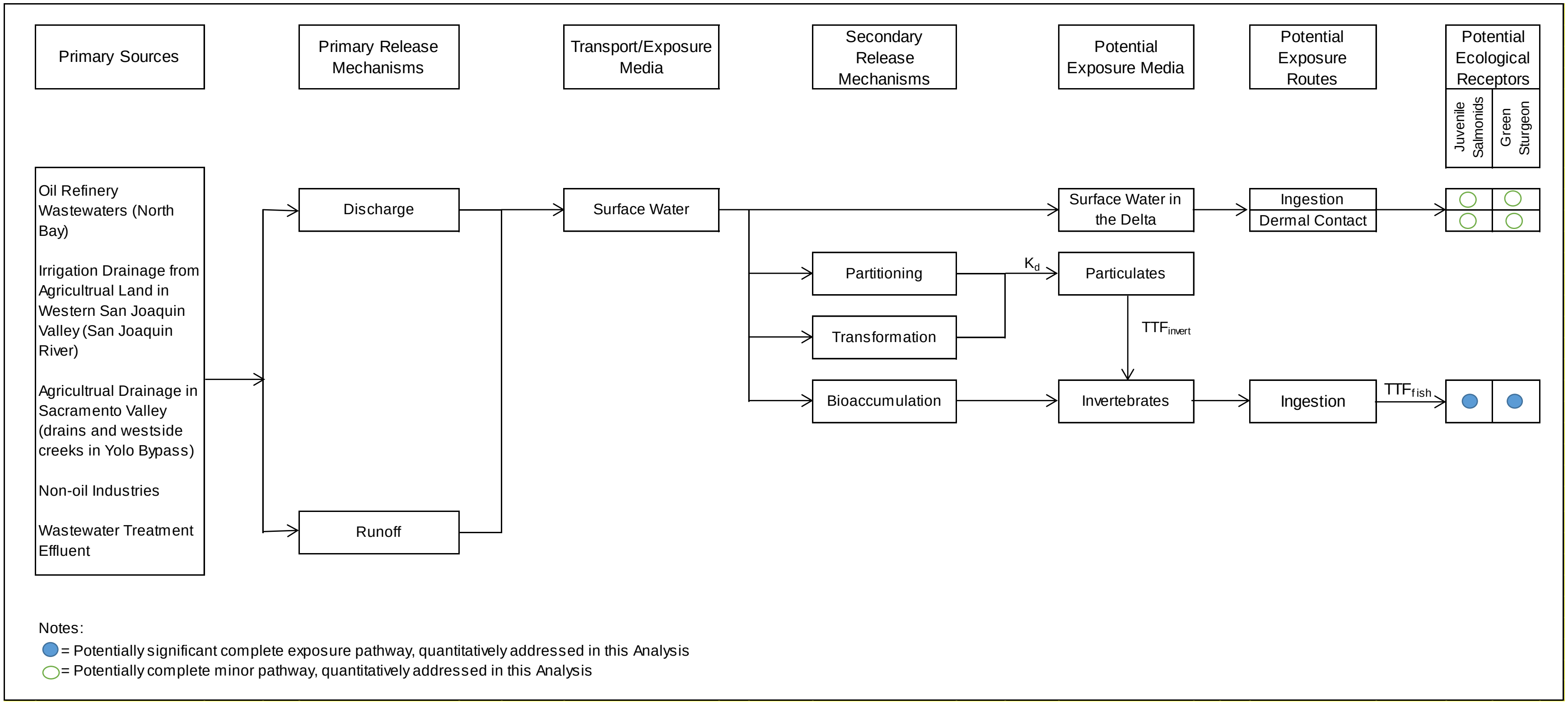


Figure 5.F-2: Ecological Conceptual Model – Selenium Analysis

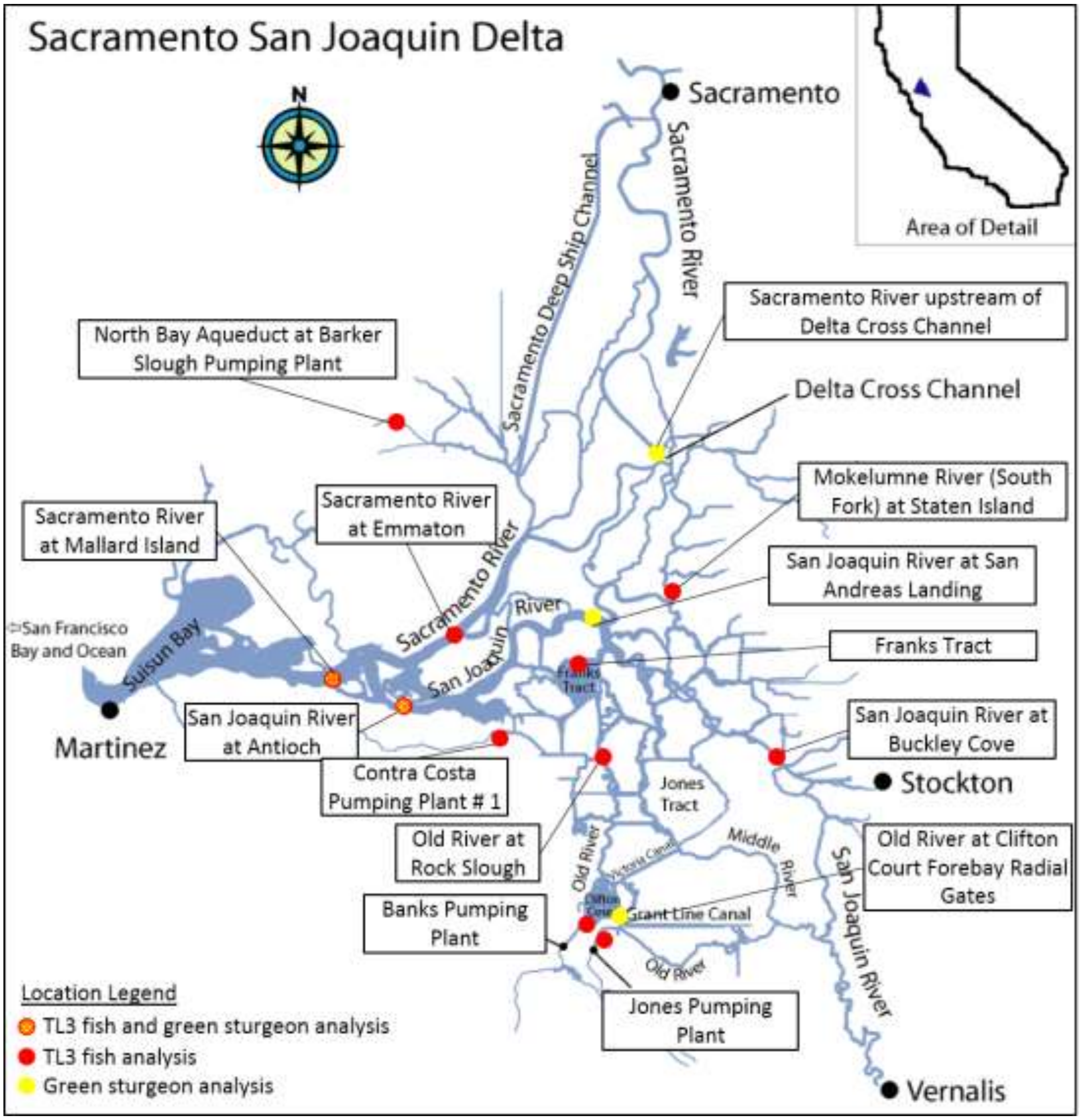
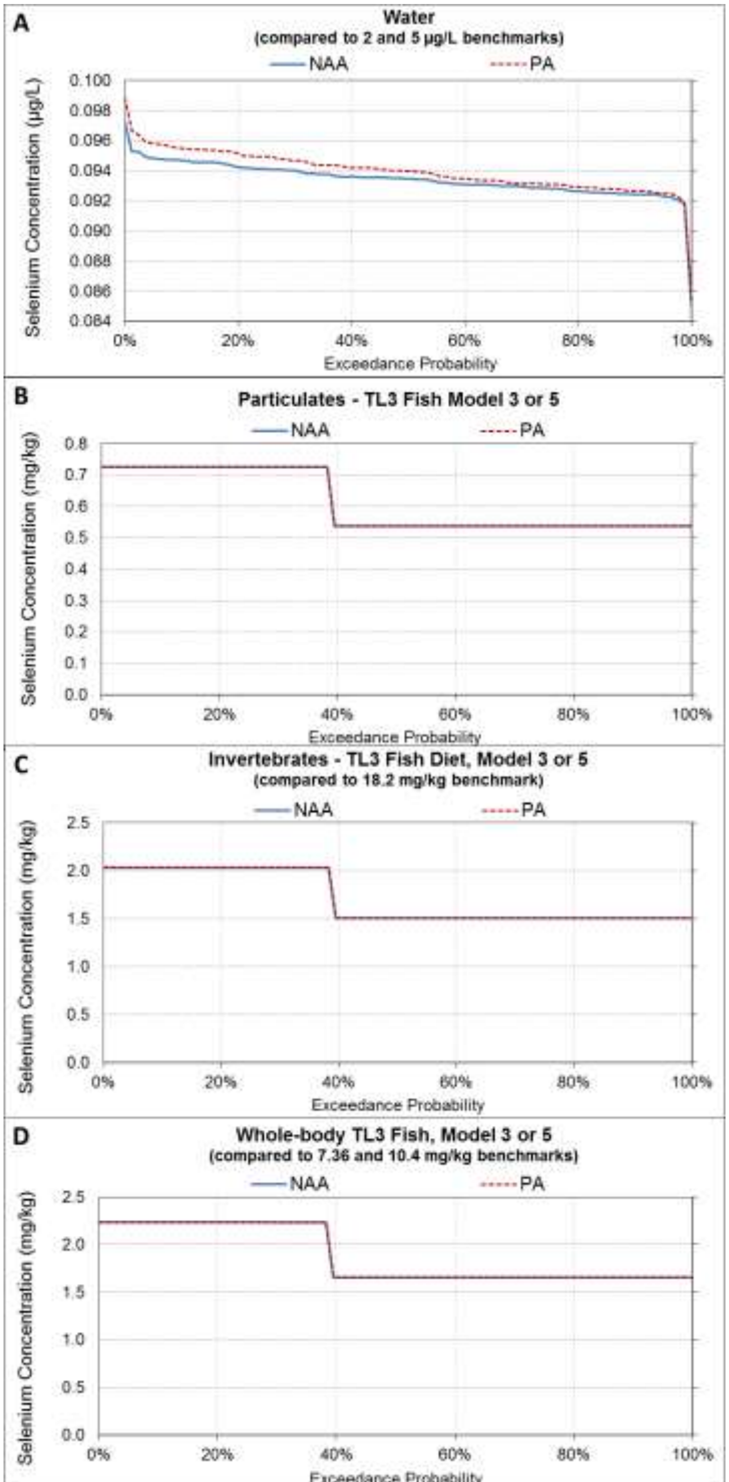
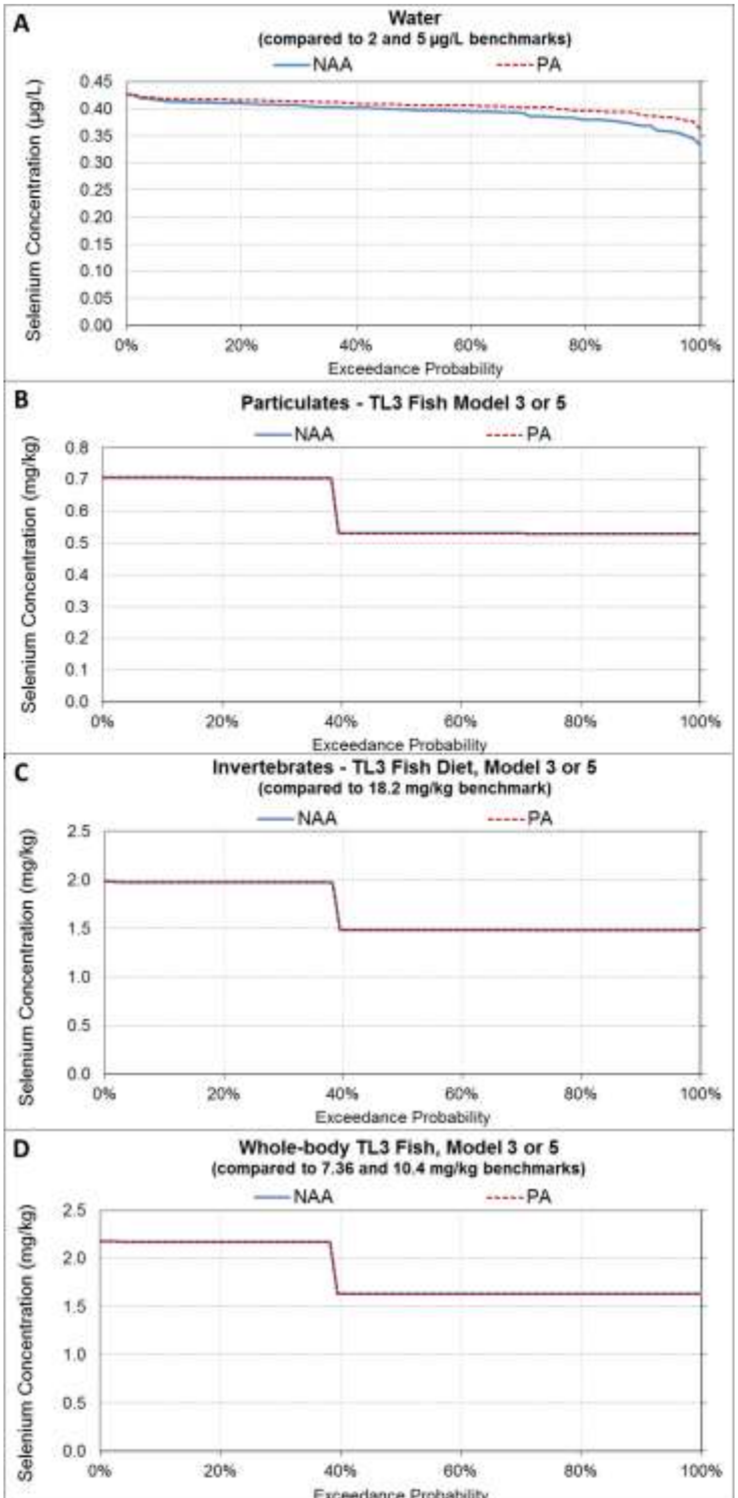


Figure 5.F-3: Location Map – Selenium Analysis



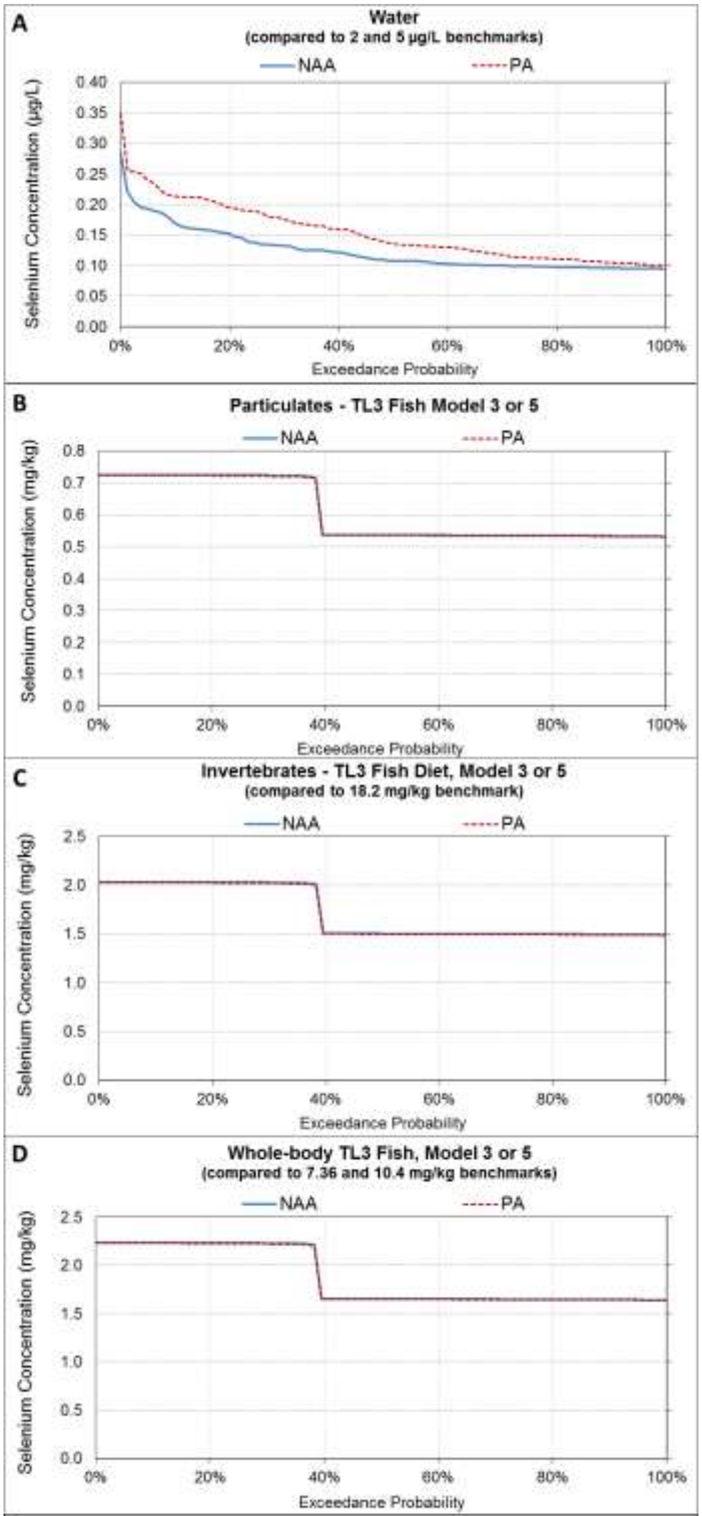
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Figure 5.F-4: Mokelumne River (South Fork) at Staten Island – TL3 Fish Probability of Exceedance



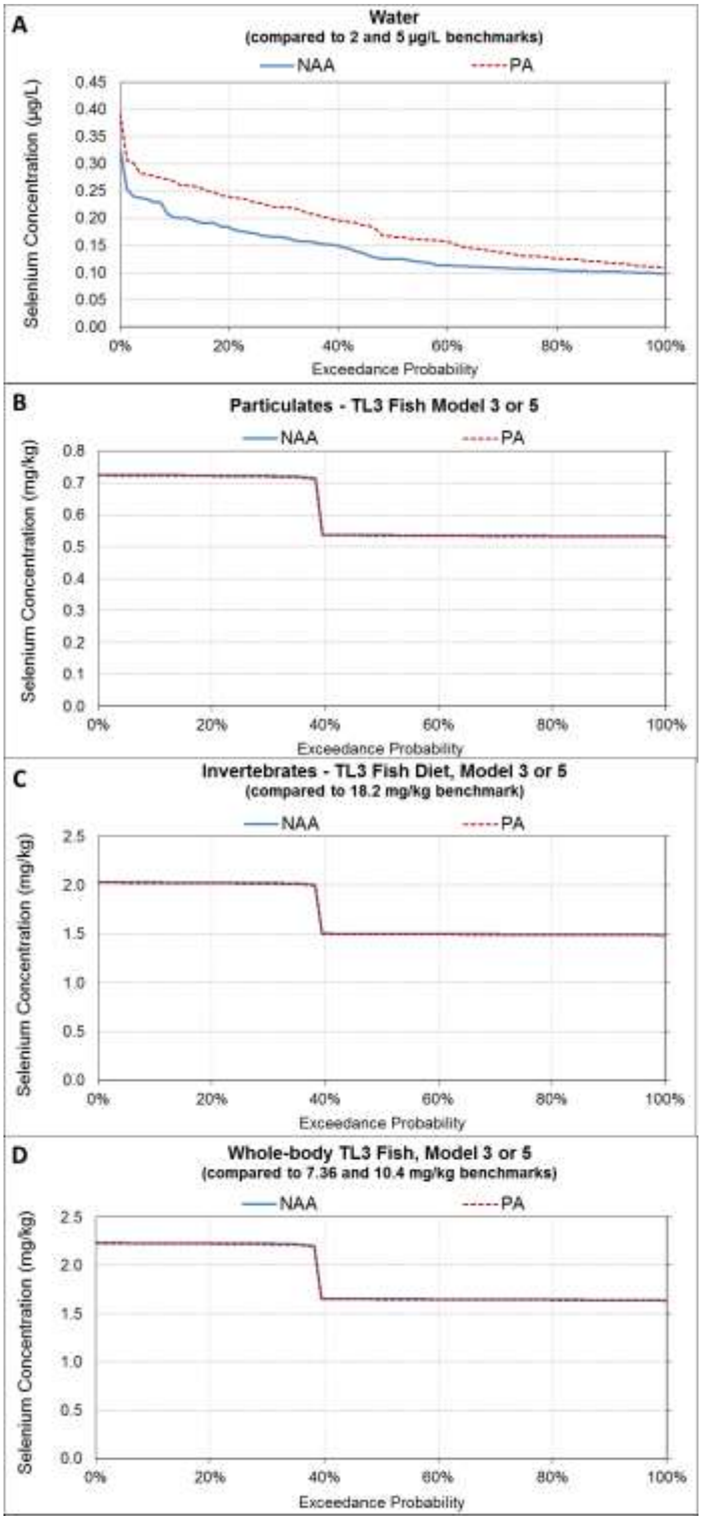
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Figure 5.F-5: San Joaquin River at Buckley Cove – TL3 Fish Probability of Exceedance



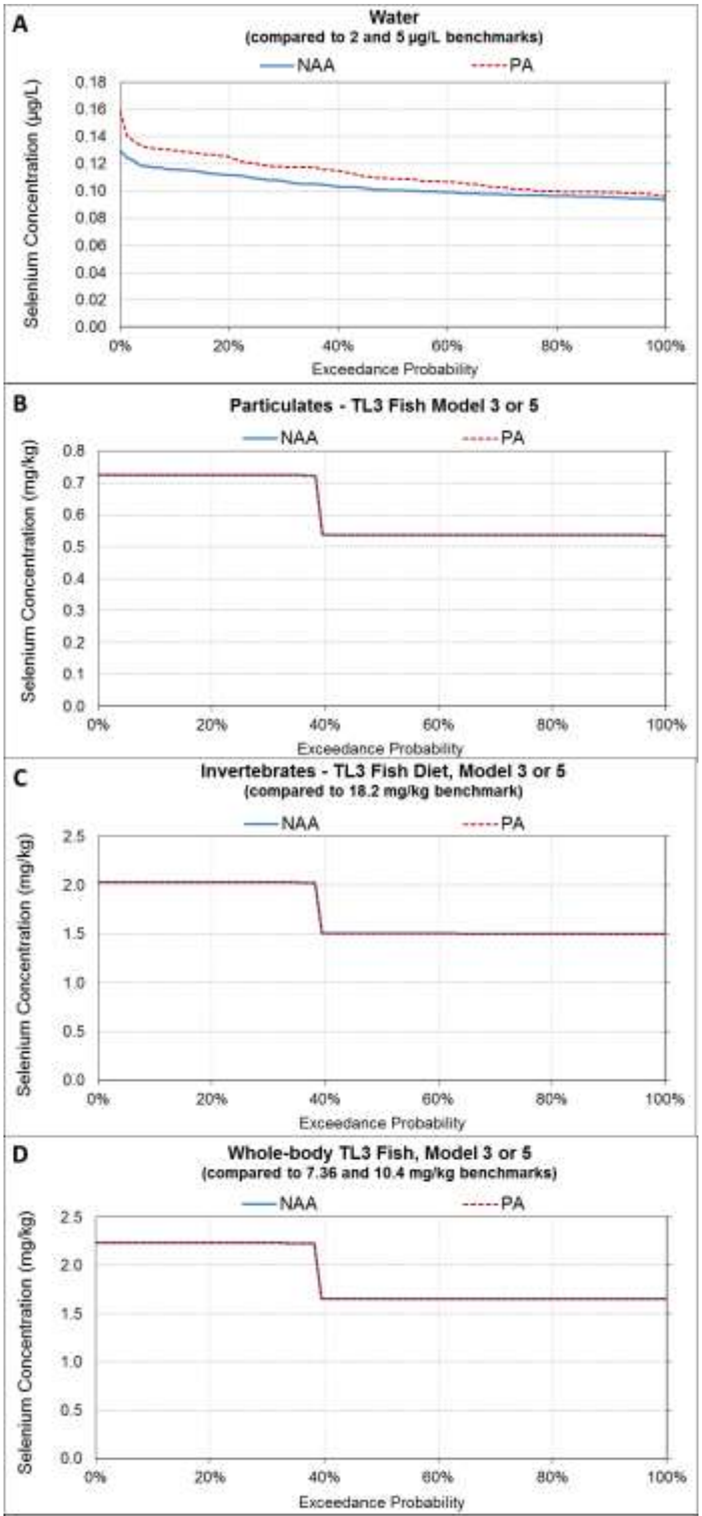
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Figure 5.F-6: Franks Tract – TL3 Fish Probability of Exceedance



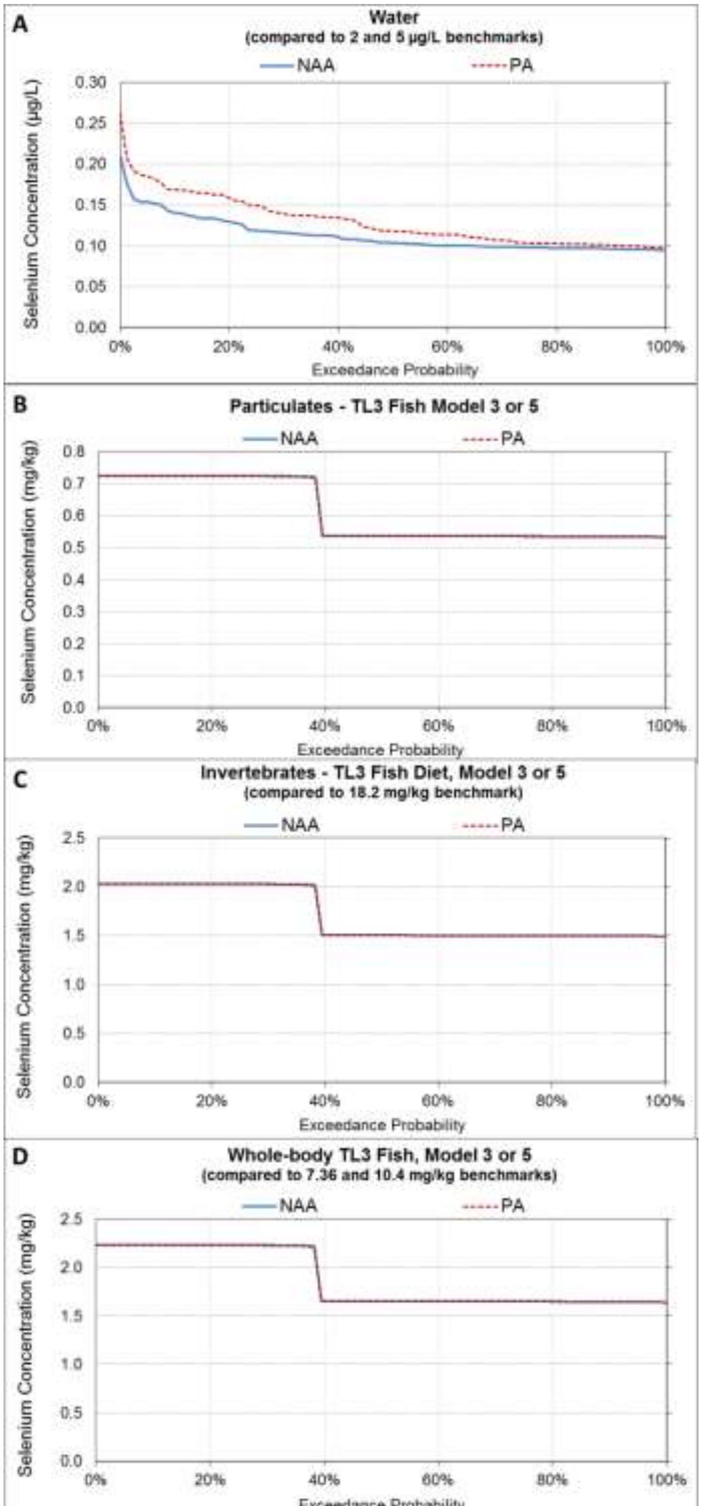
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Figure 5.F-7: Old River at Rock Slough – TL3 Fish Probability of Exceedance



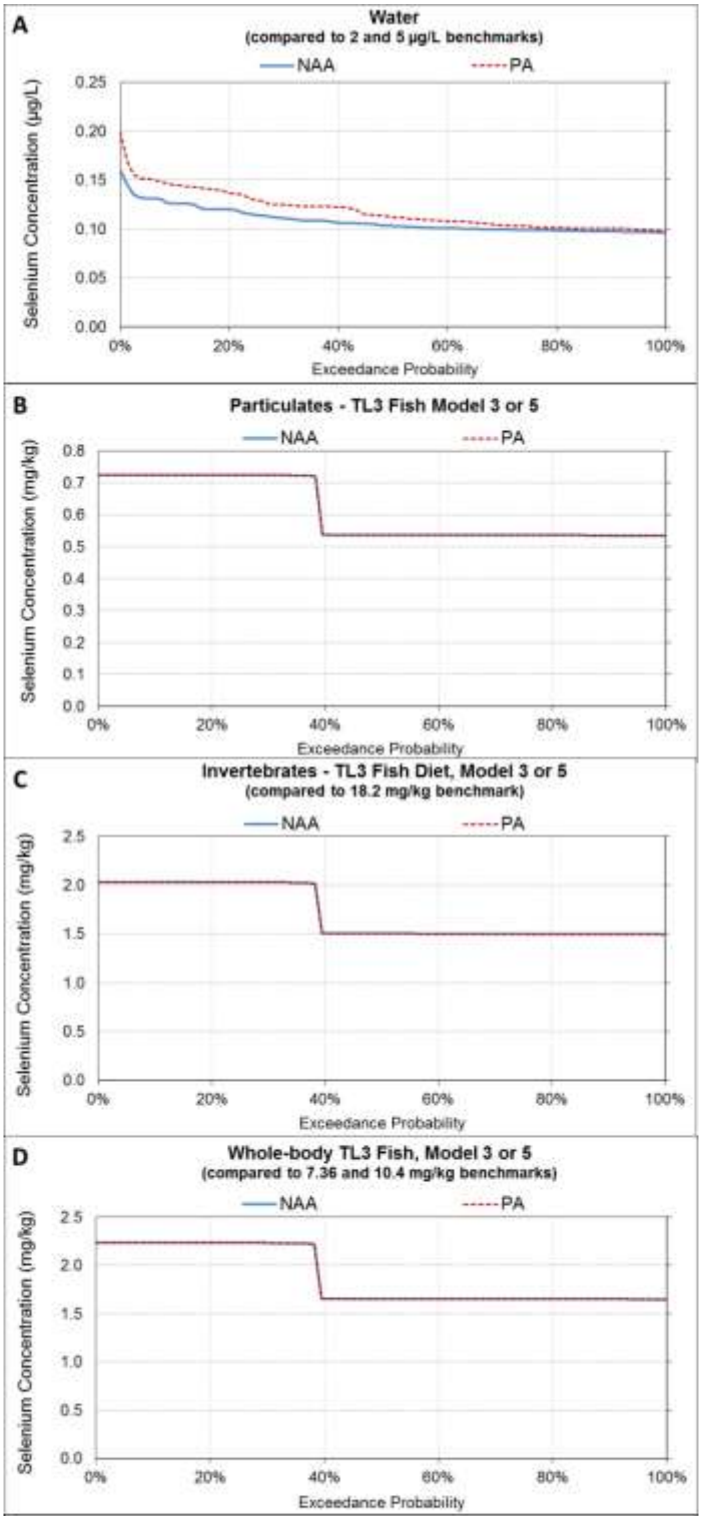
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Figure 5.F-8: Sacramento River at Emmaton – TL3 Fish Probability of Exceedance



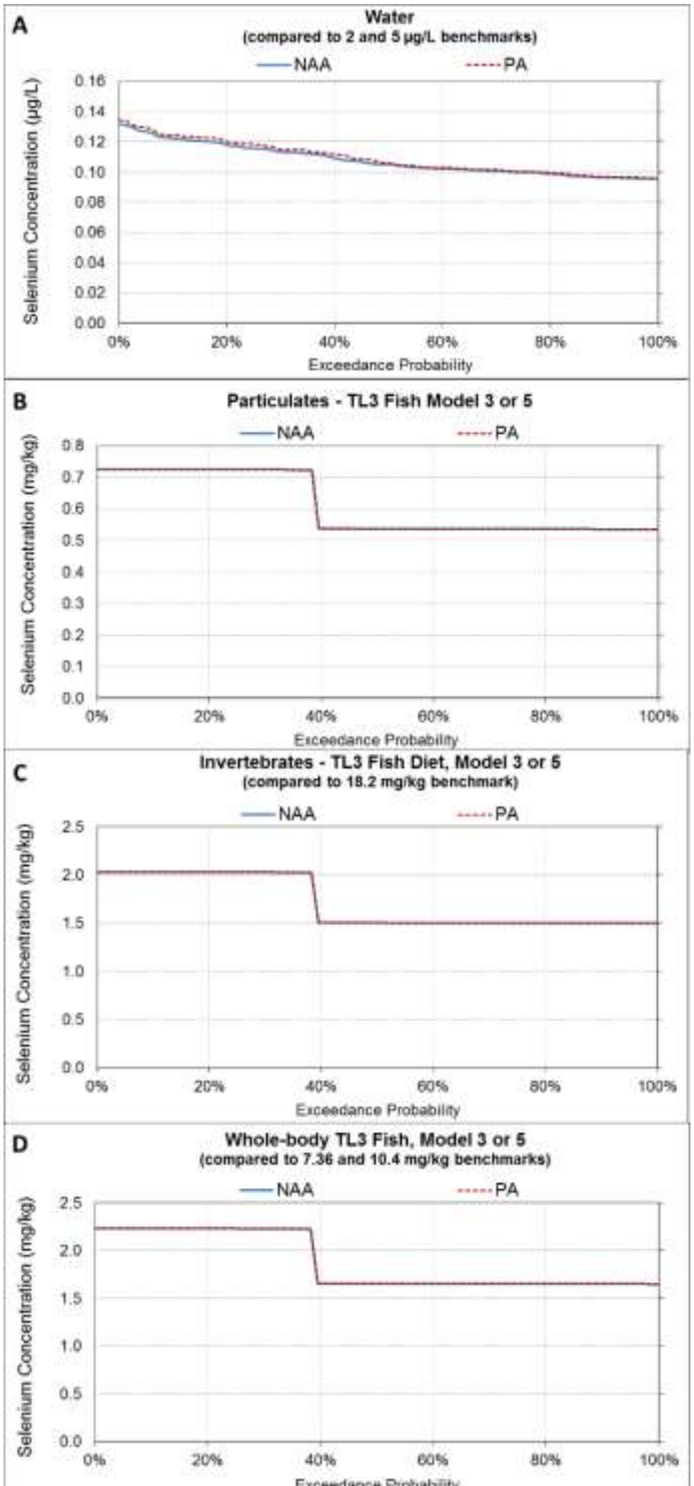
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Figure 5.F-9: San Joaquin River at Antioch – TL3 Fish Probability of Exceedance



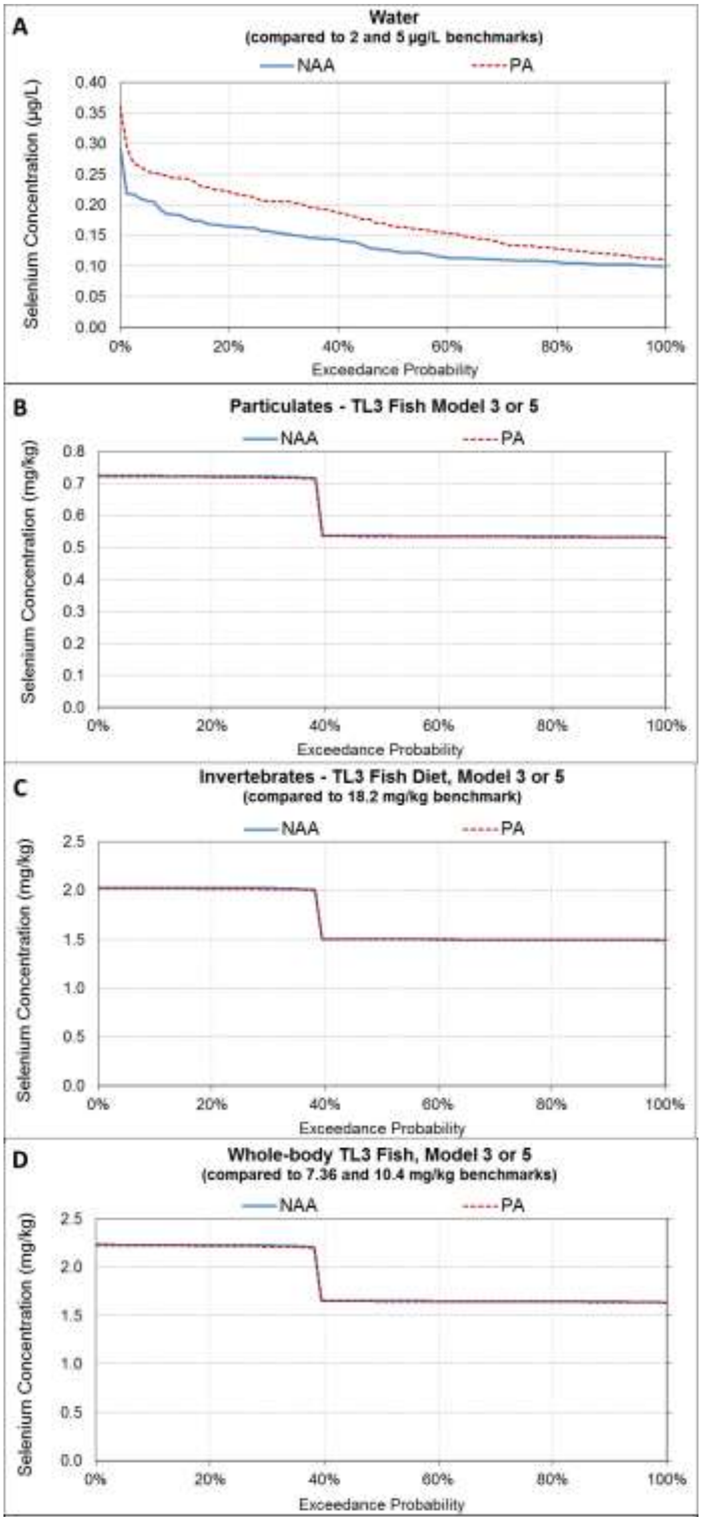
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Figure 5.F-10: Sacramento River at Mallard Island – TL3 Fish Probability of Exceedance



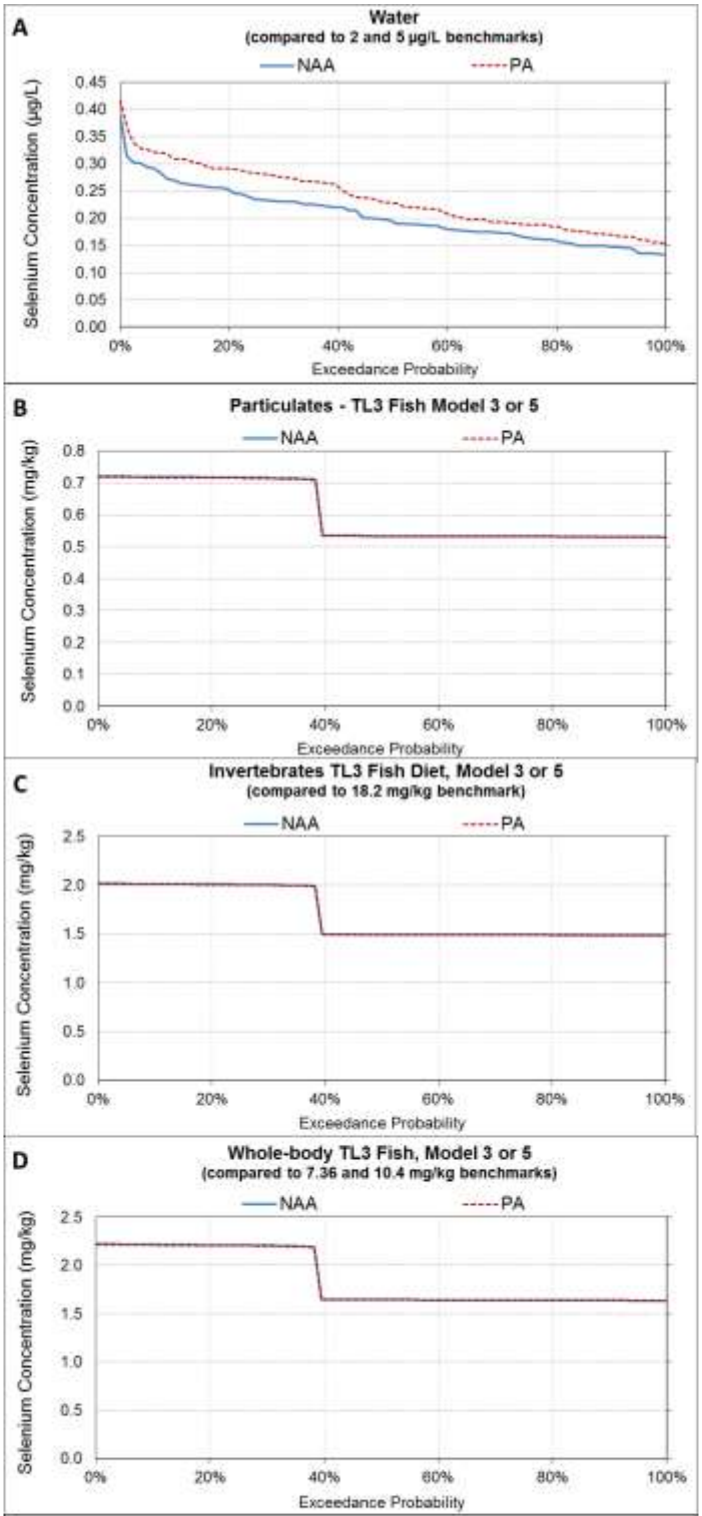
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Figure 5.F-11: North Bay Aqueduct at Barker Slough Pumping Plant – TL3 Fish Probability of Exceedance



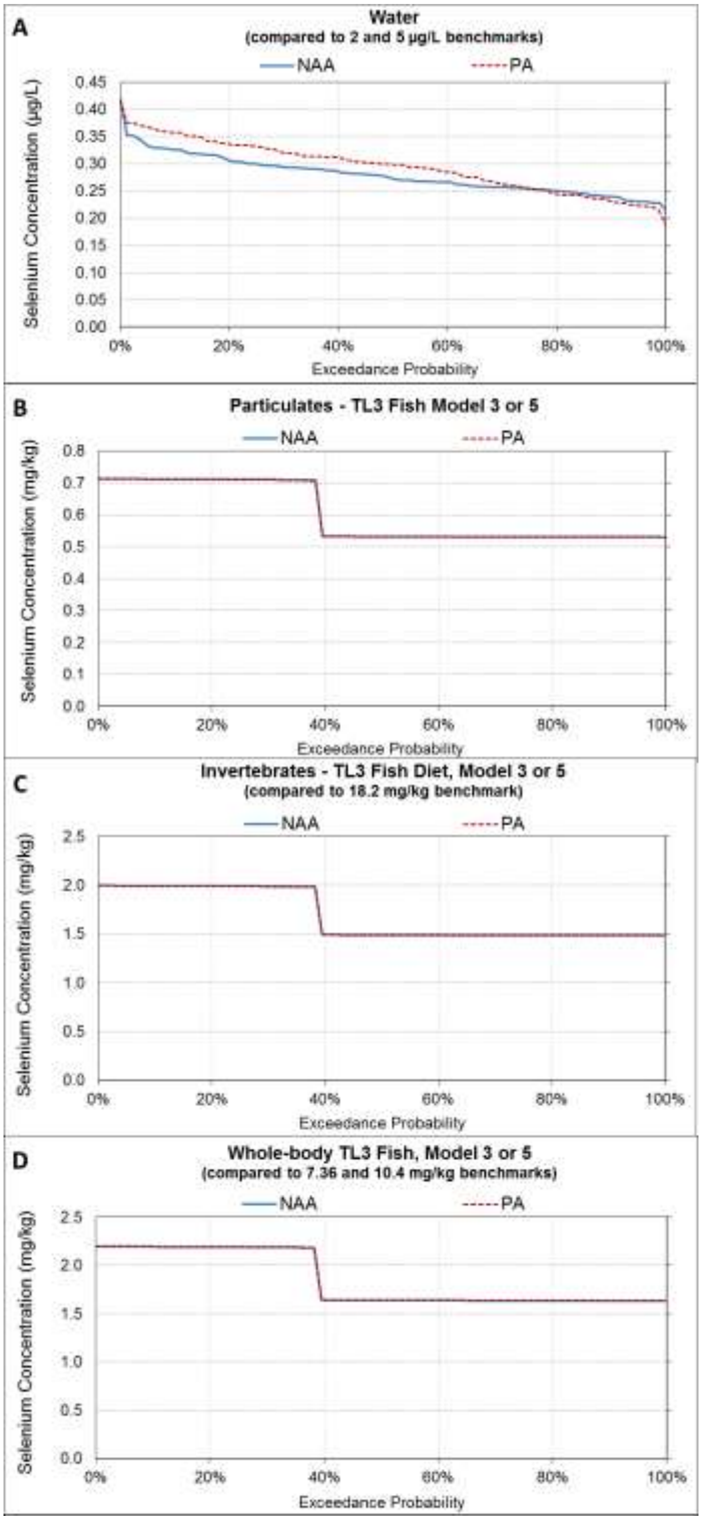
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Figure 5.F-12: Contra Costa Pumping Plant #1 – TL3 Fish Probability of Exceedance



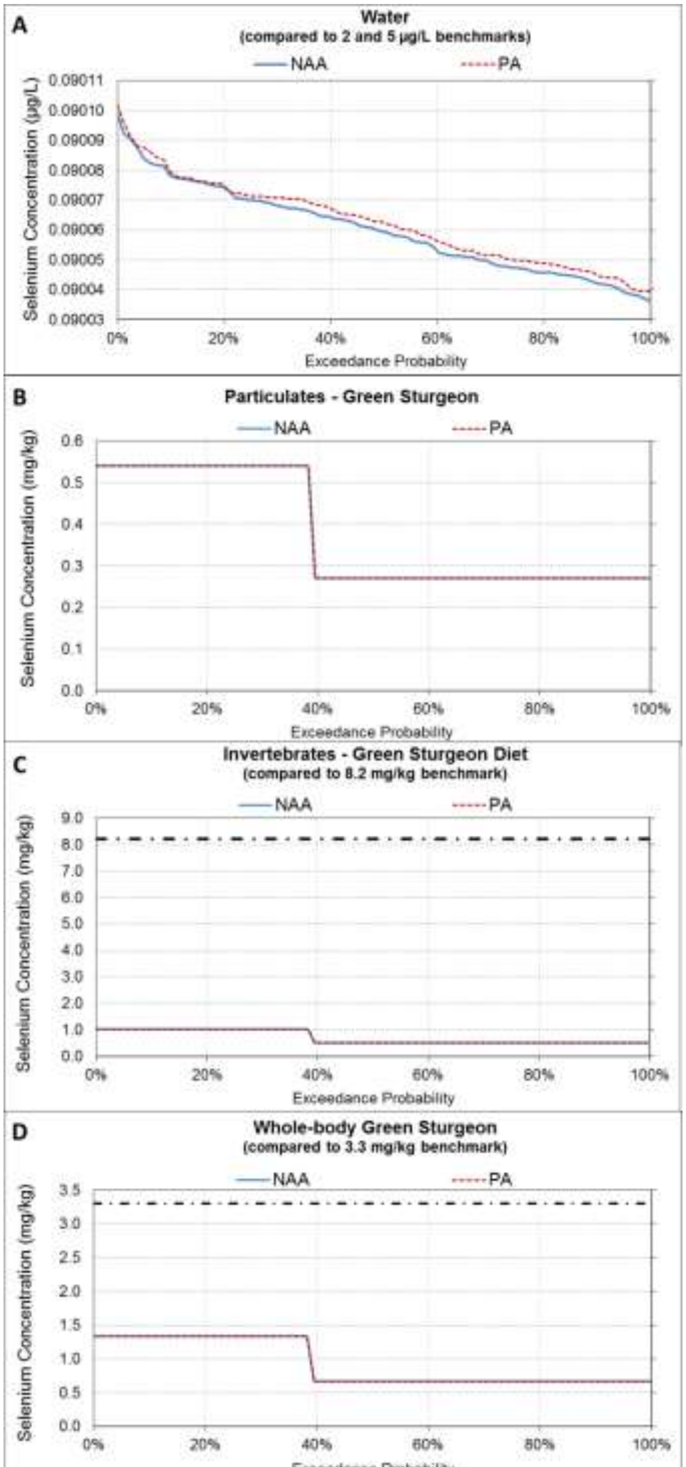
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Figure 5.F-13: Banks Pumping Plant – TL3 Fish Probability of Exceedance



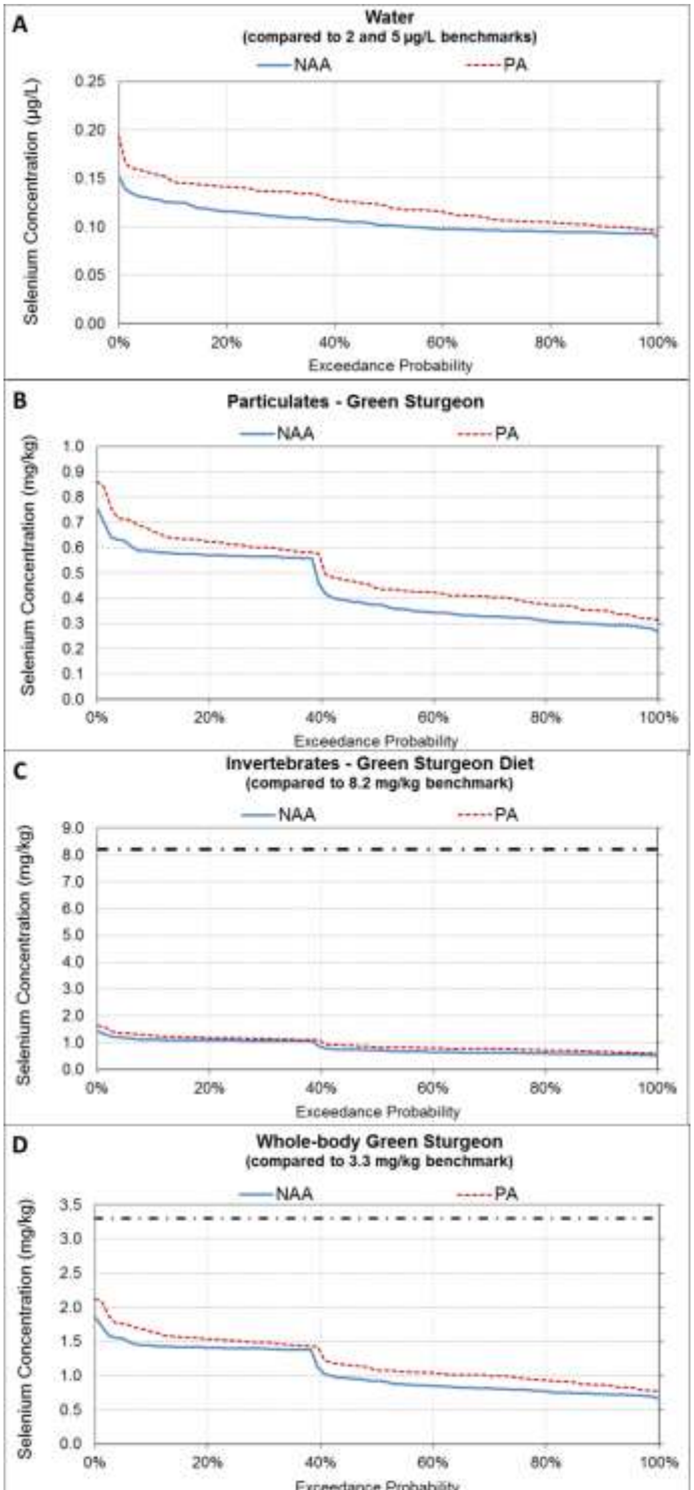
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c Model 3 was used to compute Kd values for wet, above normal, and below normal years. Model 5 was used for dry and critical years.

Figure 5.F-14: Jones Pumping Plant – TL3 Fish Probability of Exceedance



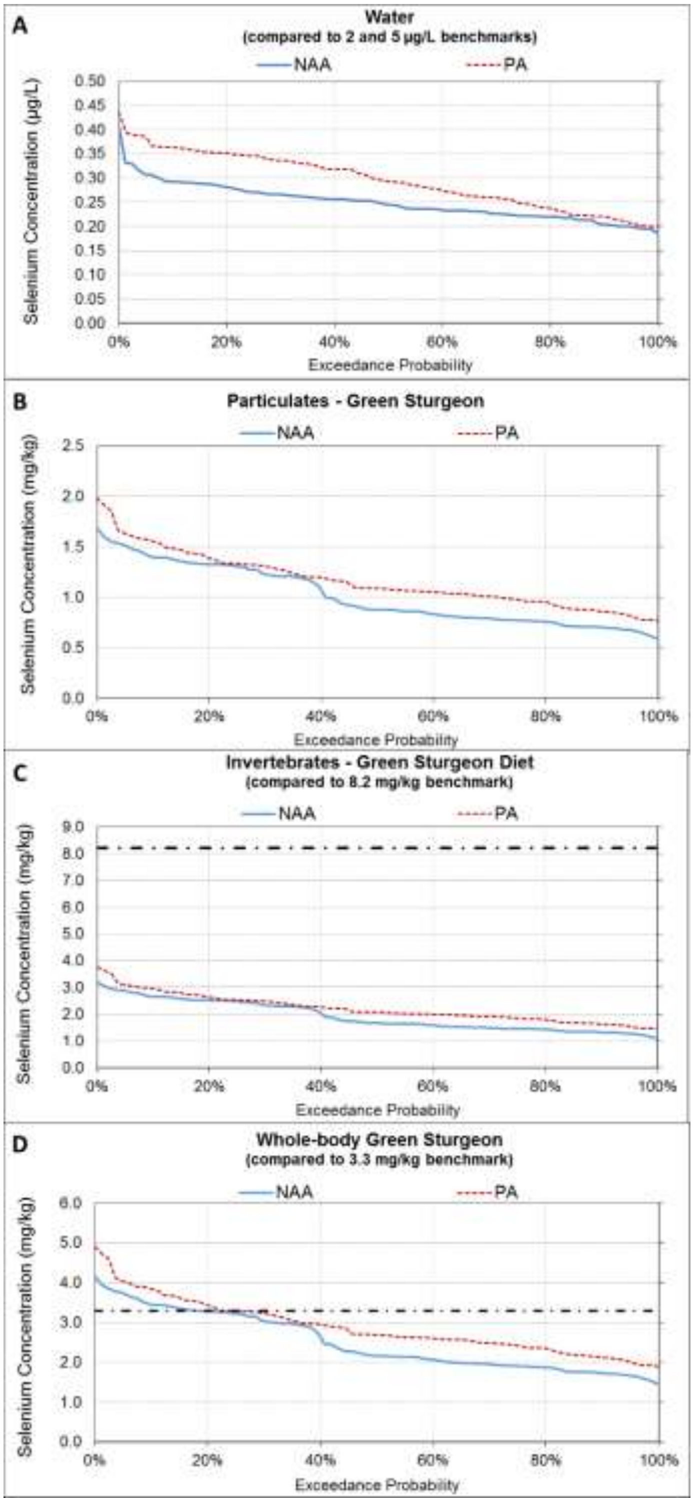
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c The Kd value for wet, above normal, and below normal years was 3,000 and for dry and critical years was 6,000.
d The TTF for invertabrates was 1.9 (see text).

Figure 5.F-15: Sacramento River upstream of Delta Cross Channel – Green Sturgeon Probability of Exceedance



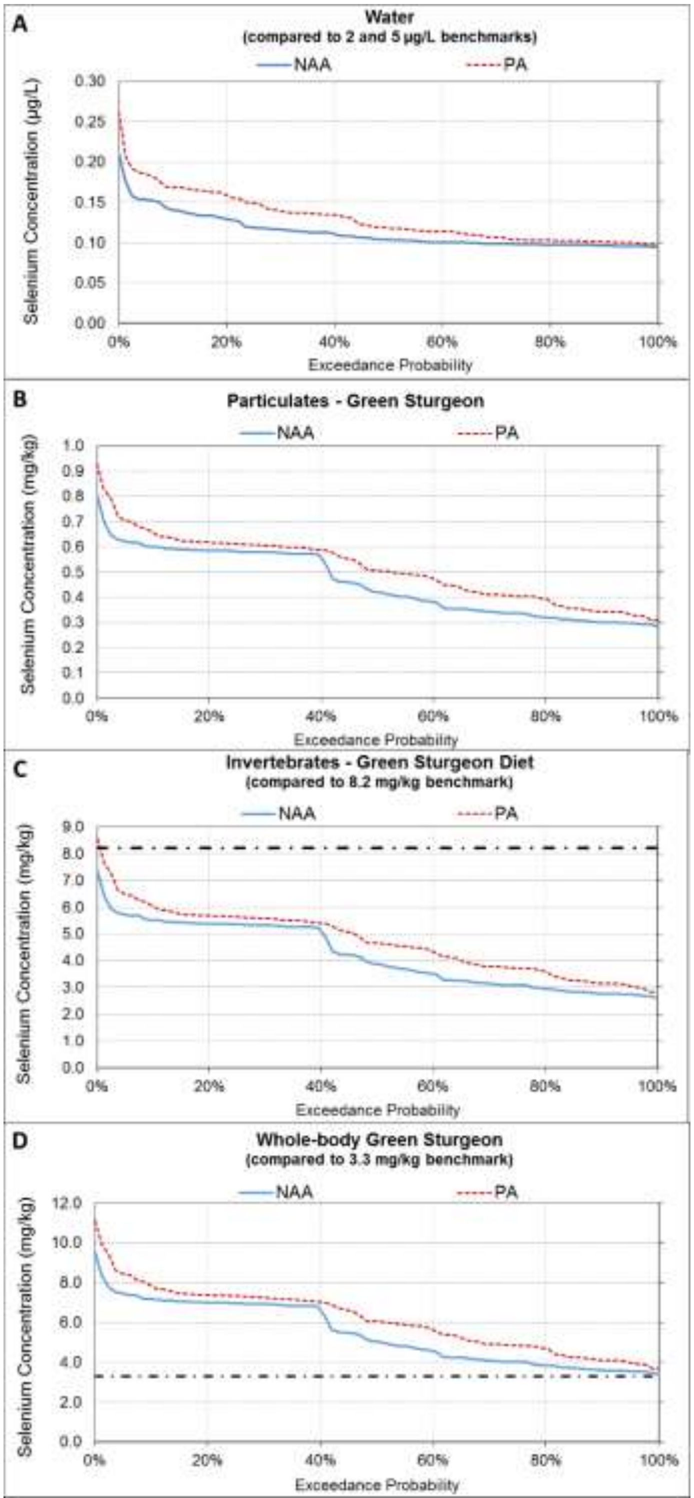
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c The Kd value for wet, above normal, and below normal years was 3,000 and for dry and critical years was 6,000.
d The TTF for invertabrates was 1.9 (see text).

Figure 5.F-16: San Joaquin River near San Andreas Landing – Green Sturgeon Probability of Exceedance



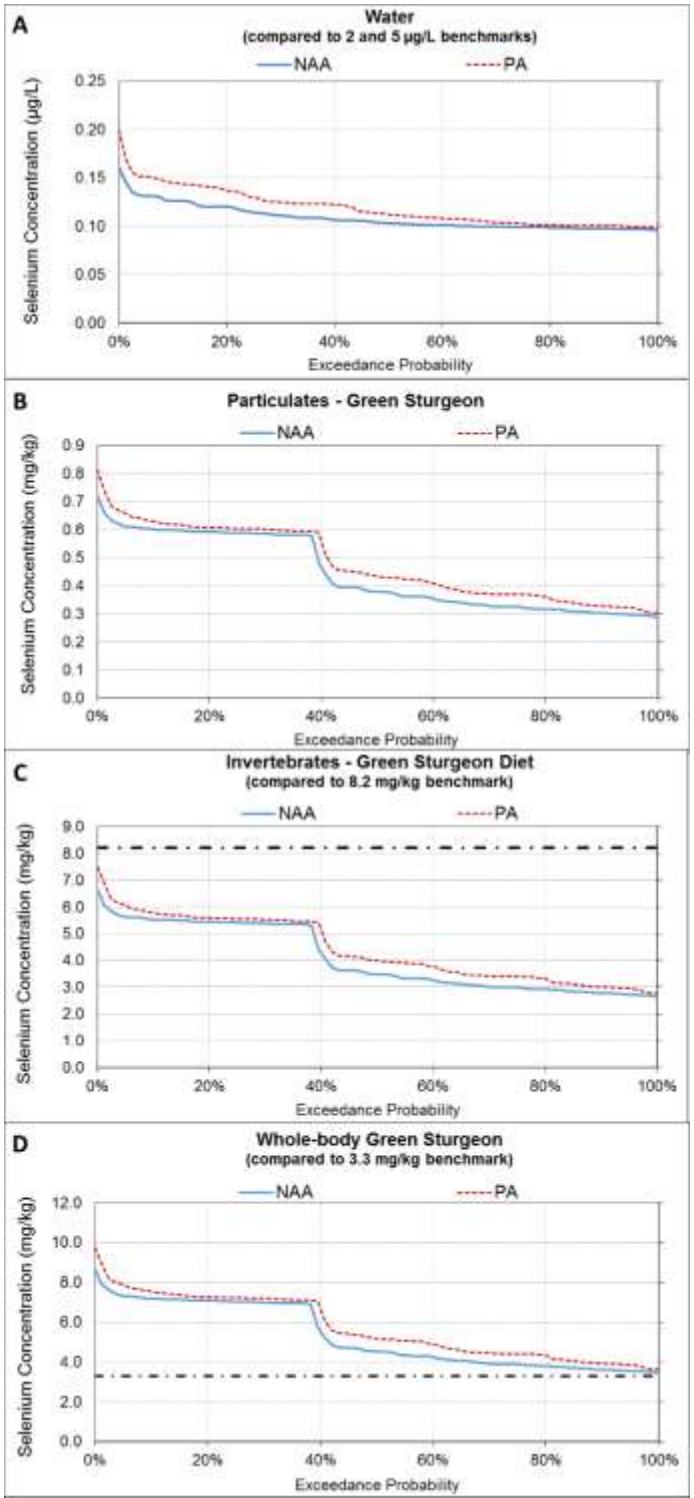
a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c The Kd value for wet, above normal, and below normal years was 3,000 and for dry and critical years was 6,000.
d The TTF for invertabrates was 1.9 (see text).

Figure 5.F-17: Old River at Clifton Court Forebay Radial Gates (West Canal) – Green Sturgeon Probability of Exceedance



a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c The Kd value for wet, above normal, and below normal years was 3,000 and for dry and critical years was 6,000.
d The TTF for invertabrates was 9.2 (see text).

Figure 5.F-18: San Joaquin River at Antioch – Green Sturgeon Probability of Exceedance



a Exceedance probability is defined as the probability a given value will be exceeded in any one year. Probability of Occurrence would be 100 minus exceedance probability.
b Based on the 82-year simulation period.
c The Kd value for wet, above normal, and below normal years was 3,000 and for dry and critical years was 6,000.
d The TTF for invertabrates was 9.2 (see text).

Figure 5.F-19: Sacramento River at Mallard Island – Green Sturgeon Probability of Exceedance

5.F.9 Attachment

Attachment 5.F-1 Water and Bioaccumulation Modeling Supplemental Information

Attachment 5.F-1 Water and Bioaccumulation Modeling Supplemental Information

This attachment contains the tables associated with the water modeling at DSM2 locations and also provides the details of the refinement/calibration of the selenium bioaccumulation models for the Delta, including tables and figures.

Attachment 5.F.1.1 Water Modeling

For DSM2 output locations, the geometric mean selenium concentrations from the inflow locations (Table 5.F-1) were combined with the modeled quarterly average percent inflow for each DSM2 output location to estimate waterborne selenium concentrations at those locations. The models used to estimate these concentrations are presented in Section 5.F.3.1.2.1 of the main Appendix 5.F text. The quarterly and average annual waterborne selenium concentrations for the DSM2 output locations are shown in Attachment Table 5.F-1 (Year 2000), Attachment Table 5.F-2 (Year 2005), and Attachment Table 5.F-3 (Year 2007).

Attachment 5.F.1.2 Refinement/Calibration of Selenium Bioaccumulation Models for the Delta

Several models were evaluated and refined to estimate selenium uptake in fish from waters in the Delta. Input parameters to the model (K_ds and the number of trophic levels) were varied among the models as refinements were made. Data for largemouth bass (*Micropterus salmoides*) collected in the Delta from areas near DSM2 output locations were used to calculate the geometric mean selenium concentration in whole-body fish (Foe 2010). The ratio of the estimated selenium concentration in fish to measured selenium in whole-body bass was used to evaluate each fish model and to focus refinements of the model. These Delta-wide models are presented in the following subsections (modeling for sturgeon did not require refinement because it relied on recent data provided by Presser and Luoma 2013 or other literature sources and assumptions), as described in the main Appendix 5.F text.

Characteristics of water flow in the Delta affect selenium bioaccumulation and the model refinements, because longer residence time for the water can be expected to increase bioaccumulation by increasing K_d. Foe (2010) reported the water year type for 2000 as “above normal” for both the Sacramento River and San Joaquin River watersheds. It came after “wet” water years and was followed by “dry” water years. Year 2005 was wetter than 2000, was reported as “above normal” for the Sacramento River watershed and wet for the San Joaquin River watershed, and occurred between periods of wet water years. Water Year 2007 was reported as dry (Sacramento River watershed) and “critically dry” (San Joaquin River watershed). It came after wet water years and was followed by critically dry water years.

There was no difference in bass selenium concentrations in the Sacramento River at Rio Vista in comparison to the San Joaquin River at Vernalis in 2000, 2005, and 2007 (Foe 2010). The lack of a difference in bioavailable selenium between the two river systems was unexpected because the San Joaquin River is considered a significant source of selenium to the Delta. Year 2005 selenium concentrations in bass were comparatively lower than those estimated for Year 2000. As expected in a wet water year, the water residence time was shorter, resulting in less selenium recycling, lower K_d values, and lower concentrations of selenium entering the food web. The dry water year (2007) resulted in a longer water residence time, higher K_d values, greater selenium recycling, and higher concentrations of bioavailable selenium entering the food web. These differences among years were considered when refining the selenium bioaccumulation model.

Models estimating whole-body selenium concentrations in fish were refined by modifying dietary composition and input parameters to closely represent measured conditions in the Delta. Each model is described in this section.

Model 1 was a basic representative of uptake by a forage fish, while Model 2 calculated sequential bioaccumulation in a more complex food web that included predatory fish eating forage fish, as shown below:

Model 1: Trophic level 3 (TL-3) fish eating invertebrates

$$C_{fish} = C_{particulate} \bullet TTF_{invertebrate} \bullet TTF_{fish} \quad \text{[Eq. 1]}$$

Model 2: Trophic level 4 (TL-4) fish eating TL-3 fish

$$C_{predatorfish} = C_{particulate} \bullet TTF_{inverterbrate} \bullet TTF_{foragefish} \bullet TTF_{predatorfish} \quad \text{[Eq. 2]}$$

Where:

C_{fish} = concentration of selenium in fish (µg/g dw)

$C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)

$TTF_{invertebrate}$ = Trophic transfer factor from particulate material to invertebrate

TTF_{fish} = Trophic transfer factor from invertebrate or fish to fish

In both Models 1 and 2, the particulate selenium concentration was estimated using Equation 2 and a default K_d of 1,000 (Presser and Luoma 2010a). The average TTFs for invertebrates (2.8) and fish (1.1) were used in each model. The outputs of estimated selenium concentrations and the ratios of predicted-to-observed bass selenium concentrations for Models 1 and 2 are presented in Attachment Table 5.F-4 and Attachment Figure 5.F-1.

Models 1 and 2 tended to substantially underestimate the whole-body selenium concentrations in fish when compared to bass data reported in Foe (2010). This was partly because Model 1 was estimating selenium concentration in a forage fish (TL-3), whereas bass are a predatory fish with expected higher dietary exposure. Consequently, Model 1 was not further developed as the selenium bioaccumulation model to represent fish in the Delta.

Model 2 is representative of predatory fish, but Model 2 was very similar to Model 1 in distribution of data and in underestimating bass data, even though an additional trophic-level transfer was included in the model. As noted here and described in much greater detail by Presser and Luoma (2010a, 2010b, 2013), the K_ds for uptake from water are far more variable than the TTFs for invertebrates or fish. Models 1 and 2 also apparently reflect the tendency of selenium (as an essential nutrient) to be more bioaccumulative when waterborne concentrations are low (as described by Stewart et al. 2010), which they were for the DSM2-modeled concentrations (i.e., 0.09 to 0.85 µg/L). Available K_d values from various sampling efforts in the Delta provided by Presser and Luoma (2010b) were reviewed for potential applicability in the modeling effort. Those values varied on the basis of locations within the Delta and Suisun Bay and also by water year and flow characteristics (often greater than 5,000 and sometimes exceeding 10,000). However, efforts to incorporate various selected K_ds (e.g., 2,000 or 3,000) into the model uniformly for different DSM2 locations failed to produce ratios of modeled-to-measured fish selenium concentrations that approximated 1 (they either over- or underestimated fish selenium because of variability in site conditions).

The available bass data and the assumed TTFs for fish (1.1) and invertebrates (2.8) were used to back-calculate a location and sample-specific K_d. It is recognized that some of the variability in bioaccumulation may be associated with the TTFs, but there were no reasonable assumptions for selection of alternative values to plug into the model.

When TTFs were held constant, back-calculation of K_d values revealed a concentration-related influence on the values. For waterborne selenium concentrations in the range of 0.09 to 0.13 µg/L (N = 50), the median K_d was 5,575; when waterborne selenium concentrations were in the range of 0.14 to 0.40 µg/L (N = 19), the median K_d was 2,431; for waterborne selenium concentrations in the range of 0.41 to 0.85 µg/L (N = 19), the median K_d was 748. These observations are consistent with an inverse relationship between waterborne selenium concentrations and bioaccumulation in aquatic organisms.

Attachment Figure 5.F-2 shows the log-log regression relation of K_d to waterborne selenium concentration when all years are included and the TTFs are held constant, while Attachment Figure 5.F-3 shows the relationship for normal/wet years (2000 and 2005) and Attachment Figure 5.F-4 shows the regression for dry years (2007), when the K_ds were generally higher.

Model 3 is based on Model 2 (with TTFs as described above) but includes the K_d estimated from the log-log regression relation for all years (Attachment Figure 5.F-2). This produced a median ratio of predicted-to-observed whole-body selenium in bass that was slightly less than 1 (Attachment Figure 5.F-1); details are provided in Attachment Table 5.F-5. Because of the noticeable differences between 2007 (the dry year) in comparison to the other two years, the next step in modeling was to evaluate 2007 separately from 2000 and 2005.

Model 4 was developed using the log-log relationship between K_d and water selenium concentrations for 2000/2005 (Attachment Figure 5.F-3), and Model 5 was developed using log-log relationship between K_d and water selenium concentrations for 2007 (Attachment Figure 5.F-4) (Attachment Table 5.F-6). These two models produced ratios of predicted-to-observed whole-body selenium in bass approximating 1, as shown in Attachment Figure 5.F-1.

As expected in a large, complex, and diverse ecological habitat such as the Delta, variations in the data distribution and in the outputs of the models are not surprising. However, it should be noted that the estimated K_ds for Models 3 (618-6,091; Attachment Table 5.F-5), 4 (598-5,145; Attachment Table 5.F-6), and 5 (1,206-8,064; Attachment Table 5.F-6) are consistent with those summarized by Presser and Luoma (2010b) for the Delta.

Attachment Figures 5.F-5 and 5.F-6 illustrate the distribution of data for selenium concentrations in largemouth bass (Foe 2010) relative to the measured or DSM2-modeled waterborne selenium concentrations (Attachment Tables 5.F-1 through 5.F-3) and Models 3, 4, and 5 to complement the boxplots shown in Attachment Figure 5.F-1. There is notably more variability in selenium concentrations in bass between 0.09 and 0.13 µg/L than at higher waterborne selenium concentrations (as shown in both Attachment Figures 5.F-5 and 5.F-6); most of the higher values are from 2007 and most of the lower ones are from 2005.

Attachment Figure 5.F-5 shows the available data for 2000, 2005, and 2007 plotted with the Model 3 prediction of selenium concentrations. As noted above in text and in Attachment Figure 5.F-1, the model slightly under-predicts the median concentrations in fish on the basis of waterborne selenium concentrations. However, overall, the model is within 1 µg/g for all values below the prediction, and within about 1.2 µg/g for the values that are above the prediction (Attachment Figure 5.F-5).

Because of the notable differences between data for 2007 in comparison to combined 2000 and 2005, we developed Model 4 for 2000/2005 and Model 5 for 2007; Attachment Figure 5.F-6 shows those model predictions in comparison to the data. These two models improved the predictions; although the figure shows more differences between data and the models at the lower waterborne concentrations (i.e., < 0.30 µg/L) than at higher ones, the divergence is generally < 0.5 µg/g at the higher waterborne concentrations. The outliers for Model 4 are mostly above the 90th percentile (i.e., over-predicting concentrations in fish), rather than below, though those below (i.e., under-predicting concentrations in fish) influence the mean to get a slight under-prediction as shown in Attachment Figure 5.F-1. For Model 5, the predictions are “tighter” with just a few outliers above or below the 90th percentile.

Overall, evaluation of water-year effects on selenium concentration in bass concluded that Model 4 is relatively predictive of selenium concentration in whole-body bass during normal to wet water years, Model 5 is considered predictive for dry water years (e.g., 2007), and Model 3 incorporates the varying bioaccumulation when all years are considered (i.e., 2000, 2005, and 2007). Although Model 3 tends to slightly overestimate selenium bioaccumulation (Attachment Table 5.F-5 and Attachment Figure 5.F-1), it was used for estimating selenium concentrations in whole-body fish to compare the PA to the NAA in this analysis for “wet, above normal, and below normal” years, and Model 5 was used for “dry and critical” years.

Attachment 5.F.1.3 References

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Attachment Table 5.F-1. Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2000

		First Quarter Inflow Percentage						Second Quarter Inflow Percentage						Third Quarter Inflow Percentage						Fourth Quarter Inflow Percentage						Estimated Waterborne Selenium Concentrations (µg/L)				
	Inflow Source →	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**					
	Inflow Location →	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***					
DSM2 Output	**Selenium (µg/L) →**	0.11	0.10	0.09	0.83	0.10	0.23	0.11	0.10	0.09	0.83	0.10	0.23	0.11	0.10	0.09	0.83	0.10	0.23	0.11	0.10	0.09	0.83	0.10	0.23	**1st Quarter**	**2nd Quarter**	**3rd Quarter**	**4th Quarter**	**Annual**
Water Location	**Location ID**																													
Big Break	BIGBRK_MID	2.94	6.88	53.15	6.59	0.18	5.70	2.95	6.37	73.59	13.55	0.27	3.12	3.13	0.45	85.63	0.44	4.15	6.12	2.13	0.20	84.85	0.02	8.76	3.96	0.13	0.20	0.10	0.10	0.13
Cache Slough	CACHS_LEN	1.46	0	53.38	0	0	31.91	1.24	1.5E-05	85.07	2.5E-05	0	13.25	1.66	4.7E-07	85.95	4.3E-07	5.9E-07	12.23	1.32	2.8E-06	89.83	1.1E-07	2.3E-05	8.67	0.12	0.11	0.11	0.10	0.11
Cache Slough Ryer	CACHSR_MID	2.88	0	54.86	0	0	20.48	3.36	9.8E-07	79.75	1.9E-06	0	16.25	1.90	9.3E-08	84.53	1.8E-07	9.2E-12	13.38	1.81	1.0E-07	89.45	6.2E-10	3.0E-06	8.54	0.10	0.11	0.11	0.10	0.11
Cosumnes R.	COSR_LEN	8.1E-06	98.82	0	0	0	0	0	100.00	0	0	0	0	0	100.00	0	0	0	0	0	100.00	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Franks Tract	FRANKST_MID	5.06	11.56	43.94	15.79	0.02	0.32	4.17	9.42	61.16	23.89	0.01	1.22	4.04	0.57	90.34	0.41	0.80	3.78	2.76	0.62	91.38	0.12	2.42	2.64	0.19	0.27	0.10	0.10	0.16
Little Holland Tract	LHOLND_L0	72.35	0	5.06	0	0	6.50	23.38	8.2E-07	63.10	1.6E-06	0	13.03	18.48	2.2E-07	68.67	4.2E-07	7.2E-13	12.68	19.63	2.6E-09	72.79	0	0	7.42	0.10	0.11	0.11	0.10	0.11
Middle R Bullfrog	MIDRBULFRG_LEN	10.54	13.07	18.37	32.20	1.9E-03	3.2E-03	5.49	9.19	14.96	70.17	4.2E-04	0.10	7.81	6.43	69.63	14.94	0.12	1.02	4.86	6.31	59.79	27.84	1	0.68	0.31	0.61	0.20	0.30	0.36
Mildred Island	MILDDRISL_MID	7.47	14.31	22.79	30.23	2.4E-03	1.8E-03	4.77	10.05	18.48	66.48	6.7E-04	0.13	6.57	4.57	83.28	4.14	0.15	1.25	4.50	6.63	71.28	16.13	0.61	0.82	0.29	0.58	0.12	0.21	0.30
Mok. R. below Cosum.	MOKBCOS_LEN	2.07	96.19	0	0	0	0	1.65	98.35	0	0	0	0	7.23	92.77	4.7E-09	0	0	0	2.47	97.53	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Mok. R. downstream Cosum.	MOKDCOS_MID	2.07	96.43	0	0	0	0	1.68	98.32	0	0	0	0	7.08	92.92	0	0	0	0	2.34	97.66	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Old R near Paradise Cut	OLDRNPARADSEC_MID	6.24	0	0	87.26	0	0	14.40	1.67	5.21	78.66	1.2E-05	0.04	10.56	3.9E-05	1.3E-04	89.44	8.8E-28	3.0E-07	2.50	1.1E-04	3.5E-04	97.50	2.8E-20	1.7E-07	0.73	0.68	0.75	0.81	0.74
Paradise Cut	PARADSECUT_LEN	4.69	0	0	91.37	0	0	2.62	0.06	0.15	97.16	1.5E-07	1.1E-03	3.43	0	0	96.57	0	0	0.96	0	0	99.04	0	0	0.76	0.81	0.81	0.82	0.80
Port of Stockton	PORTOSTOCK_L0	1.67	0	0	18.85	0	0	2.22	0	0	60.73	0	0	3.09	0	0	81.32	0	0	2.70	0	0	89.89	0	0	0.16	0.51	0.68	0.75	0.52
Sac. R. at Isleton	SACRISLTON_L0	0.33	0	95.77	0	0	0	0.31	0.00	99.60	0	0	5.5E-05	0.44	0	99.55	0	0	1.3E-05	0.28	0	99.72	0	0	1.1E-03	0.09	0.09	0.09	0.09	0.09
Sac River RM 44	SACR44_L0	0.14	0	97.93	0	0	0	0.11	0	99.81	0	0	0	0.13	0	99.86	0	0	0	0.05	0	99.94	0	0	0	0.09	0.09	0.09	0.09	0.09
Sandmound Sl.	SANDMND_MID	6.36	10.51	43.82	12.90	0.03	0.57	5.22	8.81	63.78	20.40	0.03	1.63	5.24	0.61	87.78	0.49	1.22	4.59	3.31	0.43	89.58	0.06	3.44	3.11	0.17	0.25	0.10	0.10	0.15
Sherman Island	SHERMNILND_L0	1.64	3.45	52.71	3.93	0.60	12.10	2.48	4.95	76.80	10.96	0.96	3.67	2.60	0.40	81.69	0.46	8.21	6.56	1.77	0.11	77.64	0.01	16.46	3.94	0.11	0.18	0.10	0.10	0.12
SJR Bowman	SJRBOWMN_MID	1.40	0	0	94.03	0	0	1.52	0	0	98.48	0	0	3.00	0	0	97.00	0	0	0.33	0	0	99.67	0	0	0.78	0.82	0.81	0.83	0.81
SJR N Hwy4	SJRNHWY4_MID	3.49	0	0	89.96	0	0	1.87	0	0	98.13	0	0	3.91	0	0	96.09	0	0	0.72	0	0	99.28	0	0	0.75	0.82	0.80	0.82	0.80
SJR Naval st	SJRNAVLST_L0	8.89	12.70	0.00	65.44	0	0	2.69	6.26	0	90.94	0	0	5.98	10.89	0	83.00	0	0	2.02	3.10	0.00	94.84	0	0	0.57	0.76	0.71	0.79	0.71
SJR Potato Slough	SJRPOTSL_MID	3.15	12.62	55.38	12.40	0.01	0.06	3.05	10.32	65.93	19.73	0.01	0.86	2.63	0.35	93.54	0.20	0.45	2.79	2.06	0.80	93.46	0.06	1.47	2.11	0.17	0.24	0.10	0.09	0.15
SJR Turner	SJRTURNR_MID	8.81	9.28	2.55	56.31	5.3E-05	1.0E-05	3.33	5.77	0.41	90.39	6.3E-06	2.4E-03	8.69	13.75	17.87	59.41	0.01	0.16	3.23	4.83	7.34	84.49	0.03	0.05	0.49	0.76	0.53	0.72	0.62
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	1.92	4.35	55.13	4.50	0.44	10.23	2.45	4.72	77.70	10.28	0.76	3.91	2.64	0.35	83.38	0.38	6.66	6.52	1.82	0.12	80.54	0.01	13.33	4.11	0.12	0.17	0.10	0.10	0.12
Suisun Bay	SUISNB_LEN	0.81	1.22	45.93	1.24	16.49	15.94	0.92	1.66	49.51	3.61	41.10	2.95	0.80	0.23	27.56	0.40	68.55	2.42	0.60	0.03	28.62	0.01	69.16	1.54	0.11	0.13	0.10	0.10	0.11
Sycamore Slough	SYCAMOR_MID	6.50	50.69	15.18	0	0	0	5.89	76.86	16.89	2.8E-07	0	0	5.04	14.29	80.66	1.2E-31	0	0	4.23	31.10	64.66	0	0	0	0.07	0.10	0.09	0.09	0.09
White Slough	WHITESL_L0	22.32	11.88	17.97	25.51	1.7E-08	6.0E-11	16.54	12.10	16.87	54.46	3.7E-09	6.1E-05	9.89	7.76	82.34	3.8E-03	3.0E-05	5.3E-04	11.19	12.92	75.64	0.24	4.2E-04	6.4E-04	0.26	0.50	0.09	0.10	0.24
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	14.83	22.63	29.02	22.45	5.4E-08	0	12.45	13.97	21.21	52.32	2.2E-09	2.3E-04	8.74	7.78	83.47	2.4E-03	4.0E-05	5.6E-04	5.28	14.84	79.82	0.05	5.0E-04	7.3E-04	0.25	0.48	0.09	0.09	0.23

Attachment Table 5.F-2. Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2005

		First Quarter Inflow Percentage						Second Quarter Inflow Percentage						Third Quarter Inflow Percentage						Fourth Quarter Inflow Percentage						Estimated Waterborne Selenium Concentrations (µg/L)				
	Inflow Source →	Delta Ag.	East Delta Tributaries	Sac. R.	San Joaq. R.	Martinez/ Suisun Bay	Yolo Bypass	Delta Ag.	East Delta Tributaries	Sac. R.	San Joaq. R.	Martinez/ Suisun Bay	Yolo Bypass	Delta Ag.	East Delta Tributaries	Sac. R.	San Joaq. R.	Martinez/ Suisun Bay	Yolo Bypass	Delta Ag.	East Delta Tributaries	Sac. R.	San Joaq. R.	Martinez/ Suisun Bay	Yolo Bypass					
	Inflow Location →	*Mildred Island, Center*	*Mokelumne Calaveras Cosumnes Rivers*	*Freeport*	*Vernalis*	*San Joaq. R. near Mallard Island*	*Sac. R. below Knights Landing*	*Mildred Island, Center*	*Mokelumne Calaveras Cosumnes Rivers*	*Freeport*	*Vernalis*	*San Joaq. R. near Mallard Island*	*Sac. R. below Knights Landing*	*Mildred Island, Center*	*Mokelumne Calaveras Cosumnes Rivers*	*Freeport*	*Vernalis*	*San Joaq. R. near Mallard Island*	*Sac. R. below Knights Landing*	*Mildred Island, Center*	*Mokelumne Calaveras Cosumnes Rivers*	*Freeport*	*Vernalis*	*San Joaq. R. near Mallard Island*	*Sac. R. below Knights Landing*					
DSM2 Output	Selenium (µg/L) →	0.11	0.10	0.09	0.85	0.10	0.23	0.11	0.10	0.09	0.85	0.10	0.23	0.11	0.10	0.09	0.85	0.10	0.23	0.11	0.10	0.09	0.85	0.10	0.23	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Annual
Water Location	**Location ID**																													
Big Break	BIGBRK_MID	5.87	7.57	83.73	2.41	0.24	0.18	2.90	17.21	52.77	26.69	1.6E-03	0.43	3.31	2.21	88.77	1.70	3.98	0.03	2.39	0.24	90.17	0.01	6.48	0.70	0.11	0.30	0.10	0.09	0.15
Cache Slough	CACHS_LEN	4.89	2.2E-07	93.64	8.E-07	3.8E-07	1.47	1.48	7.1E-07	94.13	8.0E-07	1.1E-08	4.38	1.94	1.7E-05	98.02	1.0E-05	1.6E-06	0.05	2.30	1.2E-05	92.72	4.6E-07	0.00	4.98	0.09	0.10	0.09	0.10	0.09
Cache Slough Ryer	CACHSR_MID	8.13	3.0E-07	91.14	1.2E-06	1.3E-06	0.73	3.74	2.5E-08	91.89	1.0E-07	2.9E-08	4.38	2.15	5.6E-07	97.77	2.6E-07	4.5E-09	0.08	2.66	8.8E-07	96.37	1.9E-08	7.6E-06	0.97	0.09	0.10	0.09	0.09	0.09
Cosumnes R.	COSR_LEN	0	100.00	0	0	0	0	0.00	100.00	0.00	0	0	0	0	100	0	0	0	0	1.2E-04	100.00	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Franks Tract	FRANKST_MID	8.65	11.65	72.50	7.E+00	0.19	0.05	4.63	16.63	26.97	51.74	1.1E-04	0.03	4.27	3.20	89.93	1.81	0.77	0.02	3.17	0.81	94.16	0.06	1.74	0.05	0.15	0.49	0.11	0.09	0.21
Little Holland Tract	LHOLND_L0	97.11	3.2E-09	2.88	9.E-09	3.9E-09	0.01	44.12	6.5E-09	53.25	2E-08	1.2E-08	2.63	18.61	5.6E-07	81.24	0.00	0.00	0.16	46.22	6.1E-08	53.77	2.8E-08	2.6E-09	0.01	0.11	0.10	0.09	0.10	0.10
Middle R Bullfrog	MIDRBULFRG_LEN	13.67	9.76	28.26	48.24	0.08	0.01	5.55	5.64	2.70	86.11	7.1E-05	8.4E-04	7.43	12.50	53.07	26.88	0.12	3.1E-03	5.54	8.75	65.65	19.67	0.39	1.1E-03	0.46	0.75	0.30	0.24	0.44
Mildred Island	MILDDRISL_MID	12.36	11.39	32.28	43.87	8.4E-02	0.01	4.81	6.98	2.78	85.43	3.6E-05	6.7E-04	6.73	12.68	65.46	14.98	0.15	3.9E-03	4.81	7.16	77.85	9.71	0.47	1.8E-03	0.43	0.74	0.21	0.17	0.38
Mok. R. below Cosum.	MOKBCOS_LEN	2.18	97.82	0	0.00	0	0	0.53	99.47	0	0	0	0	3.05	96.95	0	0	0	0	3.00	97.00	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Mok. R. downstream Cosum.	MOKDCOS_MID	2.22	97.78	0	0.00	0	0	0.53	99.47	0	0	0	0	3.05	96.95	0	0	0	0	2.93	97.07	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Old R near Paradise Cut	OLDRNPARADSEC_MID	8.95	4.7E-05	1.5E-03	91.05	1.4E-05	1.4E-06	1.43	1.7E-07	1.6E-05	98.57	1.7E-08	3.5E-10	6.64	0	5.E-09	93.36	0	0	14.49	0.24	3.16	82.09	0.02	8.1E-05	0.78	0.84	0.80	0.72	0.79
Paradise Cut	PARADSECUT_LEN	10.28	1.6E-07	6.8E-07	89.72	1.6E-11	1.7E-08	0.82	0	0	99.18	0	0	2.39	0	0	97.61	0	0	1.08	0	0	98.92	0	0	0.77	0.84	0.83	0.84	0.82
Port of Stockton	PORTOSTOCK_L0	4.70	0	0	95.30	0	0	2.83	0	0	97.16	0	0	2.20	0	0	97.80	0	0	2.20	0	0	97.79	0	0	0.82	0.83	0.83	0.83	0.83
Sac. R. at Isleton	SACRISLTON_L0	0.55	0	99.45	0.00	0	0	0.18	0	99.82	0.00	0	0	0.45	0	99.55	0.00	0	0	0.41	0	99.59	0	0	8.2E-08	0.09	0.09	0.09	0.09	0.09
Sac River RM 44	SACR44_L0	0.21	0	99.79	0.00	0	0	0.07	0	99.93	0.00	0	0	0.14	0	99.86	0.00	0	0	0.17	0	99.83	0	0	0	0.09	0.09	0.09	0.09	0.09
Sandmound Sl.	SANDMND_MID	10.51	10.17	74.35	4.65	0.25	0.07	5.35	18.03	32.15	44.41	1.5E-04	0.06	5.61	3.13	87.97	2.10	1.17	0.02	3.93	0.55	92.97	0.03	2.45	0.07	0.13	0.43	0.11	0.09	0.19
Sherman Island	SHERMNILND_L0	4.89	5.04	87.74	1.52	0.56	0.23	2.43	14.17	61.17	21.31	0.03	0.89	2.76	1.84	86.03	1.72	7.62	0.04	1.95	0.11	84.69	0.01	11.76	1.48	0.10	0.26	0.10	0.09	0.14
SJR Bowman	SJRBOWMN_MID	1.10	0	0.00	98.90	0	0	0.45	0	0	99.55	0	0	2.06	0	0	97.94	0	0	0.80	0	0	99.20	0	0	0.84	0.85	0.83	0.84	0.84
SJR N Hwy4	SJRNHWY4_MID	1.89	0	0.00	98.11	0	0	0.59	0	0	99.41	0	0	2.64	0	0	97.36	0	0	1.94	0.00	0	98.06	0	0	0.84	0.85	0.83	0.84	0.84
SJR Naval st	SJRNAVLST_L0	4.70	5.45	0.00	89.85	0	0	1.06	5.10	0	93.84	0	0	4.11	9.43	0	86.46	0	0	4.97	12.46	0	82.57	0	0	0.77	0.80	0.75	0.72	0.76
SJR Potato Slough	SJRPOTSL_MID	6.24	16.03	71.18	6.45	0.07	0.03	2.65	23.15	38.61	35.59	1.1E-05	0.01	2.75	2.58	93.40	0.83	0.42	0.01	2.16	1.30	95.35	0.02	1.04	0.13	0.14	0.36	0.10	0.09	0.17
SJR Turner	SJRTURNR_MID	6.75	4.55	1.37	87.31	0.01	0	1.49	3.20	0.00	95.31	0	0	6.05	11.77	4.90	77.27	0.01	8.4E-05	5.55	16.96	10.99	66.44	0.06	7.4E-05	0.76	0.81	0.68	0.60	0.71
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	4.87	5.29	87.53	1.67	0.37	0.27	2.37	13.56	62.61	20.61	0.02	0.84	2.82	1.68	87.76	1.46	6.24	0.03	2.05	0.14	86.70	0.01	9.68	1.42	0.10	0.25	0.10	0.09	0.14
Suisun Bay	SUISNB_LEN	2.63	1.36	66.87	0.33	28.58	0.23	1.35	6.21	59.91	8.33	22.38	1.82	0.83	0.82	31.47	1.16	65.65	0.07	0.68	0.05	32.01	0.03	66.56	0.68	0.10	0.16	0.11	0.10	0.11
Sycamore Slough	SYCAMOR_MID	14.41	68.02	17.57	8.8E-17	0	3.5E-29	3.66	95.02	1.31	1.E-18	0	3.9E-33	4.79	40.41	54.81	2.9E-20	0	1.1E-32	5.24	32.04	62.72	2.6E-18	7.7E-14	1.0E-30	0.10	0.10	0.09	0.09	0.10
White Slough	WHITESL_L0	47.62	12.39	33.06	6.93	8.2E-04	2.7E-06	15.95	8.06	2.95	73.04	1.4E-05	1.5E-07	10.03	26.20	63.17	0.61	3.0E-05	8.1E-08	9.32	12.33	78.34	0.01	4.6E-04	4.6E-08	0.15	0.65	0.10	0.09	0.25
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	20.77	29.09	44.03	6.11	2.4E-04	3.6E-06	14.40	8.89	3.00	73.72	7.9E-06	0	9.10	26.19	64.27	0.45	3.1E-05	0	6.26	14.39	79.35	1.9E-03	6.8E-04	0	0.14	0.65	0.10	0.09	0.25

Attachment Table 5.F-3. Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2007

		First Quarter Inflow Percentage						Second Quarter Inflow Percentage						Third Quarter Inflow Percentage						Fourth Quarter Inflow Percentage						Estimated Waterborne Selenium Concentrations (µg/L)				
	Inflow Source →	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**					
	Inflow Location →	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***					
	Selenium (µg/L) →	0.11	0.10	0.09	0.58	0.10	0.23	0.11	0.10	0.09	0.58	0.10	0.23	0.11	0.10	0.09	0.58	0.10	0.23	0.11	0.10	0.09	0.58	0.10	0.23	**1st Quarter**	**2nd Quarter**	**3rd Quarter**	**4th Quarter**	**Annual**
DSM2 Output Water Location	**Location ID**																													
Big Break	BIGBRK_MID	2.66	1.75	93.01	0.07	2.30	0.21	4.40	3.10	84.13	4.24	1.24	2.89	3.58	0.32	81.60	0.79	9.45	4.27	2.60	0.11	84.06	0.04	8.53	4.65	0.09	0.12	0.10	0.10	0.10
Cache Slough	CACHS_LEN	1.86	1.4E-05	97.14	2.2E-07	2.8E-05	1.01	1.99	5.1E-04	88.84	8.8E-04	1.6E-05	9.17	1.92	9.1E-06	89.20	1.9E-05	1.6E-06	8.88	1.64	1.9E-05	91.73	8.5E-06	5.1E-04	6.62	0.09	0.10	0.10	0.10	0.10
Cache Slough Ryer	CACHSR_MID	2.85	1.8E-06	96.46	4.7E-08	1.5E-05	0.68	2.66	1.2E-04	88.76	1.8E-04	1.4E-06	8.58	2.16	1.5E-05	88.35	3.1E-05	3.1E-07	9.49	1.96	4.5E-06	90.83	2.8E-06	1.9E-04	7.21	0.09	0.10	0.10	0.10	0.10
Cosumnes R.	COSR_LEN	0.00	100.00	0	0	0	0.00	0.01	99.99	0	0	0	0	0.09	99.91	0	0	0	0	0	100.00	0	0	0	0.00	0.10	0.10	0.10	0.10	0.10
Franks Tract	FRANKST_MID	3.85	4.08	90.69	0.32	0.94	0.11	6.16	5.35	77.86	9.10	0.16	1.38	4.86	0.34	88.03	0.84	2.96	2.98	3.19	0.32	91.15	0.17	2.23	2.95	0.09	0.14	0.10	0.10	0.11
Little Holland Tract	LHOLND_L0	29.80	0.00	69.38	1.2E-07	5.3E-05	0.81	22.80	8.0E-05	71.18	1.1E-04	5.2E-06	6.02	18.52	2.4E-05	73.18	0.00	4.9E-07	8.30	21.64	5.2E-07	71.72	1.4E-06	4.9E-05	6.64	0.10	0.10	0.11	0.10	0.10
Middle R Bullfrog	MIDRBULFRG_LEN	8.32	10.69	59.08	21.39	0.48	0.04	9.69	10.67	38.75	40.64	0.03	0.22	8.41	3.92	81.16	4.51	0.87	1.14	5.81	4.90	72.42	15.36	0.57	0.94	0.20	0.29	0.12	0.17	0.19
Mildred Island	MILDDRISL_MID	7.42	11.13	68.24	12.63	0.54	0.04	8.53	10.39	42.57	38.23	0.03	0.25	6.49	1.12	88.25	1.83	1.00	1.30	4.91	4.55	80.81	7.99	0.66	1.08	0.15	0.28	0.10	0.13	0.17
Mok. R. below Cosum.	MOKBCOS_LEN	1.46	98.54	0	0	0	0	6.32	93.68	6.5E-04	0	0	0	15.09	84.81	0.10	6.2E-35	0	0	2.30	97.70	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Mok. R. downstream Cosum.	MOKDCOS_MID	1.46	98.54	0	0	0	0	6.42	93.58	0	0	0	0	15.19	84.81	3.2E-04	0	0	0	2.27	97.73	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Old R near Paradise Cut	OLDRNPARADSEC_MID	3.95	5E-12	3E-06	96.05	1.7E-16	2.5E-17	15.73	1.81	12.66	69.68	0.02	0.10	10.18	1.9E-05	1.6E-04	89.82	6.9E-08	6.5E-07	2.31	9.2E-04	0.01	97.68	0	9.7E-05	0.56	0.43	0.53	0.57	0.52
Paradise Cut	PARADSECUT_LEN	1.91	0	0	98.09	0	0	4.98	0.11	0.61	94.29	6.7E-04	3.7E-03	7.14	0	0	92.86	0	0	1.24	4.1E-03	0.05	98.71	4.1E-04	4.5E-04	0.57	0.55	0.55	0.57	0.56
Port of Stockton	PORTOSTOCK_L0	1.48	0	0	98.52	0	0	2.29	0	0	97.71	0	0	6.32	0.04	0	93.64	0	0	7.16	0.05	0	92.78	0	0	0.57	0.57	0.55	0.55	0.56
Sac. R. at Isleton	SACRISLTON_L0	0.45	0	99.55	0	0	2.1E-06	0.63	8.8E-05	99.36	5.7E-08	0	0.01	0.49	0	99.51	0	0	2.9E-04	0.39	1.0E-08	99.61	0	6.7E-07	0.01	0.09	0.09	0.09	0.09	0.09
Sac River RM 44	SACR44_L0	0.20	0	99.80	0	0	0	0.30	0	99.70	0	0	0	0.15	0	99.85	0	0	0	0.11	0	99.89	0	0	0	0.09	0.09	0.09	0.09	0.09
Sandmound Sl.	SANDMND_MID	4.47	3.23	90.83	0.17	1.17	0.13	7.20	4.64	79.23	6.98	0.23	1.71	6.15	0.39	84.96	0.98	4.06	3.46	3.79	0.22	89.26	0.10	3.11	3.51	0.09	0.13	0.10	0.10	0.10
Sherman Island	SHERMNILND_L0	2.14	0.95	92.16	0.04	4.49	0.23	3.69	2.31	83.94	2.94	4.01	3.11	2.99	0.32	77.36	0.77	14.22	4.34	2.22	0.06	75.89	0.03	17.11	4.68	0.09	0.11	0.10	0.10	0.10
SJR Bowman	SJRBOWMN_MID	0.88	0	0	99.12	0	0	3.52	0	0	96.48	0	0	8.49	2.5E-04	0	91.51	0	0	0.91	0	0	99.09	0	0	0.58	0.56	0.54	0.58	0.56
SJR N Hwy4	SJRNHWY4_MID	1.82	2.8E-08	0	98.18	0	0	4.35	1.4E-07	0	95.65	0	0	12.54	0.08	4.0E-26	87.39	0	0	1.89	1.3E-04	0	98.11	0	0	0.57	0.56	0.52	0.57	0.56
SJR Naval st	SJRNAVLST_L0	4.83	6.83	0	88.35	0	0	5.86	11.12	1.3E-06	83.02	0	0	12.06	40.15	3.4E-03	47.78	6.2E-07	6.3E-06	4.73	6.37	2.5E-04	88.90	5.4E-09	7.0E-09	0.52	0.50	0.33	0.53	0.47
SJR Potato Slough	SJRPOTSL_MID	2.91	5.22	91.00	0.15	0.61	0.10	4.89	5.67	79.70	8.49	0.10	1.16	3.16	0.19	91.86	0.46	1.88	2.44	2.37	0.33	93.43	0.10	1.44	2.33	0.09	0.13	0.10	0.09	0.10
SJR Turner	SJRTURNR_MID	7.22	10.11	10.82	71.76	0.08	0.01	7.49	11.95	7.23	73.31	2.9E-03	0.02	11.09	11.29	65.50	11.02	0.46	0.63	6.16	6.57	36.18	50.55	0.19	0.35	0.44	0.45	0.15	0.34	0.35
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	2.17	1.01	92.90	0.04	3.62	0.26	3.74	2.30	84.37	3.04	3.24	3.31	3.00	0.27	79.62	0.65	12.05	4.40	2.27	0.07	78.73	0.03	14.08	4.82	0.09	0.11	0.10	0.10	0.10
Suisun Bay	SUISNB_LEN	0.87	0.23	46.77	0.01	51.97	0.14	0.94	0.51	31.58	0.43	65.55	0.98	0.84	0.16	21.30	0.36	76.08	1.25	0.59	0.02	21.39	0.01	76.63	1.36	0.10	0.10	0.10	0.10	0.10
Sycamore Slough	SYCAMOR_MID	10.20	72.58	17.22	5.1E-10	9.7E-14	4.3E-29	13.62	50.90	35.47	0.01	4.0E-09	1.1E-07	5.33	3.90	90.77	1.9E-16	3.8E-25	1.1E-22	3.69	20.36	75.95	6.0E-19	1.1E-37	2.4E-31	0.10	0.10	0.09	0.09	0.10
White Slough	WHITESL_L0	20.35	16.73	61.67	1.25	4.8E-03	2.4E-04	33.31	13.41	23.49	29.78	3.9E-04	3.2E-03	15.53	1.33	83.05	0.09	1.2E-03	2.0E-03	9.35	8.62	81.98	0.04	3.7E-04	7.1E-04	0.10	0.24	0.09	0.09	0.13
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	10.09	24.12	65.07	0.71	4.1E-03	1.9E-04	17.00	13.60	32.29	37.10	1.4E-03	0.01	7.70	1.46	90.83	1.5E-03	1.3E-03	2.2E-03	5.21	9.69	85.06	0.03	9.7E-04	2.1E-03	0.10	0.28	0.09	0.09	0.14

Attachment Table 5.F-4. Selenium Bioaccumulation from Water (µg/L) to Particulates and Fish (µg/g, dw) Using Models 1 and 2

	Year 2000								Year 2005								Year 2007							
	Concentration					Whole-body	Fish-to-Bass Ratio		Concentration					Whole-body	Fish-to-Bass Ratio		Concentration					Whole-body	Fish-to-Bass Ratio	
DSM2 Delta Water Location	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish	Bass[a]	Model 1	Model 2	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish	Bass[a]	Model 1	Model 2	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish	Bass[a]	Model 1	Model 2
	First Quarter								**First Quarter**								**First Quarter**							
Sacramento River RM 44	0.09	0.09	0.25	0.27	0.30	2.6	0.10	0.11	0.09	0.09	0.25	0.28	0.31	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.31	1.8	0.15	0.17
Cache Slough Ryer[b]	0.10	0.10	0.28	0.31	0.34	1.5	0.21	0.23	0.09	0.09	0.26	0.29	0.31	1.7	0.17	0.18	0.09	0.09	0.26	0.28	0.31	2.5	0.11	0.12
San Joaquin River Potato Slough	0.17	0.17	0.47	0.52	0.57	1.4	0.38	0.42	0.14	0.14	0.40	0.44	0.48	1.3	0.33	0.37	0.09	0.09	0.26	0.28	0.31	2.5	0.11	0.13
Franks Tract	0.19	0.19	0.53	0.58	0.64	1.6	0.35	0.39	0.15	0.15	0.41	0.45	0.49	1.1	0.39	0.43	0.09	0.09	0.26	0.29	0.32	3.0	0.10	0.11
Big Break	0.13	0.13	0.35	0.39	0.43	1.6	0.25	0.28	0.11	0.11	0.31	0.34	0.37	1.0	0.33	0.37	0.09	0.09	0.26	0.28	0.31	2.8	0.10	0.11
Middle River Bullfrog	0.31	0.31	0.86	0.95	1.05	NA	NA	NA	0.46	0.46	1.29	1.42	1.56	1.9	0.7	0.8	0.20	0.20	0.55	0.61	0.67	2.1	0.3	0.3
Old River near Paradise Cut[c]	0.73	0.73	2.05	2.25	2.48	NA	NA	NA	0.78	0.78	2.19	2.41	2.66	2.4	1.0	1.1	0.56	0.56	1.57	1.73	1.90	NA	NA	NA
Knights Landing[d]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis[e]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82
	Second Quarter								**Second Quarter**								**Second Quarter**							
Sacramento River RM 44	0.09	0.09	0.25	0.28	0.30	2.6	0.11	0.12	0.09	0.09	0.25	0.28	0.30	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.31	1.8	0.15	0.17
Cache Slough Ryer[b]	0.11	0.11	0.32	0.35	0.38	1.5	0.23	0.26	0.10	0.10	0.27	0.30	0.33	1.7	0.17	0.19	0.10	0.10	0.29	0.32	0.35	2.5	0.12	0.14
San Joaquin River Potato Slough	0.24	0.24	0.67	0.74	0.81	1.4	0.54	0.60	0.36	0.36	1.02	1.12	1.23	1.3	0.86	0.94	0.13	0.13	0.38	0.42	0.46	2.5	0.17	0.18
Franks Tract	0.27	0.27	0.76	0.83	0.92	1.6	0.51	0.56	0.49	0.49	1.36	1.50	1.65	1.1	1.31	1.44	0.14	0.14	0.39	0.43	0.47	3.0	0.14	0.16
Big Break	0.20	0.20	0.55	0.60	0.66	1.6	0.39	0.43	0.30	0.30	0.83	0.91	1.00	1.0	0.89	0.98	0.12	0.12	0.33	0.36	0.39	2.8	0.13	0.14
Middle River Bullfrog	0.61	0.61	1.71	1.88	2.07	NA	NA	NA	0.75	0.75	2.09	2.30	2.53	1.9	1.2	1.3	0.29	0.29	0.82	0.90	0.99	2.1	0.4	0.5
Old River near Paradise Cut[c]	0.68	0.68	1.89	2.08	2.29	NA	NA	NA	0.84	0.84	2.35	2.59	2.84	2.4	1.1	1.2	0.43	0.43	1.22	1.34	1.47	NA	NA	NA
Knights Landing[d]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis[e]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82
	Third Quarter								**Third Quarter**								**Third Quarter**							
Sacramento River RM 44	0.09	0.09	0.25	0.28	0.30	2.6	0.11	0.12	0.09	0.09	0.25	0.28	0.31	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.31	1.8	0.15	0.17
Cache Slough Ryer[b]	0.11	0.11	0.31	0.34	0.37	1.5	0.22	0.25	0.09	0.09	0.25	0.28	0.31	1.7	0.16	0.18	0.10	0.10	0.29	0.32	0.35	2.5	0.13	0.14
San Joaquin River Potato Slough	0.10	0.10	0.27	0.30	0.32	1.4	0.22	0.24	0.10	0.10	0.27	0.30	0.33	1.3	0.23	0.25	0.10	0.10	0.27	0.30	0.33	2.5	0.12	0.13
Franks Tract	0.10	0.10	0.28	0.31	0.34	1.6	0.19	0.20	0.11	0.11	0.29	0.32	0.36	1.1	0.28	0.31	0.10	0.10	0.28	0.31	0.34	3.0	0.10	0.11
Big Break	0.10	0.10	0.29	0.32	0.35	1.6	0.20	0.22	0.10	0.10	0.29	0.32	0.35	1.0	0.31	0.35	0.10	0.10	0.28	0.31	0.34	2.8	0.11	0.12
Middle River Bullfrog	0.20	0.20	0.57	0.63	0.69	NA	NA	NA	0.30	0.30	0.83	0.91	1.01	1.9	0.5	0.5	0.12	0.12	0.32	0.36	0.39	2.1	0.2	0.2
Old River near Paradise Cut[c]	0.75	0.75	2.11	2.32	2.55	NA	NA	NA	0.80	0.80	2.24	2.47	2.71	2.4	1.0	1.1	0.53	0.53	1.49	1.64	1.80	NA	NA	NA
Knights Landing[d]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis[e]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82
	Fourth Quarter								**Fourth Quarter**								**Fourth Quarter**							
Sacramento River RM 44	0.09	0.09	0.25	0.28	0.30	2.6	0.11	0.12	0.09	0.09	0.25	0.28	0.31	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.30	1.8	0.15	0.17
Cache Slough Ryer[b]	0.10	0.10	0.29	0.31	0.35	1.5	0.21	0.23	0.09	0.09	0.26	0.28	0.31	1.7	0.16	0.18	0.10	0.10	0.28	0.31	0.34	2.5	0.12	0.13
San Joaquin River Potato Slough	0.09	0.09	0.26	0.29	0.32	1.4	0.21	0.23	0.09	0.09	0.25	0.28	0.31	1.3	0.21	0.24	0.09	0.09	0.26	0.29	0.32	2.5	0.12	0.13
Franks Tract	0.10	0.10	0.27	0.29	0.32	1.6	0.18	0.20	0.09	0.09	0.26	0.28	0.31	1.1	0.25	0.27	0.10	0.10	0.27	0.30	0.32	3.0	0.10	0.11
Big Break	0.10	0.10	0.27	0.30	0.33	1.6	0.19	0.21	0.09	0.09	0.26	0.28	0.31	1.0	0.28	0.31	0.10	0.10	0.27	0.30	0.33	2.8	0.11	0.12
Middle River Bullfrog	0.30	0.30	0.84	0.92	1.01	NA	NA	NA	0.24	0.24	0.68	0.74	0.82	1.9	0.4	0.4	0.17	0.17	0.47	0.52	0.57	2.1	0.2	0.3
Old River near Paradise Cut[c]	0.81	0.81	2.27	2.50	2.75	NA	NA	NA	0.72	0.72	2.01	2.21	2.43	2.4	0.9	1.0	0.57	0.57	1.59	1.75	1.93	NA	NA	NA

Attachment Table 5.F-4. Selenium Bioaccumulation from Water (µg/L) to Particulates and Fish (µg/g, dw) Using Models 1 and 2

	Year 2000								Year 2005								Year 2007							
	Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio		Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio		Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio	
DSM2 Delta Water Location	**DSM2 Water**	**Particulate from Water**	**Invert. from Particulate**	**Model 1 Fish**	**Model 2 Fish**		**Model 1**	**Model 2**	**DSM2 Water**	**Particulate from Water**	**Invert. from Particulate**	**Model 1 Fish**	**Model 2 Fish**		**Model 1**	**Model 2**	**DSM2 Water**	**Particulate from Water**	**Invert. from Particulate**	**Model 1 Fish**	**Model 2 Fish**		**Model 1**	**Model 2**
Knights Landing[d]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis[e]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82

Notes:

Equations from Presser and Luoma (2010a, 2010b) were used to calculate selenium concentrations for fish. Models 1 and 2 used the default K_d (1000) and the average selenium trophic transfer factors to aquatic insects (2.8) and fish (1.1 for all trophic levels).

Model 1 = TL-3 Fish Eating Invertebrates

Model 2 = TL-4 Fish Eating TL-3 Fish

Invert. = invertebrate

K_d = particulate concentration/water concentration ratio

µg/g, dw = micrograms per gram, dry weight

NA = not available; bass not collected here

RM = river mile

TL = trophic level

[a] Geometric mean calculated from whole-body largemouth bass data presented in Foe (2010).

[b] Fish data collected at Rio Vista (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[c] Fish data collected at Old River near Tracy (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[d] Geometric mean of total selenium concentrations in water collected from years 2004, 2007, and 2008 (DWR Website 2009) was used to estimate selenium concentrations in particulates and biota (DSM2 data were not available). Fish data collected from Sacramento River at Veterans Bridge (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[e] Geometric mean of selenium concentrations (total or dissolved was not specified) in water collected from years 1999–2000 (SWAMP Website 2009) was used to estimate Year 2000 selenium concentrations in particulates and biota (DSM2 data were not available); years 2004-2005 were used for Year 2005 estimates; and years 2006-2007 were used for Year 2007 estimates.

Attachment Table 5.F-5. Selenium Bioaccumulation from Water (µg/L) to Particulates and Fish (µg/g, dw) Using Model 2 with Estimated Kd from All Years Regression for Model 3

Year 2000

DSM2 Delta Water Location	Concentration: DSM2 Water	Concentration: Particulate from Water	Concentration: Invert. from Particulate	Concentration: Model 3 Fish	K_d	Whole-body Bass[a]	Fish-to-Bass Ratio: Model 3
First Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	6091	2.6	0.69
Cache Slough Ryer[b]	0.10	0.54	1.50	1.82	5390	1.5	1.22
San Joaquin River Potato Slough	0.17	0.53	1.50	1.81	3162	1.4	1.33
Franks Tract	0.19	0.53	1.49	1.81	2832	1.6	1.10
Big Break	0.13	0.54	1.50	1.82	4255	1.6	1.17
Middle River Bullfrog	0.31	0.53	1.49	1.80	1721	NA	NA
Old River near Paradise Cut[c]	0.73	0.53	1.47	1.78	720	NA	NA
Knights Landing[d]	0.23	0.53	1.49	1.80	2316	NA	NA
Vernalis[e]	0.83	0.53	1.47	1.78	633	1.2	1.48
Second Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	5977	2.6	0.69
Cache Slough Ryer[b]	0.11	0.54	1.50	1.82	4754	1.5	1.22
San Joaquin River Potato Slough	0.24	0.53	1.49	1.80	2230	1.4	1.33
Franks Tract	0.27	0.53	1.49	1.80	1968	1.6	1.09
Big Break	0.20	0.53	1.49	1.81	2726	1.6	1.17
Middle River Bullfrog	0.61	0.53	1.48	1.79	863	NA	NA
Old River near Paradise Cut[c]	0.68	0.53	1.48	1.79	780	NA	NA
Knights Landing[d]	0.23	0.53	1.49	1.80	2316	NA	NA
Vernalis[e]	0.83	0.53	1.47	1.78	633	1.2	1.48
Third Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	5972	2.6	0.69
Cache Slough Ryer[b]	0.11	0.54	1.50	1.82	4925	1.5	1.22
San Joaquin River Potato Slough	0.10	0.54	1.50	1.82	5601	1.4	1.34
Franks Tract	0.10	0.54	1.50	1.82	5413	1.6	1.11
Big Break	0.10	0.54	1.50	1.82	5222	1.6	1.17
Middle River Bullfrog	0.20	0.53	1.49	1.81	2612	NA	NA
Old River near Paradise Cut[c]	0.75	0.53	1.47	1.78	698	NA	NA
Knights Landing[d]	0.23	0.53	1.49	1.80	2316	NA	NA
Vernalis[e]	0.83	0.53	1.47	1.78	633	1.2	1.48
Fourth Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	5973	2.6	0.69
Cache Slough Ryer[b]	0.10	0.54	1.50	1.82	5257	1.5	1.22
San Joaquin River Potato Slough	0.09	0.54	1.50	1.82	5718	1.4	1.34
Franks Tract	0.10	0.54	1.50	1.82	5631	1.6	1.11
Big Break	0.10	0.54	1.50	1.82	5541	1.6	1.17
Middle River Bullfrog	0.30	0.53	1.49	1.80	1779	NA	NA
Old River near Paradise Cut[c]	0.81	0.53	1.47	1.78	648	NA	NA

Year 2005

DSM2 Delta Water Location	Concentration: DSM2 Water	Concentration: Particulate from Water	Concentration: Invert. from Particulate	Concentration: Model 3 Fish	K_d	Whole-body Bass[a]	Fish-to-Bass Ratio: Model 3
First Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	5970	1.5	1.25
Cache Slough Ryer[b]	0.09	0.54	1.50	1.82	5801	1.7	1.05
San Joaquin River Potato Slough	0.14	0.54	1.50	1.81	3771	1.3	1.39
Franks Tract	0.15	0.54	1.50	1.81	3669	1.1	1.58
Big Break	0.11	0.54	1.50	1.82	4854	1.0	1.78
Middle River Bullfrog	0.46	0.53	1.48	1.79	1149	1.9	0.9
Old River near Paradise Cut[c]	0.78	0.53	1.47	1.78	671	2.4	0.7
Knights Landing[d]	0.23	0.53	1.49	1.80	2316	2.2	0.8
Vernalis[e]	0.85	0.53	1.47	1.78	618	1.9	0.94
Second Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	5972	1.5	1.25
Cache Slough Ryer[b]	0.10	0.54	1.50	1.82	5545	1.7	1.05
San Joaquin River Potato Slough	0.36	0.53	1.48	1.80	1459	1.3	1.37
Franks Tract	0.49	0.53	1.48	1.79	1088	1.1	1.56
Big Break	0.30	0.53	1.49	1.80	1796	1.0	1.76
Middle River Bullfrog	0.75	0.53	1.47	1.78	705	1.9	0.9
Old River near Paradise Cut[c]	0.84	0.53	1.47	1.78	626	2.4	0.7
Knights Landing[d]	0.23	0.53	1.49	1.80	2316	2.2	0.8
Vernalis[e]	0.85	0.53	1.47	1.78	618	1.9	0.94
Third Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	5971	1.5	1.25
Cache Slough Ryer[b]	0.09	0.54	1.51	1.82	5938	1.7	1.05
San Joaquin River Potato Slough	0.10	0.54	1.50	1.82	5529	1.3	1.39
Franks Tract	0.11	0.54	1.50	1.82	5111	1.1	1.59
Big Break	0.10	0.54	1.50	1.82	5151	1.0	1.78
Middle River Bullfrog	0.30	0.53	1.49	1.80	1788	1.9	0.9
Old River near Paradise Cut[c]	0.80	0.53	1.47	1.78	657	2.4	0.7
Knights Landing[d]	0.23	0.53	1.49	1.80	2316	2.2	0.8
Vernalis[e]	0.85	0.53	1.47	1.78	618	1.9	0.94
Fourth Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	5971	1.5	1.25
Cache Slough Ryer[b]	0.09	0.54	1.50	1.82	5850	1.7	1.05
San Joaquin River Potato Slough	0.09	0.54	1.51	1.82	5907	1.3	1.39
Franks Tract	0.09	0.54	1.51	1.82	5880	1.1	1.59
Big Break	0.09	0.54	1.50	1.82	5828	1.0	1.79
Middle River Bullfrog	0.24	0.53	1.49	1.80	2204	1.9	0.9
Old River near Paradise Cut[c]	0.72	0.53	1.47	1.78	735	2.4	0.7

Year 2007

DSM2 Delta Water Location	Concentration: DSM2 Water	Concentration: Particulate from Water	Concentration: Invert. from Particulate	Concentration: Model 3 Fish	K_d	Whole-body Bass[a]	Fish-to-Bass Ratio: Model 3
First Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	5971	1.8	0.99
Cache Slough Ryer[b]	0.09	0.54	1.51	1.82	5873	2.5	0.72
San Joaquin River Potato Slough	0.09	0.54	1.50	1.82	5839	2.5	0.73
Franks Tract	0.09	0.54	1.50	1.82	5779	3.0	0.61
Big Break	0.09	0.54	1.51	1.82	5871	2.8	0.64
Middle River Bullfrog	0.20	0.53	1.49	1.81	2699	2.1	0.85
Old River near Paradise Cut[c]	0.56	0.53	1.48	1.79	940	NA	NA
Knights Landing[d]	0.23	0.53	1.49	1.80	2316	NA	NA
Vernalis[e]	0.58	0.53	1.48	1.79	910	2.4	0.74
Second Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	5969	1.8	0.99
Cache Slough Ryer[b]	0.10	0.54	1.50	1.82	5236	2.5	0.71
San Joaquin River Potato Slough	0.13	0.54	1.50	1.81	3973	2.5	0.73
Franks Tract	0.14	0.54	1.50	1.81	3871	3.0	0.61
Big Break	0.12	0.54	1.50	1.82	4618	2.8	0.64
Middle River Bullfrog	0.29	0.53	1.49	1.80	1817	2.1	0.8
Old River near Paradise Cut[c]	0.43	0.53	1.48	1.79	1217	NA	NA
Knights Landing[d]	0.23	0.53	1.49	1.80	2316	NA	NA
Vernalis[e]	0.58	0.53	1.48	1.79	910	2.4	0.74
Third Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	5971	1.8	0.99
Cache Slough Ryer[b]	0.10	0.54	1.50	1.82	5176	2.5	0.71
San Joaquin River Potato Slough	0.10	0.54	1.50	1.82	5565	2.5	0.73
Franks Tract	0.10	0.54	1.50	1.82	5394	3.0	0.61
Big Break	0.10	0.54	1.50	1.82	5287	2.8	0.64
Middle River Bullfrog	0.12	0.54	1.50	1.82	4629	2.1	0.85
Old River near Paradise Cut[c]	0.53	0.53	1.48	1.79	992	NA	NA
Knights Landing[d]	0.23	0.53	1.49	1.80	2316	NA	NA
Vernalis[e]	0.58	0.53	1.48	1.79	910	2.4	0.74
Fourth Quarter							
Sacramento River RM 44	0.09	0.54	1.51	1.82	5972	1.8	0.99
Cache Slough Ryer[b]	0.10	0.54	1.50	1.82	5344	2.5	0.71
San Joaquin River Potato Slough	0.09	0.54	1.50	1.82	5692	2.5	0.73
Franks Tract	0.10	0.54	1.50	1.82	5605	3.0	0.61
Big Break	0.10	0.54	1.50	1.82	5475	2.8	0.64
Middle River Bullfrog	0.17	0.53	1.50	1.81	3175	2.1	0.85
Old River near Paradise Cut[c]	0.57	0.53	1.48	1.79	927	NA	NA

Attachment Table 5.F-5. Selenium Bioaccumulation from Water (µg/L) to Particulates and Fish (µg/g, dw) Using Model 2 with Estimated Kd from All Years Regression for Model 3

	Year 2000							Year 2005							Year 2007						
	Concentration						Fish-to-Bass Ratio	Concentration						Fish-to-Bass Ratio	Concentration						Fish-to-Bass Ratio
DSM2 Delta Water Location	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 3 Fish	K_d	Whole-body Bass[a]	Model 3	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 3 Fish	K_d	Whole-body Bass[a]	Model 3	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 3 Fish	K_d	Whole-body Bass[a]	Model 3
Knights Landing[d]	0.23	0.53	1.49	1.80	2316	NA	NA	0.23	0.53	1.49	1.80	2316	2.2	0.8	0.23	0.53	1.49	1.80	2316	NA	NA
Vernalis[e]	0.83	0.53	1.47	1.78	633	1.2	1.48	0.85	0.53	1.47	1.78	618	1.9	0.94	0.58	0.53	1.48	1.79	910	2.4	0.74

Notes:

Equations from Presser and Luoma (2010a, 2010b) were used to calculate selenium concentrations for fish. Model 3 used the average selenium trophic transfer factors to aquatic insects (2.8) and fish (1.1 for all trophic levels).

Model 3 = Model 2 (TL-4 Fish Eating TL-3 Fish) with K_d estimated using all years regression (log K_d = 2.72-1.01(logDSM2))

Invert. = invertebrate

K_d = particulate concentration/water concentration ratio

µg/g, dw = micrograms per gram, dry weight

NA = not available; bass not collected here

RM = river mile

TL = trophic level

[a] Geometric mean calculated from whole-body largemouth bass data presented in Foe (2010).

[b] Fish data collected at Rio Vista (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[c] Fish data collected at Old River near Tracy (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[d] Geometric mean of total selenium concentrations in water collected from years 2004, 2007, and 2008 (DWR Website 2009) was used to estimate selenium concentrations in particulates and biota (DSM2 data were not available). Fish data collected from Sacramento River at Veterans Bridge (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[e] Geometric mean of selenium concentrations (total or dissolved was not specified) in water collected from years 1999–2000 (SWAMP Website 2009) was used to estimate Year 2000 selenium concentrations in particulates and biota (DSM2 data were not available); years 2004-2005 were used for Year 2005 estimates; and years 2006-2007 were used for Year 2007 estimates.

Attachment Table 5.F-6. Selenium Bioaccumulation from Water (µg/L) to Particulates and Fish (µg/g, dw) Using Model 2 with Estimated Kd from Normal/Wet Years Regression for Model 4 and Dry Years Regression for Model 5

	Year 2000							Year 2005							Year 2007						
	Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio	Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio	Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio
DSM2 Delta Water Location	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish	K_d		Model 4	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish	K_d		Model 4	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 5 Fish	K_d		Model 5
	First Quarter							**First Quarter**							**First Quarter**						
Sacramento River RM 44	0.09	0.45	1.27	1.54	5145	2.6	0.58	0.09	0.45	1.27	1.54	5050	1.5	1.06	0.09	0.73	2.03	2.46	8063	1.8	1.33
Cache Slough Ryer[b]	0.10	0.46	1.28	1.55	4586	1.5	1.04	0.09	0.46	1.27	1.54	4915	1.7	0.89	0.09	0.73	2.03	2.46	7929	2.5	0.97
San Joaquin River Potato Slough	0.17	0.47	1.31	1.59	2777	1.4	1.17	0.14	0.47	1.30	1.58	3278	1.3	1.20	0.09	0.73	2.03	2.46	7883	2.5	0.99
Franks Tract	0.19	0.47	1.32	1.60	2504	1.6	0.97	0.15	0.47	1.30	1.58	3194	1.1	1.38	0.09	0.73	2.03	2.46	7802	3.0	0.82
Big Break	0.13	0.46	1.29	1.57	3672	1.6	1.01	0.11	0.46	1.29	1.56	4156	1.0	1.53	0.09	0.73	2.03	2.46	7926	2.8	0.87
Middle River Bullfrog	0.31	0.48	1.35	1.64	1568	NA	NA	0.46	0.49	1.38	1.67	1072	1.9	0.9	0.20	0.71	2.00	2.42	3616	2.1	1.14
Old River near Paradise Cut[c]	0.73	0.50	1.41	1.71	691	NA	NA	0.78	0.51	1.42	1.72	646	2.4	0.7	0.56	0.70	1.96	2.37	1247	NA	NA
Knights Landing[d]	0.23	0.48	1.33	1.61	2072	NA	NA	0.23	0.48	1.33	1.61	2072	2.2	0.7	0.23	0.71	1.99	2.41	3098	NA	NA
Vernalis[e]	0.83	0.51	1.42	1.72	612	1.2	1.43	0.85	0.51	1.42	1.72	598	1.9	0.91	0.58	0.70	1.96	2.37	1206	2.4	0.99
	Second Quarter							**Second Quarter**							**Second Quarter**						
Sacramento River RM 44	0.09	0.45	1.27	1.54	5055	2.6	0.58	0.09	0.45	1.27	1.54	5051	1.5	1.06	0.09	0.73	2.03	2.46	8061	1.8	1.33
Cache Slough Ryer[b]	0.11	0.46	1.29	1.56	4076	1.5	1.04	0.10	0.46	1.28	1.55	4711	1.7	0.89	0.10	0.72	2.03	2.45	7061	2.5	0.96
San Joaquin River Potato Slough	0.24	0.48	1.34	1.62	1999	1.4	1.19	0.36	0.49	1.37	1.65	1342	1.3	1.26	0.13	0.72	2.02	2.44	5343	2.5	0.98
Franks Tract	0.27	0.48	1.35	1.63	1778	1.6	0.99	0.49	0.49	1.39	1.68	1018	1.1	1.46	0.14	0.72	2.02	2.44	5204	3.0	0.82
Big Break	0.20	0.47	1.32	1.60	2415	1.6	1.03	0.30	0.48	1.35	1.63	1632	1.0	1.60	0.12	0.72	2.02	2.45	6220	2.8	0.86
Middle River Bullfrog	0.61	0.50	1.40	1.70	819	NA	NA	0.75	0.51	1.42	1.71	677	1.9	0.9	0.29	0.71	1.99	2.40	2424	2.1	1.1
Old River near Paradise Cut[c]	0.68	0.50	1.41	1.70	745	NA	NA	0.84	0.51	1.42	1.72	606	2.4	0.7	0.43	0.70	1.97	2.38	1617	NA	NA
Knights Landing[d]	0.23	0.48	1.33	1.61	2072	NA	NA	0.23	0.48	1.33	1.61	2072	2.2	0.7	0.23	0.71	1.99	2.41	3098	NA	NA
Vernalis[e]	0.83	0.51	1.42	1.72	612	1.2	1.43	0.85	0.51	1.42	1.72	598	1.9	0.91	0.58	0.70	1.96	2.37	1206	2.4	0.99
	Third Quarter							**Third Quarter**							**Third Quarter**						
Sacramento River RM 44	0.09	0.45	1.27	1.54	5051	2.6	0.58	0.09	0.45	1.27	1.54	5051	1.5	1.06	0.09	0.73	2.03	2.46	8064	1.8	1.33
Cache Slough Ryer[b]	0.11	0.46	1.29	1.56	4214	1.5	1.04	0.09	0.45	1.27	1.54	5024	1.7	0.89	0.10	0.72	2.03	2.45	6980	2.5	0.96
San Joaquin River Potato Slough	0.10	0.46	1.28	1.55	4755	1.4	1.14	0.10	0.46	1.28	1.55	4698	1.3	1.18	0.10	0.72	2.03	2.46	7510	2.5	0.99
Franks Tract	0.10	0.46	1.28	1.55	4605	1.6	0.94	0.11	0.46	1.28	1.55	4363	1.1	1.36	0.10	0.72	2.03	2.45	7276	3.0	0.82
Big Break	0.10	0.46	1.28	1.55	4452	1.6	1.00	0.10	0.46	1.28	1.55	4395	1.0	1.52	0.10	0.72	2.03	2.45	7131	2.8	0.87
Middle River Bullfrog	0.20	0.47	1.33	1.60	2320	NA	NA	0.30	0.48	1.35	1.64	1625	1.9	0.9	0.12	0.72	2.02	2.45	6235	2.1	1.15
Old River near Paradise Cut[c]	0.75	0.51	1.42	1.71	671	NA	NA	0.80	0.51	1.42	1.72	633	2.4	0.7	0.53	0.70	1.96	2.37	1317	NA	NA
Knights Landing[d]	0.23	0.48	1.33	1.61	2072	NA	NA	0.23	0.48	1.33	1.61	2072	2.2	0.7	0.23	0.71	1.99	2.41	3098	NA	NA
Vernalis[e]	0.83	0.51	1.42	1.72	612	1.2	1.43	0.85	0.51	1.42	1.72	598	1.9	0.91	0.58	0.70	1.96	2.37	1206	2.4	0.99
	Fourth Quarter							**Fourth Quarter**							**Fourth Quarter**						
Sacramento River RM 44	0.09	0.45	1.27	1.54	5052	2.6	0.58	0.09	0.45	1.27	1.54	5050	1.5	1.06	0.09	0.73	2.03	2.46	8064	1.8	1.33
Cache Slough Ryer[b]	0.10	0.46	1.28	1.55	4480	1.5	1.04	0.09	0.46	1.27	1.54	4954	1.7	0.89	0.10	0.72	2.03	2.45	7209	2.5	0.96
San Joaquin River Potato Slough	0.09	0.46	1.28	1.54	4849	1.4	1.14	0.09	0.45	1.27	1.54	4999	1.3	1.18	0.09	0.73	2.03	2.46	7682	2.5	0.99
Franks Tract	0.10	0.46	1.28	1.54	4780	1.6	0.94	0.09	0.46	1.27	1.54	4978	1.1	1.35	0.10	0.73	2.03	2.46	7564	3.0	0.82
Big Break	0.10	0.46	1.28	1.55	4708	1.6	1.00	0.09	0.46	1.27	1.54	4936	1.0	1.51	0.10	0.72	2.03	2.46	7386	2.8	0.87
Middle River Bullfrog	0.30	0.48	1.35	1.64	1617	NA	NA	0.24	0.48	1.34	1.62	1978	1.9	0.8	0.17	0.72	2.01	2.43	4260	2.1	1.14
Old River near Paradise Cut[c]	0.81	0.51	1.42	1.72	625	NA	NA	0.72	0.50	1.41	1.71	704	2.4	0.7	0.57	0.70	1.96	2.37	1229	NA	NA
Knights Landing[d]	0.23	0.48	1.33	1.61	2072	NA	NA	0.23	0.48	1.33	1.61	2072	2.2	0.7	0.23	0.71	1.99	2.41	3098	NA	NA

Attachment Table 5.F-6. Selenium Bioaccumulation from Water (µg/L) to Particulates and Fish (µg/g, dw) Using Model 2 with Estimated Kd from Normal/Wet Years Regression for Model 4 and Dry Years Regression for Model 5

	Year 2000							Year 2005							Year 2007						
	Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio	Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio	Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio
DSM2 Delta Water Location	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish	K_d		Model 4	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish	K_d		Model 4	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 5 Fish	K_d		Model 5
Vernalis[e]	0.83	0.51	1.42	1.72	612	1.2	1.43	0.85	0.51	1.42	1.72	598	1.9	0.91	0.58	0.70	1.96	2.37	1206	2.4	0.99

Notes:

Equations from Presser and Luoma (2010a, 2010b) were used to calculate selenium concentrations for fish. Models 4 and 5 used the average selenium trophic transfer factors to aquatic insects (2.8) and fish (1.1 for all trophic levels).

Model 4 = Model 2 (TL-4 Fish Eating TL-3 Fish) with K_d estimated using normal/wet years regression (log K_d = 2.71-0.95(logDSM2))

Model 5 = Model 2 (TL-4 Fish Eating TL-3 Fish) with K_d estimated using dry years (2007) regression (log K_d = 2.84-1.02(logDSM2))

Invert. = invertebrate

K_d = particulate concentration/water concentration ratio

µg/g, dw = micrograms per gram, dry weight

NA = not available; bass not collected here

RM = river mile

TL = trophic level

[a] Geometric mean calculated from whole-body largemouth bass data presented in Foe (2010).

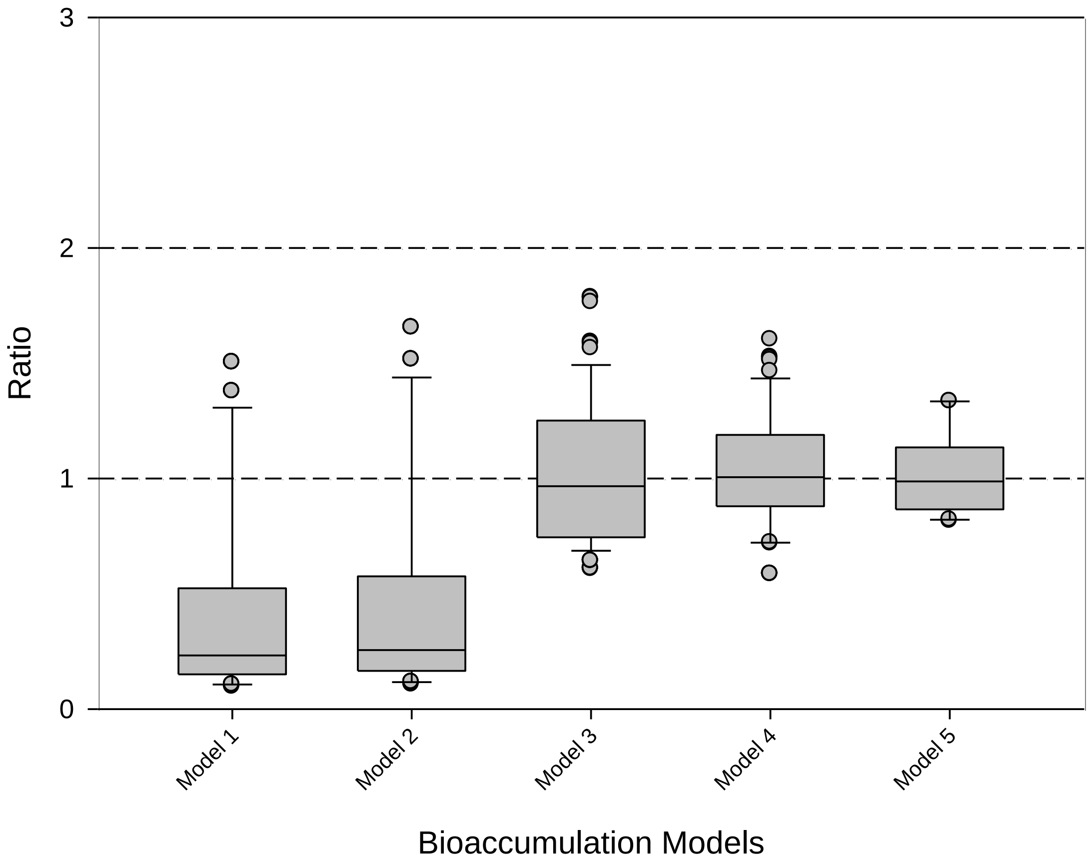
[b] Fish data collected at Rio Vista (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[c] Fish data collected at Old River near Tracy (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[d] Geometric mean of total selenium concentrations in water collected from years 2004, 2007, and 2008 (DWR Website 2009) was used to estimate selenium concentrations in particulates and biota (DSM2 data were not available). Fish data collected from Sacramento River at Veterans Bridge (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[e] Geometric mean of selenium concentrations (total or dissolved was not specified) in water collected from years 1999–2000 (SWAMP Website 2009) was used to estimate Year 2000 selenium concentrations in particulates and biota (DSM2 data were not available); years 2004-2005 were used for Year 2005 estimates; and years 2006-2007 were used for Year 2007 estimates.

Attachment Figure 5.F-1. Ratios of Predicted Selenium Concentrations in Fish Models 1 through 5 to Observed Selenium Concentrations in Largemouth Bass



For Models 1 and 2, default values (K_d = 1000, TTF_{invert} = 2.8, TTF_{fish} = 1.1) were used in calculations as follows:

Model 1=Trophic level 3 (TL-3) fish eating invertebrates

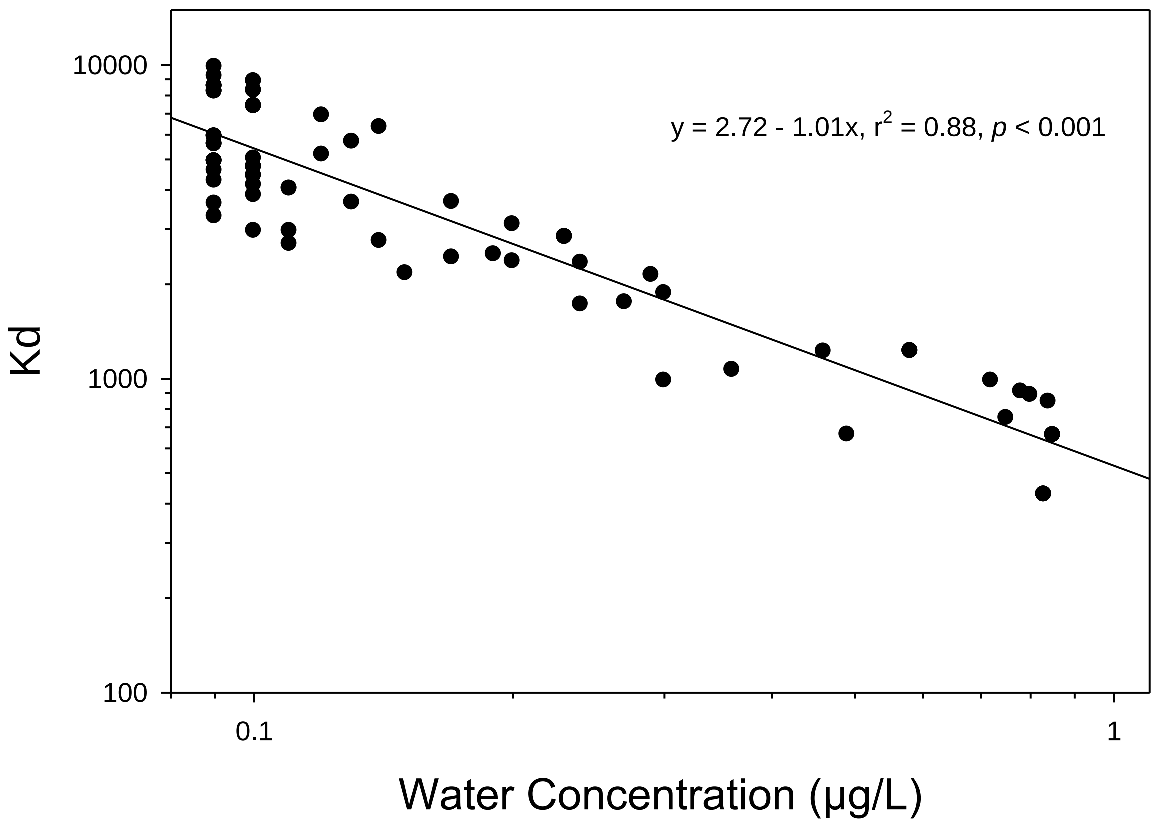
Model 2= TL-4 fish eating TL-3 fish

Model 3=Model 2 with K_d estimated using all years regression (log Kd = 2.72-1.01(logDSM2))

Model 4=Model 2 with K_d estimated using normal/wet years (2000/2005) regression (log Kd = 2.71-0.95(logDSM2))

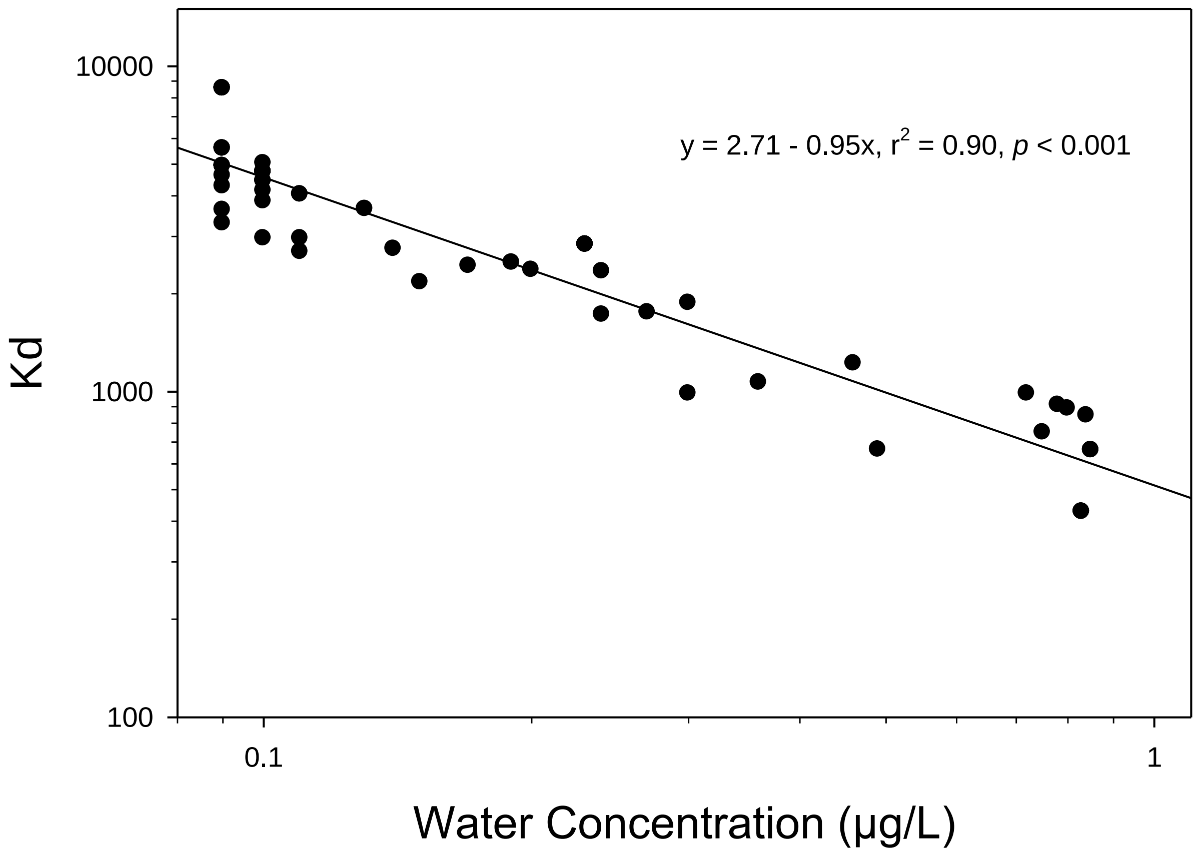
Model 5=Model 2 with K_d estimated using dry years (2007) regression (logKd = 2.84-1.02(logDSM2))

Attachment Figure 5.F-2. Log-log Regression Relation of Estimated K_d to Waterborne Selenium Concentration for Model 3 in All Years (Based on Years 2000, 2005, and 2007)



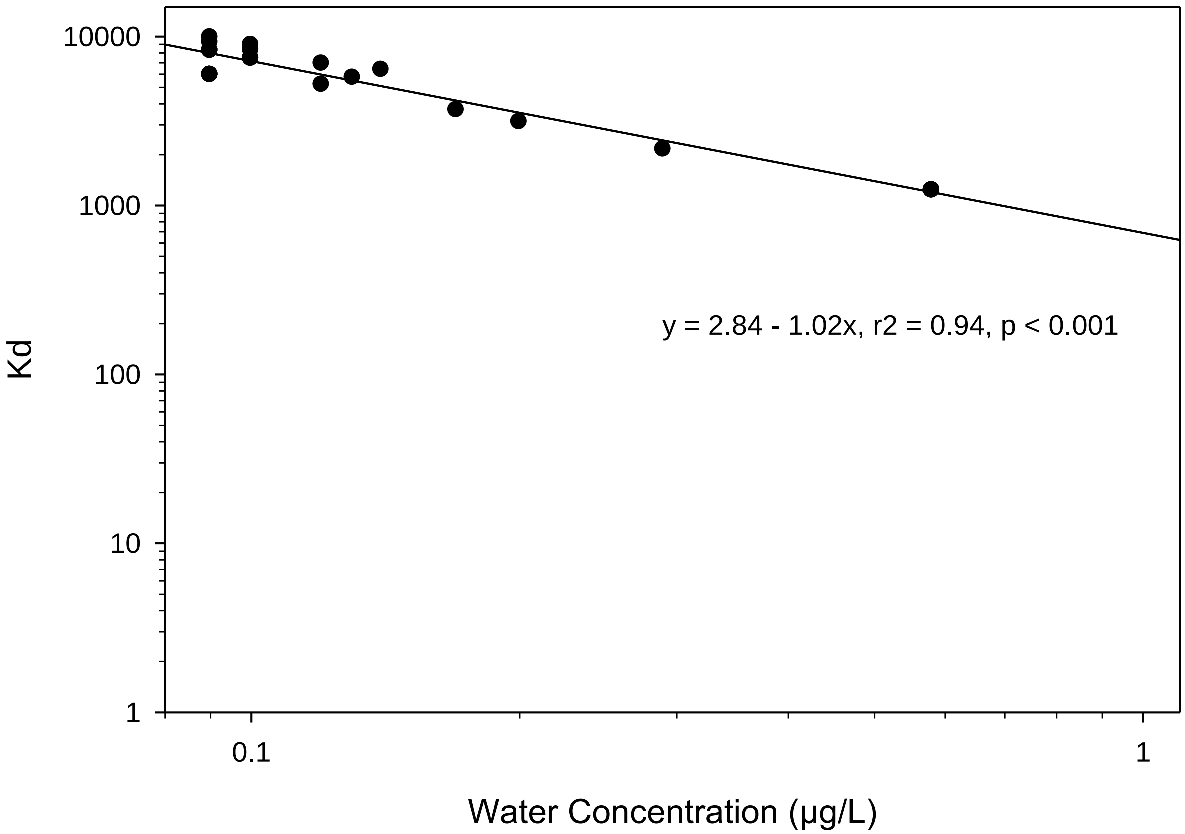
To predict the K_d (y) from water concentrations using the regression equation, take the log of the water concentration (x), multiply it by the slope (-1.01), which gives a positive number for x<1 (i.e., waterborne selenium concentrations less than 1 µg/L); then add this number to the intercept (2.72) and take the antilog.

Attachment Figure 5.F-3. Log-log Regression Relation of Estimated K_d to Waterborne Selenium Concentration for Model 4 in Normal/Wet Years (Based on Years 2000 and 2005)



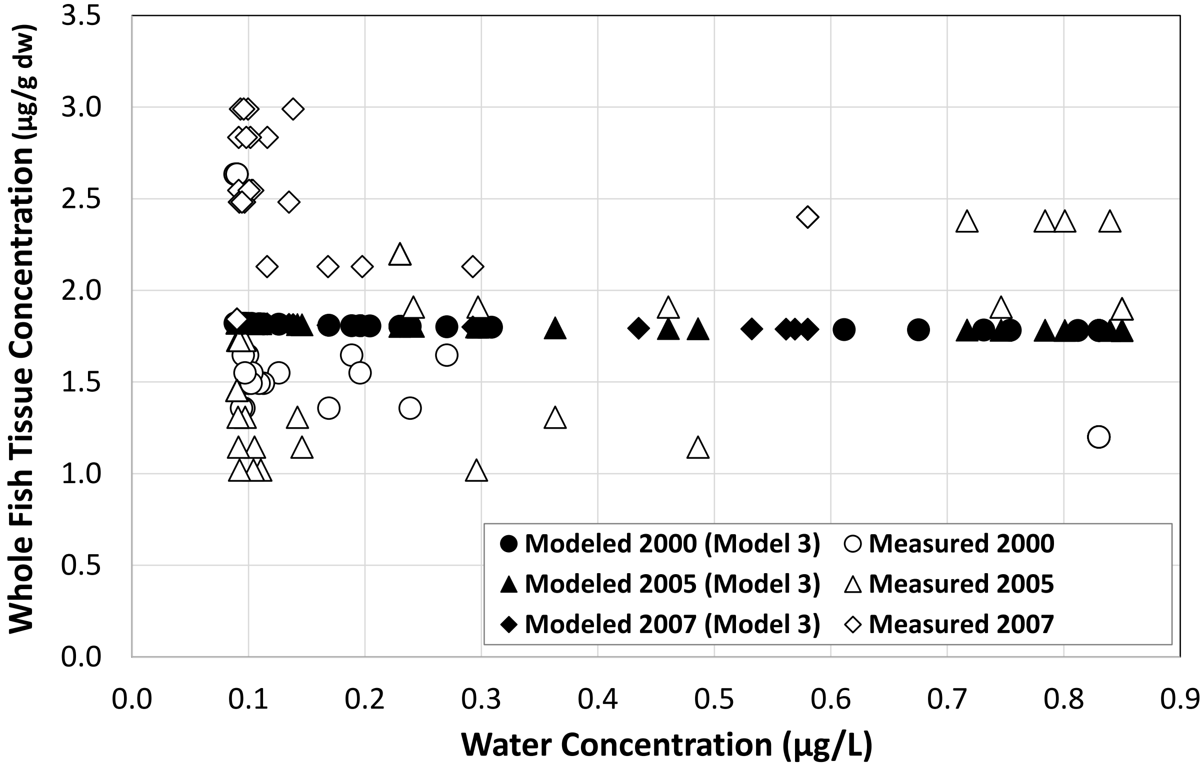
To predict the K_d (y) from water concentrations using the regression equation, take the log of the water concentration (x), multiply it by the slope (-0.95), which gives a positive number for x<1 (i.e., waterborne selenium concentrations less than 1 µg/L); then add this number to the intercept (2.71) and take the antilog.

Attachment Figure 5.F-4. Log-log Regression Relation of Estimated K_d to Waterborne Selenium Concentration for Model 5 in Dry Years (Based on Year 2007)



To predict the K_d (y) from water concentrations using the regression equation, take the log of the water concentration (x), multiply it by the slope (-1.02), which gives a positive number for x<1 (i.e., waterborne selenium concentrations less than 1 µg/L); then add this number to the intercept (2.84) and take the antilog.

Attachment Figure 5.F-5. Distribution of Data for Selenium Concentrations in Largemouth Bass Relative to Waterborne Selenium for Model 3



Attachment Figure 5.F-6. Distribution of Data for Selenium Concentrations in Largemouth Bass Relative to Waterborne Selenium for Model 4 and Model 5