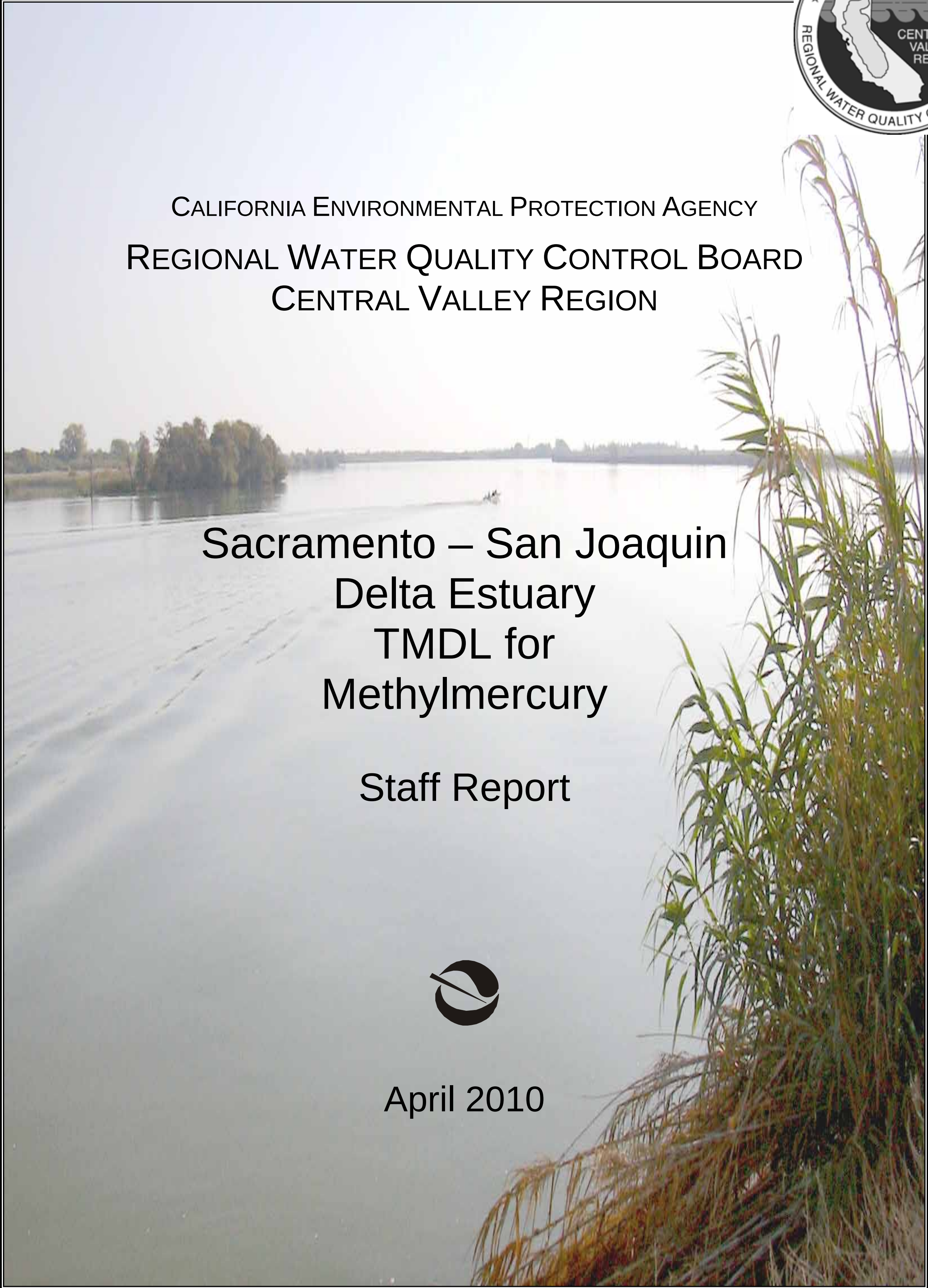

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

Sacramento – San Joaquin Delta Estuary TMDL for Methylmercury

Staff Report

April 2010

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DISCLAIMER
This publication is a report by staff of the California Regional Water Quality Control Board, Central Valley Region. This report contains the evaluation of alternatives and technical support for the adoption of a Basin Plan Amendment to the Water Quality Control Plan for the Sacramento and San Joaquin River Basins (Resolution No. R5-2010-0043). Mention of specific products does not represent endorsement of those products by the Central Valley Water Board.

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SACRAMENTO – SAN JOAQUIN DELTA ESTUARY TMDL FOR METHYLMERCURY

Staff Report

EXECUTIVE SUMMARY

This draft report presents California Regional Water Quality Control Board, Central Valley Region (Central Valley Water Board) staff recommendations for establishing a Total Maximum Daily Load (TMDL) for methylmercury in the Sacramento-San Joaquin Delta Estuary (the Delta). The report contains an analysis of the mercury impairment, a review of the primary sources, a linkage between methylmercury sources and impairments, and recommended mercury reductions to eliminate the impairment.

This TMDL report is one component in the Central Valley Water Board's water quality attainment strategy to resolve the mercury impairment in the Delta. The second component is implementing a control program through amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (the Basin Plan), as described in the proposed Basin Plan amendments and text in the draft Basin Plan Amendment staff report.

Scope, Numeric Targets & Extent of Impairment

In 1990 the Central Valley Water Board identified the Delta as impaired by mercury because fish had elevated levels of mercury that posed a risk for human and wildlife consumers. As a result, the Delta methylmercury TMDL addresses all waterways within the legal Delta boundary. In addition, the San Francisco Bay Regional Water Quality Control Board (San Francisco Water Board) identified Central Valley outflows *via* the Delta as one of the principal sources of total mercury to San Francisco Bay and, in its 2006 mercury TMDL for San Francisco Bay, assigned the Central Valley a load reduction of 110 kg/yr. Therefore, the final mercury TMDL control plan for the Delta must ensure protection of human and wildlife health in the Delta and meet the San Francisco Bay TMDL load allocation for the Central Valley.

This TMDL report addresses both methyl and total mercury sources. Reductions in ambient aqueous methylmercury and methylmercury sources are required to reduce methylmercury concentrations in fish. The methylmercury linkage and source analyses divide the Delta into eight subareas based on the hydrologic characteristics and mixing of the source waters. Because the Yolo Bypass acts as a substantial source of methylmercury and total mercury to the Delta, the entire Yolo Bypass was included in the Yolo Bypass subarea. The Yolo Bypass is a 73,300-acre floodplain on the west side of the lower Sacramento River, about two thirds of which is within the legal Delta boundary.

A separate methylmercury allocation scheme was developed for each subarea because the levels of impairment and the methylmercury sources in the subareas are substantially different. Reductions in total mercury loads are needed to reduce aqueous methylmercury in the Delta, to maintain compliance with the USEPA's criterion of 50 ng/l, and to comply with the San Francisco Bay mercury control program.

The concentration of methylmercury in fish tissue is the type of numeric target selected for the Delta methylmercury TMDL. Acceptable fish tissue levels of methylmercury for the trophic level (TL) food groups consumed by piscivorous wildlife species (that is, species that feed on fish) were calculated using a method developed by the U.S. Fish and Wildlife Service that uses daily intake levels, body weights and consumption rates. Numeric targets were developed to protect humans in a manner analogous to targets for wildlife using a method approved by the U.S. Environmental Protection Agency and Delta-specific information.

Three numeric targets are recommended for the protection of humans and piscivorous wildlife: 0.24 mg/kg (wet weight) in muscle tissue of large[1] trophic level four (TL4) fish such as bass and catfish; 0.08 mg/kg (wet weight) in muscle tissue of large TL3 fish such as carp and salmon; and 0.03 mg/kg (wet weight) in whole TL2 and TL3 fish less than 50 mm in length. The targets for large TL3 and TL4 fish are protective of (a) humans eating 32 g/day (8 ounces, uncooked fish per week) of commonly consumed, large fish; and (b) all wildlife species that consume large fish. The target for small TL2 and TL3 fish is protective of wildlife species that consume small fish.

Elevated fish methylmercury concentrations occur along the periphery of the Delta while lower body burdens occur in the central Delta. Concentrations are greater than recommended as safe by the USFWS for wildlife in all subareas except in the Central Delta subarea. The Central Delta subarea requires no reduction to meet the proposed large TL3 fish target for human protection and an 8% reduction to meet the proposed large TL4 fish target for human protection. Percent reductions in fish methylmercury levels ranging from 0% to 75% in the peripheral Delta subareas will be needed to meet the numeric targets for wildlife and human health protection.

Linkage

The Delta linkage analysis focuses on the comparison of methylmercury concentrations in water and biota. Statistically significant, positive correlations have been found between aqueous methylmercury and aquatic biota, indicating that methylmercury levels in water is one of the primary factors determining methylmercury concentrations in fish.

The Delta TMDL linkage focuses on the correlation between aqueous methylmercury and largemouth bass methylmercury because (1) largemouth bass was the only species systematically collected near many of the aqueous methylmercury sampling locations used to develop the methylmercury mass balance for the Delta (next section) and (2) largemouth bass is a useful bioindicator of spatial variation in mercury accumulation in the aquatic food chain because it maintains a localized home range and has a high trophic position in the Delta food web. It was possible to describe the recommended fish tissue targets in terms of the mercury concentration in standard 350 mm largemouth bass. A methylmercury concentration of 0.28 mg/kg in 350 mm largemouth bass is equivalent to the target of 0.24 mg/kg for large TL4 fish. A methylmercury concentration of 0.24 mg/kg in 350 mm largemouth bass is equivalent to the target of 0.08 mg/kg for TL3 fish. A methylmercury concentration of 0.42 mg/kg in 350 mm largemouth bass is equivalent to the target of 0.03 mg/kg for small fish. The methylmercury

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[1] Large fish are defined as 150-500 mm total length or legal catch length if designated by CDFG.

concentration of 0.24 mg/kg in bass predicted for the TL3 fish tissue target is the lowest of the bass values predicted for the three fish tissue targets and is therefore most likely protective of both human and wildlife consumers of higher and lower trophic level fish in the Delta. As a result, a methylmercury concentration of 0.24 mg/kg in 350 mm largemouth bass is referred to as the recommended implementation goal for largemouth bass.

The mercury concentrations in standard 350-mm largemouth bass for each Delta subarea were regressed against the average unfiltered methylmercury concentrations in water in each Delta subarea. Substitution of the recommended implementation goal for largemouth bass (0.24 mg/kg) into the equation developed by this regression results in a predicted, average safe methylmercury concentration in ambient water of 0.066 ng/l. Incorporation of an explicit margin of safety of about 10% results in the recommended implementation goal for unfiltered ambient water of 0.06 ng/l methylmercury. This implementation goal would be applied as an annual average methylmercury concentration in ambient waters of the Delta. The recommended implementation goal is currently met in the Central Delta subarea and nearly met in the West Delta subarea.

Sources – Methylmercury

Average annual methylmercury inputs and exports were estimated for water years (WY) 2000 to 2003, a relatively dry period that encompasses the available information. Sources of methylmercury in Delta waters include tributary inputs from upstream watersheds and within-Delta sources such as methylmercury flux from wetland and in-channel sediments, municipal and industrial wastewater, agricultural drainage, and urban runoff. Losses include water outflow to San Francisco Bay, exports to southern California, removal of dredged sediments, photodegradation, uptake by biota, and particle settling. Figure 1 illustrates the average daily methylmercury imports to and exports from the Delta and Yolo Bypass. Methylmercury flux from wetland and open water sediments within the Delta and Yolo Bypass accounts for about 35% of methylmercury inputs to the Delta/Yolo Bypass. Tributaries contribute about 58% of the Delta/Yolo Bypass methylmercury inputs. The difference between the sum of known inputs and exports is a measure of the uncertainty of the loading estimates and of the importance of other loss processes at work in the Delta. The sum of known water inputs and exports for WY2000-2003 balances to within about 5%, indicating that all the major water inputs and exports have been identified. In contrast, the methylmercury budget for WY2000-2003 does not balance. Average annual methylmercury inputs and exports were approximately 14.3 g/day (5.2 kg/yr) and 6.7 g/day (2.5 kg/yr), respectively (Figure 1). Exports were only about 50% of inputs, indicating that the Delta acts as a net sink for methylmercury. Recent studies have shown that methylmercury photodegradation and particle settling can account for this with-Delta loss.

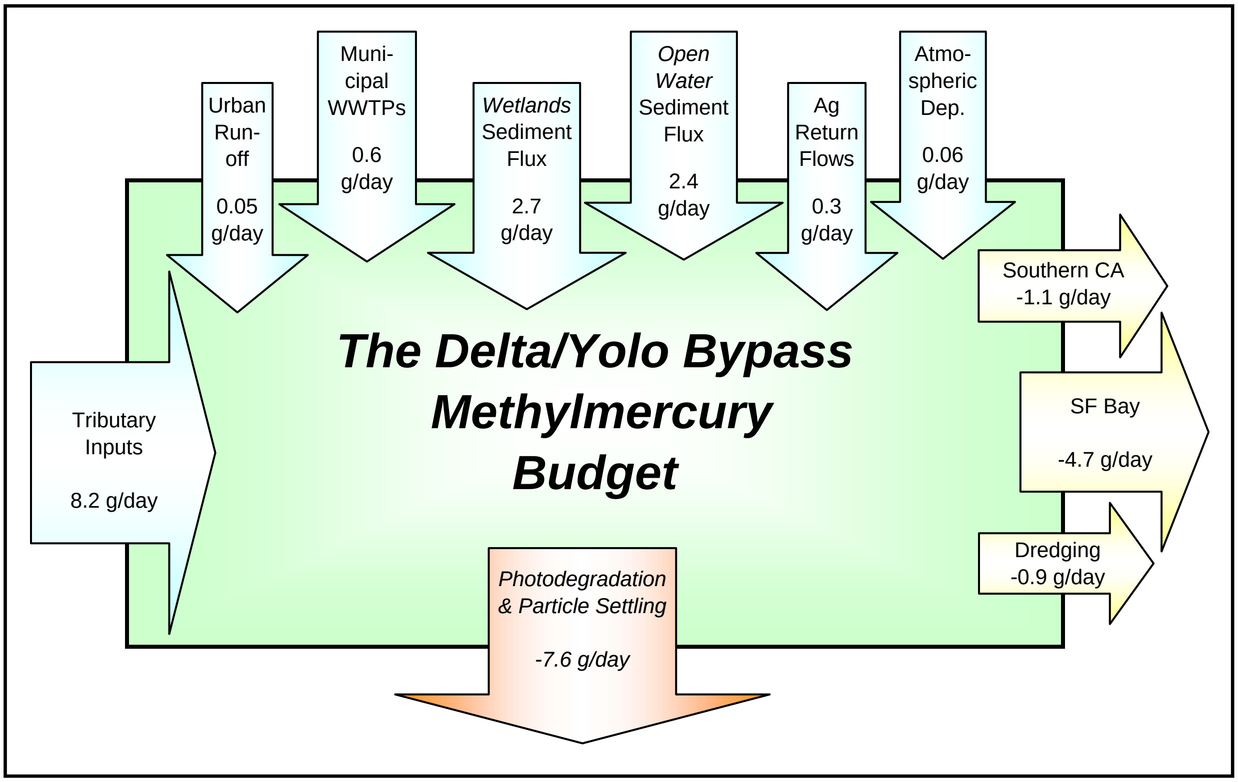

Figure 1: Average Daily Methylmercury Inputs to and Exports from the Delta/Yolo Bypass.

Sources – Total Mercury & Suspended Sediment

Sources of total mercury in the Delta and Yolo Bypass include tributary inflows from upstream watersheds, atmospheric deposition, urban runoff, and municipal and industrial wastewater. More than 97% of identified total mercury loading to the Delta/Yolo Bypass comes from tributary inputs; within-Delta sources are a very small component of overall loading. Losses include outflow to San Francisco Bay, water exports to southern California, removal of dredged sediments, and evasion.

The Sacramento Basin, which is comprised of the Sacramento River and Yolo Bypass tributary watersheds, contributes 80% or more of total mercury fluxing through the Delta. Of the watersheds in the Sacramento Basin, the Cache Creek and upper Sacramento River (above Colusa) watersheds contribute the most mercury. The Cache Creek, Feather River, American River, and Putah Creek watersheds in the Sacramento Basin, and the Cosumnes River in the San Joaquin Basin, have both relatively large mercury loadings and high mercury concentrations in suspended sediment, which makes these watersheds attractive candidates for load reduction programs.

Methylmercury Allocations & Total Mercury Limits

Methylmercury allocations were made in terms of the existing assimilative capacity of the different Delta subareas. To determine by how much methylmercury in ambient Delta waters needs to be reduced to achieve the proposed fish targets, the existing average methylmercury concentration in water in each Delta subarea was compared to the proposed methylmercury goal for ambient water (0.06 ng/l). The amount of reduction needed in each subarea is expressed as a percent of the ambient concentration. Percent reductions required in order to meet the goal ranged from 0% in the Central Delta subarea to about 80% in the Yolo Bypass and Mokelumne River subareas.

In order to achieve the proposed fish targets in each Delta subarea, loads of methylmercury from within-Delta point and nonpoint sources and tributary inputs need to be reduced in proportion to the desired decrease in concentrations needed for ambient waters to meet the proposed goal. The percent reductions and allocations were calculated as percentages of existing loads. The percent reductions vary by subarea because the percent reductions required for ambient water methylmercury levels in each subarea to meet the proposed methylmercury goal vary. No reductions were recommended for sources to the Central and West Delta because the fish and water methylmercury levels achieve or almost achieve the proposed numeric targets and implementation goals, and because methylmercury levels are expected to decrease in these subareas as control actions take place upstream. Percent reductions were applied to point and nonpoint source loads within other subareas, except those sources that act as dilution (i.e., have existing average methylmercury concentrations at or below the proposed methylmercury goal of 0.06 ng/l). No individual point source would be expected to reduce its discharged methylmercury concentrations to below the proposed implementation goal (or, for nonpoint sources, below their intake water methylmercury concentrations).

A total mercury load reduction strategy was developed to comply with the San Francisco Bay mercury control program, to maintain compliance with the USEPA's criterion of 50 ng/l, and to help reduce aqueous methylmercury in the Delta. Staff applied the San Francisco Bay TMDL's allocated reduction of 110 kg total mercury reduction to tributary inputs to the Delta/Yolo Bypass because within-Delta sources comprise only a couple percent of total mercury inputs. Initial mercury reduction efforts should focus on the watersheds that export the largest volume of highly contaminated sediment such as the Cache Creek, Feather River, American River, Cosumnes River, and Putah Creek watersheds. Chapter 4 of the draft Basin Plan Amendment staff report describes additional strategies for minimizing increases from total mercury sources.

The methylmercury allocations and total mercury limits described in this report reflect the preferred implementation alternative described in Chapter 4 of the draft Basin Plan Amendment staff report and are designed to address the beneficial use impairment in all areas of the Delta and to comply with the total mercury allocation assigned by the San Francisco Bay TMDL. However, as described in the draft Basin Plan Amendment staff report, a number of alternatives are possible. The Central Valley Water Board will consider a variety of mercury reduction strategies and implementation alternatives as part of the Basin Plan amendment process. All Central Valley Water Board regulatory actions will be taken during public hearings.

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ACRONYMS

§	Section
ARB	California Air Resources Board
AWQC	Ambient water quality criterion
BAF	Bioaccumulation factor
Basin Plan	Central Valley Region Water Quality Control Plan for the Sacramento River and San Joaquin River Basins
bwt	Body weight
CCSB	Cache Creek Settling Basin
CDEC	California Data Exchange Center
CDFG	California Department of Fish and Game
CDHS	California Department of Health Services, re-organized in 2007 and renamed “California Department of Health” (CDPH). Reports issued before the 2007 re-organization are cited as “CDHS” reports.
CDPH	California Department of Health
CEIDARS	California emission inventory department and reporting system
cfs	Cubic feet per second
CFSII	Continuing survey of food intake by individuals
CMP	Coordinated Monitoring Program
CSS	Combined Sewer system
CTR	California Toxics Rule
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board (a.k.a. Central Valley Water Board)
CWA	Federal Clean Water Act
df	Degrees of freedom (for statistical analyses)
DMC	Delta Mendota Canal
DTMC	Delta Tributaries Mercury Council
DWR	California Department of Water Resources
EC	Electrical conductivity
FCM	Food chain multipliers
GIS	Geographic Information System
HCI	Hydrologic Classification Index
Hg	Mercury
IEP	Interagency Ecological Program
IRIS	Integrated Risk Information System
LMB	Largemouth bass
LOAEC’s	Lowest observed adverse effect concentrations
MCL	California/USEPA drinking water standards maximum contaminant levels
MDN	Mercury Deposition Network
mgd	Million gallons per day
MeHg	Monomethyl mercury (also referred to as methylmercury in this report)
MS4	Municipal Separate Storm Sewer System

ACRONYMS, *continued*

NA	Not applicable
NADP	National Atmospheric Deposition Program
NAS	National Academy of Sciences
NEMD	Natomas East Main Drain
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source
NWI	National Wetland Inventory
O	Oxygen
o/oo	Parts per thousand (salinity)
OBS	Optical back scatter
OEHHA	Office of Environmental Health Hazard Assessment
RFD	Reference dose
RSC	Relative source contribution
San Francisco Water Board	San Francisco Bay Regional Water Quality Control Board
SFBADPS	San Francisco Bay Atmospheric Deposition Pilot Study
SFEI	San Francisco Estuary Institute
SRCSD	Sacramento Regional County Sanitation District
SRWP	Sacramento River Watershed Program
State Board	State Water Resources Control Board (also shown as SWRCB in reference citations)
Subwatershed	Portion of watershed that is either upstream or downstream of the most-downstream major dam
SWIM	Surface water information
SWP	State water project
SWRCB	State Water Resources Control Board
TDSL	Total diet safe level
TL	Trophic level
TLR	Trophic level ratios
TMDL	Total Maximum Daily Load
TSS	Total suspended solids
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USEPA	U.S. Environmental Protection Agency
USFDA	U.S. Food and Drug Administration.
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
ww	Wet weight concentration (e.g., for fish tissue mercury concentrations)
WWTP	Wastewater treatment plants
X2	Location in the Estuary with 2-o/oo bottom salinity

UNITS OF MEASURE

µg	microgram
µg/g	microgram per gram
µg/l	microgram per liter
µm	micrometer
cfs	cubic feet per second
cm	centimeter
g	Gram
g/day	gram per day
g/l	gram per liter
in/yr	inches per year
kg	kilogram
l	liter
m	meter
mg	milligram
mg/g	milligram per gram
ml	milliliter
mm	millimeter
ng	nanograms
ng/l	nanograms per liter
o/oo	parts per thousand (salinity)
ppb	parts per billion; usually µg/kg
ppm	parts per million; usually mg/kg or µg/g
ppt	parts per trillion; usually ng/kg

1 INTRODUCTION

This draft report presents Central Valley Regional Water Quality Control Board (Central Valley Water Board) staff recommendations for establishing a Total Maximum Daily Load for methylmercury in the Sacramento-San Joaquin Delta Estuary (Figure 1.1). The report contains an analysis of the mercury impairment, a discussion of the primary sources, a linkage between sources and impairments, and recommended methyl and total mercury reductions to eliminate the impairment. The report is one component in the Central Valley Water Board's water quality attainment strategy to resolve the mercury impairment in the Delta.

The Federal Clean Water Act (CWA) requires states to identify water bodies that do not meet their designated beneficial uses and to develop programs to eliminate impairments. States refer to the control program as a Total Maximum Daily Load (TMDL) program. A TMDL is the total maximum daily load of a pollutant that a water body can assimilate and still attain beneficial uses. The Central Valley Water Board determined in 1990 that the Delta was impaired because fish had elevated levels of mercury that posed a risk for human and wildlife consumers. In addition, the San Francisco Bay Regional Water Quality Control Board (San Francisco Bay Water Board) identified Central Valley outflows via the Delta as one of the principal sources of total mercury to San Francisco Bay and assigned the Central Valley a load reduction (Johnson and Looker, 2004; SFBRWQCB, 2006). Therefore, the final mercury TMDL control plan for the Delta must ensure protection of human and wildlife health in the Delta and meet the San Francisco Bay Water Board's mercury load allocation to the Central Valley.

In order to meet state and federal requirements, the TMDL development process must include compiling and considering available information and appropriate analyses relevant to defining the impairment, identifying sources, and assigning responsibility for actions to resolve the impairment. This report has the following sections that reflect the key elements of the Delta methylmercury TMDL development process:

- Chapter 2 – Problem Statement: Presents information that explains the overall regulatory framework for this TMDL, lists future milestones and describes the extent of mercury impairment in the Delta.
- Chapter 3 – Controllable Processes: Describes the methylation processes that are potentially controllable in the Delta. The concepts summarized in this chapter guided the development of the methylmercury TMDL for the Delta, particularly the linkage analyses (Chapter 5), methyl and total mercury source analyses (Chapters 6 and 7), and methylmercury allocation and implementation strategies described in Chapter 4 of the draft Basin Plan Amendment staff report.
- Chapter 4 – Numeric Targets: Proposes numeric targets for methylmercury concentrations in fish, which, if met, would protect beneficial uses of Delta waters.
- Chapter 5 – Linkage Analysis: Describes the mathematical relationship between aqueous methylmercury concentrations and the proposed numeric targets for fish mercury levels, which is used to determine an aqueous methylmercury goal that guides the allocation of methylmercury source reductions within the statutory Delta boundary and tributary inputs.
- Chapters 6 & 7 – Source Assessment: Identifies and quantifies concentrations and loads of methyl and total mercury sources.

- Chapter 8 – Allocations: Presents recommended methylmercury allocations and total mercury limits for Delta sources to reduce methylmercury concentrations in fish and to comply with the USEPA's California Toxics Rule mercury criterion and the San Francisco Bay Mercury TMDL allocation for total mercury leaving the Central Valley watershed. This chapter also describes the margin of safety afforded by the analyses' uncertainties and consideration of seasonal variations.

Since the June 2006 draft TMDL Report issued for scientific peer review, staff made several changes to the TMDL Report in response to comments made by the scientific peer reviewers and other agencies and stakeholders, as reflected in the February 2008 draft TMDL Report:

- Expansion of the numeric target evaluation (Chapter 4) to include results from recent interviews of local community-based groups and pilot surveys and recent final and draft fish mercury advisories for the Delta region.
- Expansion of the methylmercury source analysis (Chapter 6) and methylmercury allocation scheme (Chapter 8) to include methylmercury inputs to the portion of the Yolo Bypass that is north of the legal Delta using methods evaluated and found acceptable by the scientific peer reviewers. About 72% of the 73,300-acre Yolo Bypass is within the legal Delta boundary. Previous analyses indicated that the Yolo Bypass is a substantial source of methylmercury to the Delta, such that it makes sense to expand the methylmercury allocation scheme for the legal Delta to include the northern Yolo Bypass. Sacramento and Feather Rivers (via Fremont and Sacramento Weirs), Cache Creek, Willow Slough, and the Knights Landing Ridge Cut from the Colusa Basin all drain directly to the Yolo Bypass north of the legal Delta. Sources within the northern Yolo Bypass include wetlands and open water habitats, two WWTP discharges, agricultural lands, and a small amount of urbanized land. The 2006 draft TMDL Report included methylmercury allocations for sources within 30 miles of the legal Delta boundary; this revised report only includes allocations for dischargers within the legal Delta and the Yolo Bypass.
- Additional explanation of, and calculations for, the proposed methylmercury allocations to more directly address expected increases in source loading from predicted population growth and wetland restoration efforts.
- Changes to the methylmercury allocation strategy such that point and nonpoint sources with load-based allocations do not also have concentration allocations; this allows for a greater range of implementation options.
- Re-evaluation of the wetland and open-water methylmercury contributions (Chapter 6) using 2006 National Wetlands Inventory (NWI) wetland and open water acreages for the Delta/Yolo Bypass rather than the 1997 NWI acreages.
- Minor changes to methylmercury, total mercury and TSS load calculations (Chapters 6 and 7) based on additional quality assurance review of the concentration data and their use in regression-based load analyses.
- Minor textual changes throughout the report to clarify concepts and correct typographical errors identified in the June 2006 report.
- Expansion and re-location of the "Public Outreach" chapter (Chapter 9 in the June 2006 TMDL report) to the draft Basin Plan Amendment staff report (Chapter 8, "Public Participation & Agency Consultation").

Since the February 2008 draft TMDL Report issued for public review, staff made several more changes to the TMDL Report in response to comments made by stakeholders, as reflected in this revised draft TMDL Report:

- Changes to the methylmercury allocation strategy so that NPDES facilities have more implementation options to address future population growth, regionalization, and reclamation.
- Minor modifications to methylmercury and total mercury load calculations (Chapters 6 and 7) based on (a) new inputs from NPDES facilities that previously did not discharge to surface water, (b) decreases because some NPDES facilities have ceased their discharges to surface water, (c) new discharge data for NPDES facilities for which previously no data were available; and (d) additional quality assurance review of the tributary inputs and NPDES facility concentration data and their use in load analyses.
- Addition of new information from recently completed CalFed mercury science reports and other recent published literature.
- Minor textual changes throughout the report to clarify concepts and correct typographical errors identified in the February 2008 report.

Staff reviewed key mercury studies in the Delta and elsewhere that have been published since the Delta methylmercury TMDL was drafted. These studies include the 2008 CALFED Bay Delta Program mercury studies and atmospheric deposition and wetland methylmercury loading research. Several of these studies are cited in Chapters 3, 6, and 7. Others have been discussed in stakeholder meetings. Staff concluded that recent information does not necessitate changes in the Delta TMDL at this time and generally supports a phased implementation strategy that includes development of methylmercury management measures, production of upstream TMDLs to address methylmercury and inorganic mercury sources, and methylmercury reductions for sources within the Delta. Staff will use studies published after the TMDL was developed to revise methylmercury and mercury load calculations and implementation strategy when the Delta methylmercury control program is reviewed at the end of Phase 1.

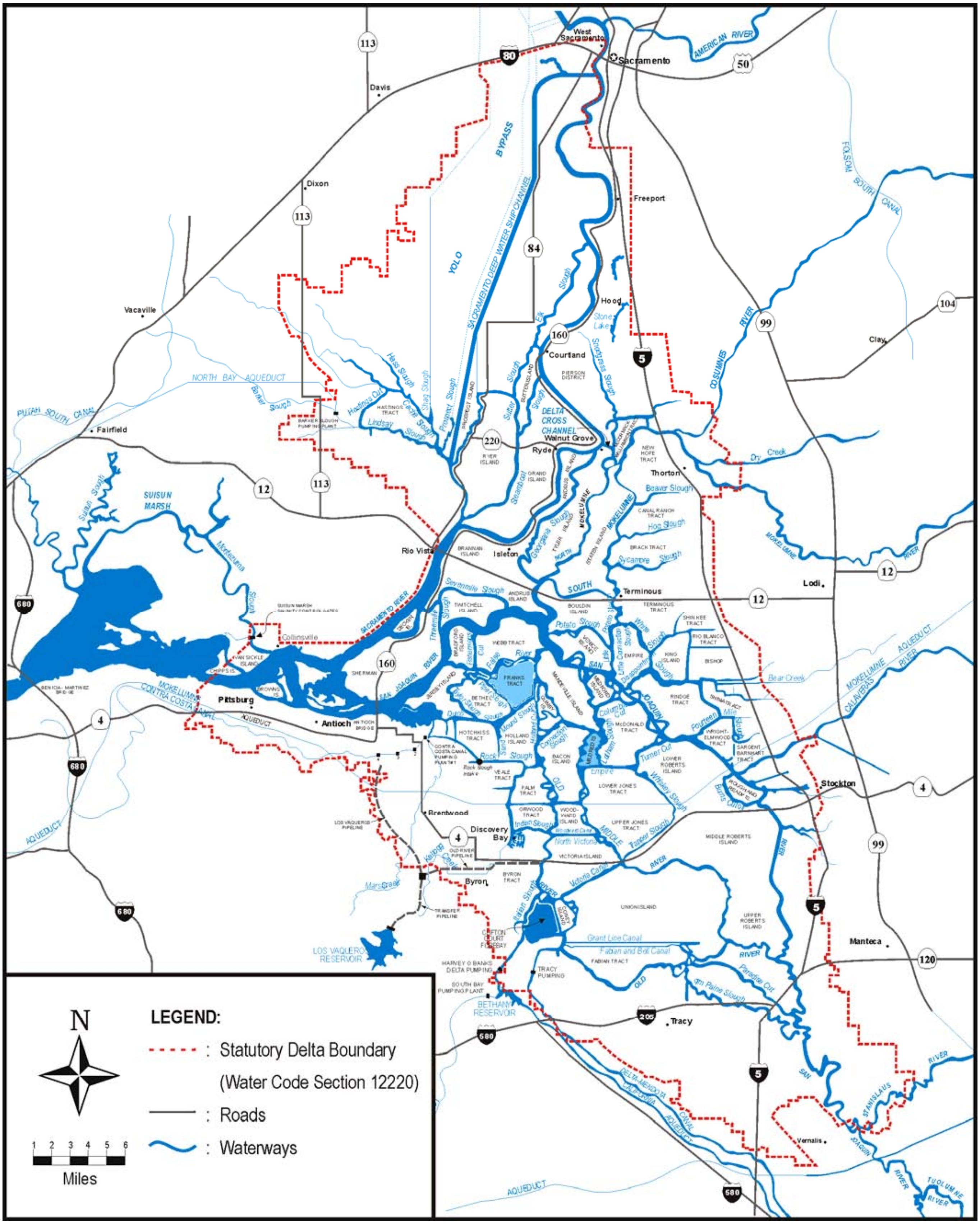

Figure 1.1: The Sacramento-San Joaquin Delta [DWR, 1995].
The dotted red line outlines the statutory boundary of the Delta.

2 PROBLEM STATEMENT

The Central Valley Water Board determined that the Delta is impaired by mercury. Fish tissue data collected since 1970 in the Delta indicate that mercury levels exceed numeric criteria established for the protection of human and wildlife health. This Problem Statement presents information in four sections:

1. Regulatory Background and TMDL Timeline
2. Delta Characteristics and TMDL Scope
3. Mercury Effects & Sources
4. Beneficial Uses, Applicable Standards & Extent of Impairment

2.1 Regulatory Background & TMDL Timeline

2.1.1 Clean Water Act 303(d) Listing and Total Maximum Daily Load Development

Section 303(d) of the federal Clean Water Act requires states to:

- Identify waters not attaining water quality standards (referred to as the “303(d) list”).
- Set priorities for addressing the identified pollution problems.
- Establish a “Total Maximum Daily Load” for each identified water body and pollutant to attain water quality standards.

In 1990 the State Water Resources Control Board (State Water Board) adopted the 303(d) List that identified Delta waterways as impaired for mercury because of the presence of a fish consumption advisory (SWRCB-DWQ, 1990). The 1998 303(d) List identified the TMDL control program for mercury in the Delta as a high priority (SWRCB-DWQ, 2003).

A TMDL represents the maximum load (usually expressed as a rate, such as kilograms per day (kg/day) or other appropriate measure) of a pollutant that a water body can receive and still meet water quality objectives. A TMDL describes the reductions needed to meet water quality objectives and allocates those reductions among the sources in the watershed. Water bodies on the 303(d) List are not expected to meet water quality objectives even if point source dischargers comply with their current discharge permit requirements. TMDLs must include the following elements: description of the problem (Chapter 2), numerical water quality target (Chapter 4), analysis of current loads (Chapters 6 and 7), and load reductions needed to eliminate impairments (Chapter 8).

2.1.2 Porter-Cologne Basin Plan Amendment Process

The State of California Porter-Cologne Water Quality Control Act (Section 13240) requires the Central Valley Water Board to develop a water quality control plan for each water body in the Central Valley that does not meet its designated beneficial uses. The Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (the Basin Plan) is the legal document that describes the beneficial uses of all water bodies in these basins, water quality objectives to protect them, and, if the objectives are not being met, an implementation program to correct the impairment (CVRWQCB, 2009). The water quality management strategy for mercury in the Delta includes:

- TMDL Development: involves the technical analysis of methyl and total mercury sources, fate and transport of each, development of proposed mercury fish tissue objectives, and a description of the amount of source reduction necessary to attain the proposed objectives.
- Basin Planning: focuses on the development of Basin Plan amendments and a staff report for Central Valley Water Board consideration. The draft Basin Plan amendments propose site-specific fish tissue objectives for the Delta and an implementation plan to achieve the objectives. The draft Basin Plan Amendment staff report includes information and analyses required to comply with the California Environmental Quality Act (CEQA). The Basin Planning process satisfies State Water Board regulations for the implementation of CEQA.[2]
- Implementation: focuses on the establishment of a framework that ensures that appropriate practices or technologies are implemented (§13241 and §13242 of the Porter-Cologne Water Quality Act), including those elements necessary to meet federal TMDL requirements (CWA Section 303(d)).

The proposed Basin Plan amendments are legally enforceable once they have been adopted by the Central Valley and State Water Boards and approved by the Office of Administrative Law and the USEPA. Central Valley Water Board staff solicited public participation and scientific review throughout the TMDL development and implementation planning phases. Chapter 8 in the draft Basin Plan Amendment staff report describes the extensive public participation, scientific peer review, and agency consultation that have taken place to date. Also, the Basin Plan amendments will be adopted and approved in a public forum.

2.1.3 Timeline and Process for the Delta Mercury Management Strategy

The Delta methylmercury TMDL and Basin Planning processes began with the development of a draft technical mercury TMDL report, which was submitted to the USEPA in August 2005 and posted on the Central Valley Water Board website for public review. The June 2006 TMDL Report incorporated additional information from ongoing sampling and analyses and public input received on the August 2005 draft TMDL report. The February 2008 draft TMDL report addressed scientific peer review comments and considered Central Valley Water Board member comments and questions voiced during the March 2007 workshop, additional input from agencies and other stakeholders, and supplementary evaluations to support the Basin Planning effort. This draft TMDL Report, along with the accompanying draft Basin Plan Amendment staff report and formal responses to comments under separate cover, addresses Central Valley Water Board member and stakeholder comments voiced during the April 2008 hearing and 2008-2009 Stakeholder Process. Chapter 8 in the draft Basin Plan Amendment

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[2] The Secretary of Resources has certified the planning process for Basin Plans as a regulatory program pursuant to PRC § 21080.5 and CEQA Guidelines §15251(g). This certification means basin planning is exempt from CEQA provisions that relate to preparing Environmental Impact Reports and Negative Declarations. The Basin Plan Staff Report satisfies the requirements of State Board Regulations for Implementation of CEQA, Exempt Regulatory Programs, which are found in the California Code of Regulations, Title 23, Division 3, Chapter 27, Article 6, beginning with Section 3775.

staff report provides a detailed description of the CEQA scoping, Board, and public workshops and other stakeholder meetings that have taken place to date, including the formal Stakeholder Process. After staff has addressed any public comments on the draft TMDL and Basin Plan Amendment staff reports during the formal public review period, the final draft TMDL and Basin Plan Amendment staff reports will be presented to the Central Valley Water Board for their consideration in 2010.

2.1.4 Units and Terms Used in this Report

This report uses the term “total mercury” (TotHg) to indicate the sum of all forms of mercury (Hg) in water: physical states (e.g., dissolved, colloidal or particulate bound), chemical states (e.g., elemental, mercurous ion, or mercuric ion), organic compounds (e.g., monomethylmercury), and inorganic compounds (e.g., cinnabar). Monomethylmercury is the predominant form of organic mercury present in biological systems and will be noted in this report as “methylmercury” (MeHg). Because methylmercury typically composes only a small portion of total mercury in ambient water,[3] the phrases “inorganic mercury” and “total mercury” are sometimes used synonymously.

Concentrations of methyl and total mercury in water (also referred to as “aqueous” methyl and total mercury) are reported in units of nanograms per liter (ng/l). Aqueous methylmercury concentrations are rounded to three decimal places and total mercury concentrations are rounded to two decimal places. Concentrations of suspended sediment are analyzed as total suspended solids (TSS) and use units of milligrams per liter (mg/l) rounded to one decimal place. In Chapter 7 (Source Assessment – Total Mercury & Suspended Sediment), the concentration of total mercury in suspended sediment is calculated as the ratio of concentrations of mercury to suspended sediments (TotHg:TSS). Units for the concentration of mercury in suspended sediment are part per million (ppm; equivalent to ng/mg or mg/kg), dry weight. Mercury levels in sediment and soil are also presented as part per million, dry weight. The units for loads of methylmercury and total mercury are grams per year (g/yr) and kilograms per year (kg/yr), respectively. Sediment loads are given in terms of millions of kilograms per year (kg/yr x 10^6 or Mkg/yr). Water flow is presented in units of acre-feet per year or million acre-feet per year (M acre-ft) for annual rates, cubic feet per second (cfs) for instantaneous flow measurements, and million gallons per day (mgd) for treatment plants. Load calculations are typically rounded to two significant figures with calculations completed prior to rounding. For this draft report, additional significant figures occasionally were included to improve the reader’s ease in verifying calculations.

Concentrations of mercury in fish tissue are reported as milligrams per kilogram (mg/kg), wet weight basis, rounded to two decimal places. Mercury is typically analyzed as “total mercury” in fish because of the additional cost required for methylmercury analysis. However, mercury exists almost entirely in the methylated form in small and top trophic level[4] fish (Becker and

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[3] For example, a comparison of average annual methylmercury and total mercury loads from tributary watersheds to the Delta (Tables 6.2 and 7.1) indicates that methylmercury loading comprises only about 2% of all total mercury loading from the tributaries.

[4] Trophic levels are numerical descriptions of an aquatic food web. The USEPA’s 1997 Mercury Study Report to Congress used the following criteria to designate trophic levels based on an organism’s feeding habits:

Trophic level 1: Phytoplankton and bacteria.
Trophic level 2: Zooplankton, benthic invertebrates and some small fish.

Bigham, 1995; Nichols *et al*., 1999; Slotton *et al.*, 2004). Therefore, even though all the fish mercury data presented in the report were generated by laboratory analyses for total mercury, the data are described as “methylmercury concentrations in fish”.

Rates of fish consumption are given as grams of fish eaten per day (g/day) or meals per week. One adult human meal is assumed to be eight uncooked ounces (227 grams). Humans and wildlife species consume fish and other aquatic organisms from various size ranges and trophic levels. Safe fish tissue levels are identified in Chapter 4 for different trophic level and size classifications. These classifications are termed “trophic level food groups”.

For this report, methylmercury fish tissue concentrations in trophic level food groups are recommended as the TMDL water quality **targets**. The tissue targets will be proposed as options for the Central Valley Water Board to consider when adopting fish tissue objectives. The term **implementation goal** in this report refers to methylmercury concentrations in standard 350-mm largemouth bass and unfiltered water, which are correlated to the targets. The implementation goal for methylmercury in unfiltered ambient water is Central Valley Water Board staff’s best estimate of the annual average methylmercury concentration in water needed to achieve the fish tissue targets. The “implementation goal” for methylmercury in ambient water is used to determine the methylmercury source load reductions necessary to meet the targets. The water and largemouth bass methylmercury goals are not being proposed as water quality objectives.

2.2 Delta Characteristics and TMDL Scope

2.2.1 Delta Geography

The Sacramento-San Joaquin Delta, along with the San Francisco Bay, forms the largest estuary on the west coast of North America. The Delta encompasses a maze of over 1,100 miles of river channels surrounding about 738,000 acres (1,153 square miles) of diked islands and tracts in Alameda, Contra Costa, Sacramento, San Joaquin, Solano and Yolo counties (Figure 1.1 and Figure A.1 in Appendix A). Many of the Delta waterways follow natural courses while others have been constructed to provide deep-water navigation channels, to improve water circulation, or to obtain material for levee construction (DWR, 1995). The legal boundary of the Delta is defined in California Water Code Section 12220. Appendix A illustrates the more than 100 named waterways addressed by this TMDL.

The Delta and its source watersheds comprise nearly 40% of the landmass of the State of California (Table 2.1 and Figure 2.1). The Sacramento, San Joaquin, Mokelumne, Cosumnes, and Calaveras rivers all flow into the Delta, carrying approximately 47% of the State’s total runoff (DWR, 2005). Major reservoirs and lakes in the Sacramento Basin include Shasta, Whiskeytown, Oroville, Englebright, Camp Far West, Folsom, Black Butte, Indian Valley, Clear Lake and Lake Berryessa. Major reservoirs and lakes in the San Joaquin Basin include Camanche, New Hogan, New Melones/Tulloch, Don Pedro, McClure, Burns, Bear, Owens, Eastman, Hensley, Millerton and Marsh Creek.

Trophic level 3: Organisms that consume zooplankton, benthic invertebrates, and other TL2 organisms.
Trophic level 4: Organisms that consume TL3 organisms.

The legal Delta encompasses the southern two thirds of the Yolo Bypass, a 73,300-acre floodplain on the west side of the lower Sacramento River. The Fremont and Sacramento Weirs route floodwaters from the Sacramento River and its associated tributary watersheds around the Sacramento urban area to the Yolo Bypass. Cache and Putah Creeks, Willow Slough, and the Knights Landing Ridge Cut from the Colusa Basin all drain directly to the Yolo Bypass.

The Sacramento River contributes an average annual water volume of 18.3 million acre-feet and the Yolo Bypass and the San Joaquin River contribute an average of 5.8 million acre-feet. Diversions in the Delta include the State Water Project (Banks Pumping Plant and the North Bay Aqueduct), Central Valley Project (Tracy Pumping Plant), and Contra Costa Water District, which withdraw average annual water volumes of about 3.7 million, 2.5 million, and 126 thousand acre-feet, respectively (DWR, 2005). During a typical water year,[5] the Delta receives runoff only from the Sacramento and San Joaquin Basins in the Central Valley (Figure 2.1). During infrequent flood events, the Tulare Basin in the southern Central Valley connects with the San Joaquin River system.

The mean annual precipitation in the City of Stockton in the eastern Delta is approximately 14 inches, with the majority of rain falling between November and March. Temperatures at Stockton typically average 62 degrees Fahrenheit (^{o}F), with summer highs exceeding 90 ^{o}F and winter lows dropping below 40 ^{o}F.

The Delta had a population of 410,000 people in 1990 (DWR, 1995). As of the 2000 Census, about 462,000 people resided in the Delta region (DWR, 2005). Rapid growth is occurring in urban areas in and surrounding the Delta, especially in Elk Grove (27% growth per year – the highest growth rate in California), Tracy (5.9% per year), Brentwood (12.3% per year), and Rio Vista (11.1% per year).

Agriculture and recreation are the two primary businesses in the Delta. The Delta also provides habitat for over five hundred species of wildlife (DWR, 1995; Herbold *et al.*, 1992). The Delta is the major source of fresh water to San Francisco Bay and supplies drinking water for over two-thirds of the State’s population (over 23 million people) and irrigation water for more than seven million acres of farmland statewide (DWR, 2005). Table 2.2 lists additional features of the Delta.

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[5] A “water year” (WY) is defined as the period between 1 October and 30 September of the following year; for example, WY2001 is the period between 1 October 2000 and 30 September 2001. Water year types in California are classified according to the natural water production of the major basins. See Appendix E for more information about water year classifications.

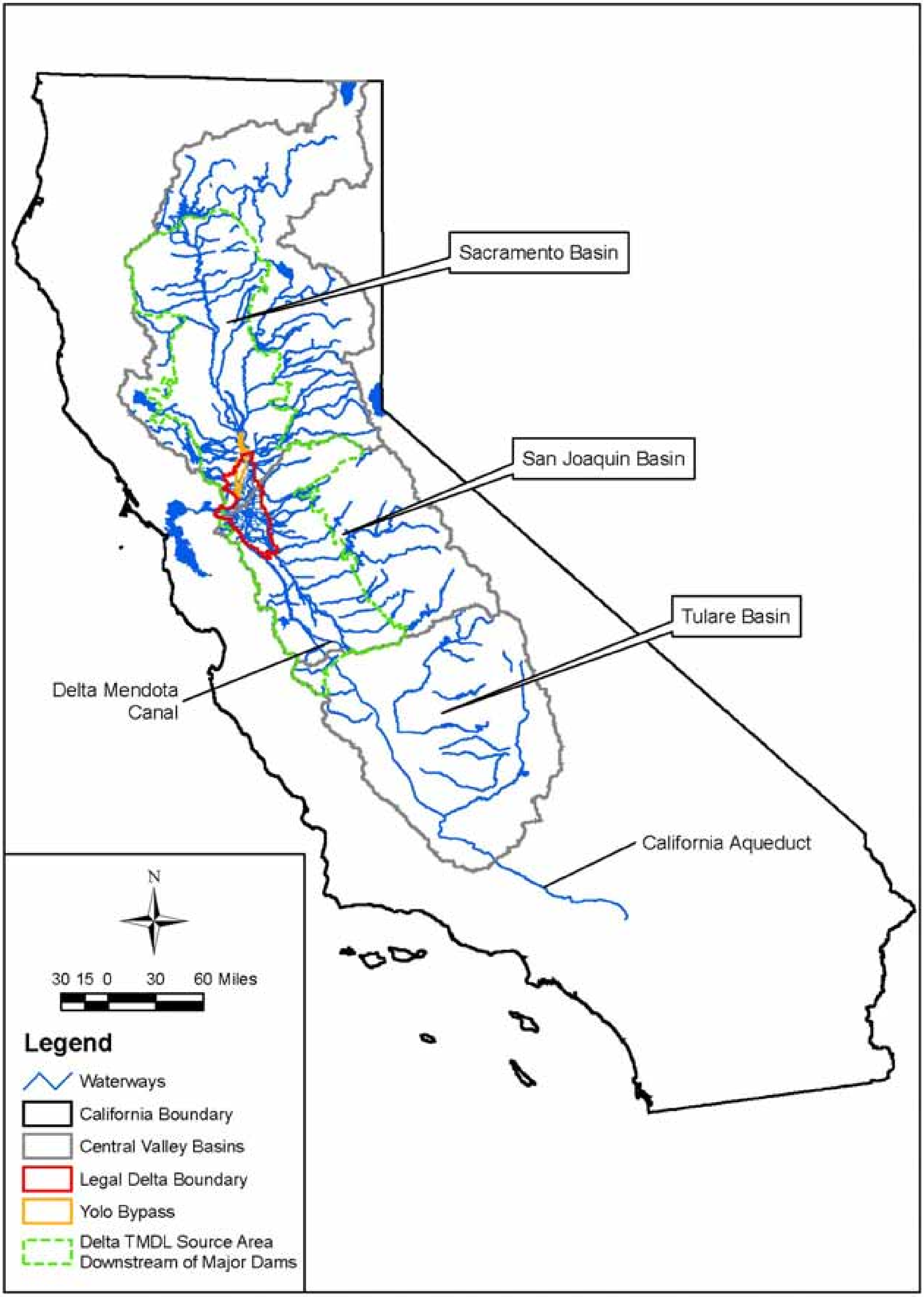

Figure 2.1: The Central Valley

Table 2.1: Spatial Perspective of the Delta and Its Source Regions

Region	Acres	Square Miles	% of California	% of Central Valley
California	101,445,246	158,508	---	---
Central Valley	37,982,554	59,348	37%	---
Delta (legal boundary)	737,630	1,153	1%	1.9%
Delta Watershed (Statutory Delta & all tributary watersheds that ultimately drain directly to the Delta)	27,226,796	42,542	27%	72%
Delta Watershed Area Downstream of Major Dams	12,469,054	19,483	12%	33%
Sacramento River Watershed	17,410,314	27,204	17%	46%
San Joaquin River Watershed	9,801,103	15,314	10%	26%

Table 2.2: Key Delta Features (DWR, 1995 and 2005)

<table>
<tr><td>Population:</td><td>410,000 (1990), 462,000 (2000)</td><td rowspan="3">Area (acres):</td><td rowspan="3">Agriculture: 538,000
Cities & towns: 64,000
Water surface: 61,000
Undeveloped: 75,000
Total: 738,000</td></tr>
<tr><td>Incorporated cities entirely within the Delta:</td><td>Antioch, Brentwood, Isleton, Pittsburg, Tracy</td></tr>
<tr><td>Major cities partly within the Delta:</td><td>Sacramento, Stockton, West Sacramento</td></tr>
<tr><td># of unincorporated towns and villages:</td><td>14</td><td>Total length of all leveed channels:</td><td>1,100 miles (1987)</td></tr>
<tr><td rowspan="2">Main crops:</td><td rowspan="2">Alfalfa
asparagus
corn
fruit
grain & hay
grapes
pasture
safflower
sugar beets
tomatoes</td><td>Diversions from the Delta:</td><td>Central Valley Project
State Water Project
Contra Costa Canal
City of Vallejo
Western Delta Industry
1,800+ Agricultural diversions</td></tr>
<tr><td>Rivers flowing into the Delta:</td><td>Calaveras
San Joaquin
Cosumnes
Mokelumne
Sacramento</td></tr>
</table>

		# of Species [(a)]	# of Federal & State Species of Concern [(a)]	# of Non-Native Species [(b)]
Fish and wildlife:	Birds:	230	7	3
	Mammals:	45	9	7
	Fish:	52	8	30
	Reptiles & amphibians:	25	6	1
	Flowering plants:	150	54	70
	Invertebrates:	na	21	13
	Major anadromous fish: American shad, salmon, steelhead trout, striped bass, sturgeon			

(a) Endangered, threatened, and candidate species per the federal and State listings as cited in the Sacramento – San Joaquin Delta Atlas (DWR, 1995) and updated using the California Department of Fish and Game's Natural Diversity Database, accessed January 2010 (CDFG, 2010).

(b) Introduced species in the Sacramento – San Joaquin Delta, as cited in the Sacramento – San Joaquin Delta Atlas (DWR, 1995).

2.2.2 TMDL Scope & Delta Subareas

This TMDL addresses fish mercury impairment in all waterways within the legal Delta, except the westernmost portion of the Delta near Chipps Island that falls within the jurisdiction of the San Francisco Bay Regional Water Quality Control Board (Figure 2.2; see Appendix A for a list of named waterways). Tributaries are considered to be nonpoint sources to the Delta and are evaluated at or near the locations where they cross the statutory Delta boundary. Assessment of point and nonpoint sources that contribute to tributary discharges to the Delta is ongoing and will be described in reports for future mercury TMDL programs for those watersheds and implementation activities for the Delta methylmercury TMDL.

The methylmercury source analysis and linkage analysis for the Delta TMDL divide the Delta into eight regions based on the hydrologic characteristics and mixing of the source waters (Figure 2.2) (e.g., DWR, 1991 and 1962). A hydrology-based methylmercury TMDL is proposed in this report as it more accurately reflects the concentrations and sources of methylmercury and the extent of fish impairment. As described in Chapter 8 (Allocations), essentially a separate methylmercury allocation scheme is developed for each subarea because the methylmercury sources and level of fish impairment in each subarea are different. The following paragraphs describe the delineation of the hydrologic subareas. These subareas are different from the Delta water body segment delineation (“portions”) defined by the State Water Board for the 2006 Clean Water Act Section 303(d) List (SWRCB-DWQ, 2006).

Sacramento River: This subarea is dominated by Sacramento River flows. It is bound to the east by the legal Delta boundary and to the west by the eastern levee of the Sacramento Deep Water Ship Channel. Sacramento River flows influence the Upper and Lower Mokelumne River in the Delta because of diversions by the Delta Cross Channel near Walnut Grove (Figure A.1 in Appendix A). The Delta Cross Channel controls diversions of fresh water from the Sacramento River to Snodgrass Slough and the Mokelumne River to combat salt-water intrusion in the Delta, to dilute local pollution, and to more efficiently supply the federal Central Valley Project and State Water Project pumps in the southern Delta. Although drawn as a line, the Sacramento River subarea’s boundary with the South Yolo Bypass, Central Delta, and West Delta subareas is defined by a gradient in water quality characteristics that varies with the tidal cycle, magnitude of wet weather flows, diversions by within-Delta control structures, and releases from reservoirs in the upstream watersheds.

Yolo Bypass - North & South: The Yolo Bypass is a 73,300-acre floodplain on the west side of the lower Sacramento River (see Section E.2.2 and Figure E.2 in Appendix E for the floodplain boundary definition). The Fremont and Sacramento Weirs route floodwaters to the Yolo Bypass from the Sacramento and Feather Rivers and their associated tributary watersheds. Cache and Putah Creeks, Willow Slough, and the Knights Landing Ridge Cut from the Colusa Basin all drain directly to the Yolo Bypass. The legal Delta encompasses only the southern two thirds of the Yolo Bypass. The “Yolo Bypass – North” subarea is defined by Fremont Weir to the north and Lisbon Weir to the south and includes areas within and north of the legal Delta boundary. The “Yolo Bypass – South” subarea is defined by Lisbon Weir to the north and the southern end of Cache Slough to the south. Lisbon Weir (Figure E.2) limits the range of tidal fluctuation upstream in the Yolo Bypass.

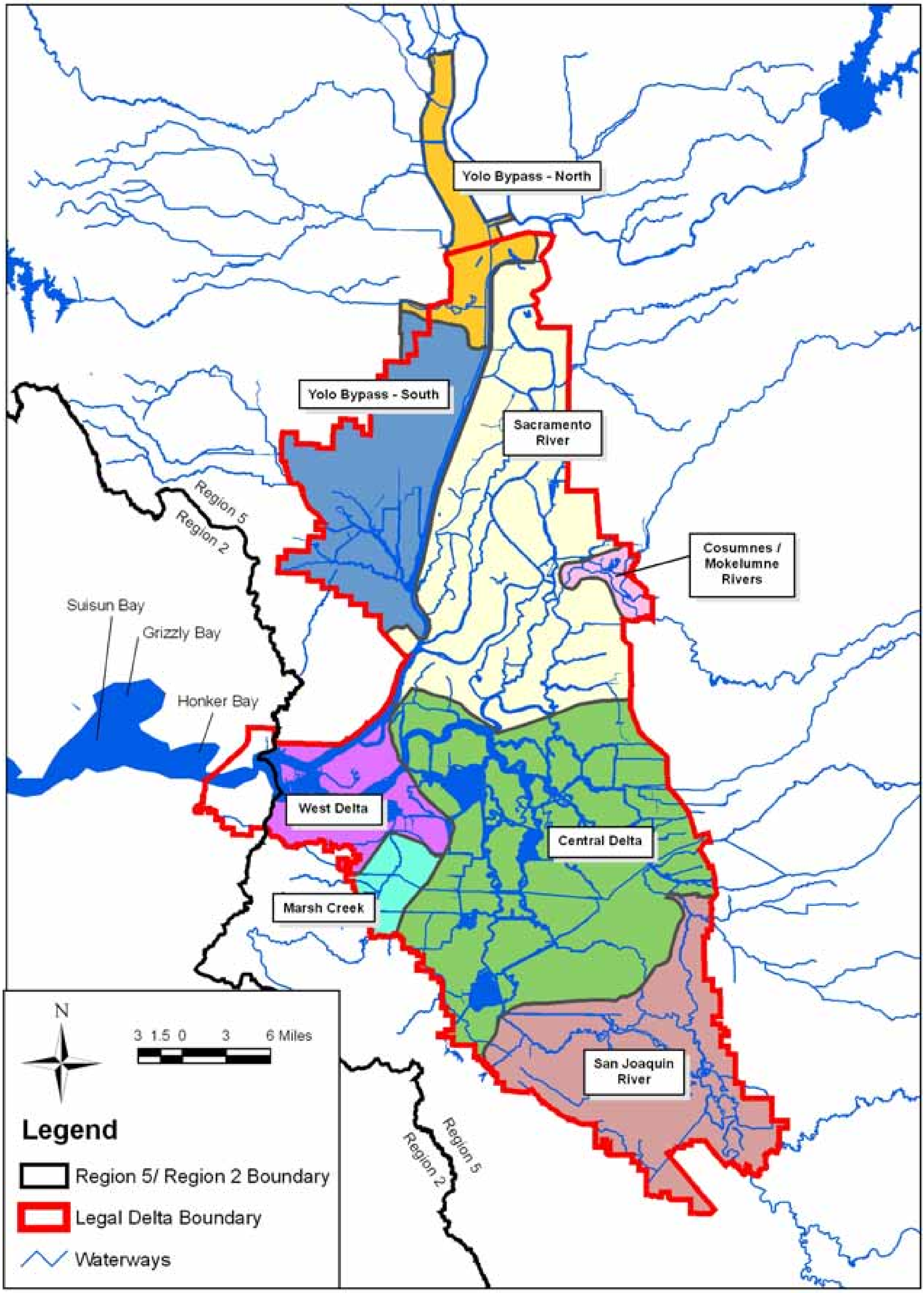

Figure 2.2: Hydrology-Based Delineation of Subareas within the Legal Delta and Yolo Bypass

Cosumnes/Mokelumne Rivers: This subarea includes the lower Cosumnes and Mokelumne Rivers and is defined by the legal Delta boundary to the east and the Delta Cross Channel confluence with the Mokelumne to the west.

San Joaquin River: This subarea is defined by the legal Delta boundary to the east and south, and Grantline Canal and the beginning of the Stockton Deep Water Channel to the north. At present, the San Joaquin River is almost entirely diverted out of the Delta by way of Old River and Grantline Canal for export south of the Delta via the state and federal pumping facilities near Tracy.

Marsh Creek: This subarea is defined by the portion of the Marsh Creek watershed within the legal Delta boundary that is upstream of tidal effects.

West Delta: The West Delta subarea encompasses the confluence of the Sacramento and San Joaquin Rivers, which transport water from the Central Valley to the San Francisco Bay. The western border of the West Delta subarea is defined by the jurisdictional boundary between the Central Valley Regional Water Quality Control Board (Region 5) and the San Francisco Water Board (Region 2) (Figure 2.2). Water quality characteristics are determined by the tidal cycle, magnitude of wet weather flows, controlled flow diversions by within-Delta structures, and releases from reservoirs in the upstream watersheds.

Central Delta: The Central Delta includes a myriad of natural and constructed channels that transport water from the upper watersheds to San Francisco Bay to the west and the state and federal pumps to the southwest. The Central Delta tends to be most influenced by waters from the Sacramento River.

2.3 Mercury Effects & Sources

2.3.1 Mercury Chemistry and Accumulation in Biota

Mercury (Hg) can exist in various forms in the environment. Physically, mercury can exist in water in a dissolved, colloidal or particulate bound state. Chemically, mercury can exist in three oxidation states: elemental (Hg^0), mercurous ion (monovalent, Hg^+), or mercuric ion (divalent, Hg^{+2}). Ionic mercury can react with other chemicals to form both organic and inorganic compounds, such as cinnabar (HgS), and can be converted by sulfate reducing bacteria to more toxic organic compounds, such as monomethylmercury (CH_3Hg) or dimethylmercury ($(CH_3)_2Hg$). Important factors controlling the conversion rate of inorganic to organic mercury include temperature, percent organic matter, redox potential, salinity, pH, and mercury concentration. Monomethylmercury is the predominant form of organic mercury present in biological systems and will be noted in this report as methylmercury or "MeHg". Because dimethylmercury is an unstable compound that dissociates to monomethylmercury at neutral or acid pH, it is not a concern in freshwater systems (USEPA, 1997a). Chapter 3 provides more information about potentially controllable methylation processes in the Delta region.

Both inorganic and organic mercury can be taken up by aquatic organisms from water, sediments and food. Low trophic level species such as phytoplankton obtain all their mercury directly from the water. *Bioconcentration* describes the net accumulation of mercury directly from water. The *bioconcentration factor* is the ratio of mercury concentration in an organism to mercury concentration in water. Mercury may also accumulate in aquatic organisms from consumption of mercury-contaminated prey (USEPA, 1997b). Mercury *bioaccumulates* in organisms when rates of uptake are greater than rates of elimination.

Repeated consumption and accumulation of mercury from contaminated food sources results in tissue concentrations of mercury that are higher in each successive level of the food chain. This process is termed *biomagnification*. Methylmercury accumulates within organisms more than inorganic mercury because inorganic mercury is less well absorbed and/or more readily eliminated than methylmercury. The proportion of mercury that exists as the methylated form generally increases with the level of the food chain. Methylmercury comprises 85% to 100% of the total mercury measured in fish (Becker and Bigham, 1995; Nichols *et al.*, 1999; Slotton *et al.*, 2004).

Consumption of contaminated, high trophic level fish is the primary route of methylmercury exposure. For example, the aquatic food web provides more than 95% of humans' intake of methylmercury (USEPA, 1997a). Wildlife species of potential concern that consume fish and other aquatic organisms from the Delta include piscivorous fish, herons, egrets, mergansers, grebes, bald eagle, kingfisher, peregrine falcon, osprey, mink, raccoon and river otter.

2.3.2 Toxicity of Mercury

Mercury is a potent neurotoxicant. Methylmercury is the most toxic form of this metal. Methylmercury exposure causes multiple effects, including tingling or loss of tactile sensation, loss of muscle control, blindness, paralysis, birth defects and death. Adverse neurological effects in children appear at dose levels five to ten times lower than associated with toxicity in adults (NRC, 2000). Children may be exposed to methylmercury during fetal development, by eating fish, or through both modes. Effects of methylmercury are dose dependent.

Wildlife species may also experience neurological, reproductive or other detrimental effects from mercury exposure. Behavioral effects such as impaired learning, reduced social behavior and impaired physical abilities have been observed in mice, otter, mink and macaques exposed to methylmercury (Wolfe *et al.*, 1998). Reproductive impairment following mercury exposure has been observed in multiple species, including common loons and western grebe (Wolfe *et al.*, 1998), walleye (Whitney, 1991 in Huber, 1997), mink (Dansereau *et al.*, 1999) and fish (Huber, 1997; Wiener and Spry, 1996).

2.3.3 Mercury Sources & Historic Mining Activities

Identified sources of methyl and total mercury in the Delta and in tributary watersheds include geothermal springs, methylmercury flux from sediments in wetlands and open water habitats, municipal and industrial dischargers, agricultural drainage, urban runoff, atmospheric deposition, and erosion of naturally mercury-enriched soils and excavated overburden and tailings from historic mining operations. Although none are present within the legal Delta, historic mercury and gold mining sites – along with their associated contaminated waterways – may contribute a substantial portion of the total mercury in the tributary discharges to the Delta.

Chapters 6 and 7 provide a detailed assessment of the within-Delta sources of methyl and total mercury.

As noted in source analyses in Chapters 6 and 7, tributary inputs to the Delta are the largest sources of methyl and total mercury. These tributaries drain many of the major mercury mining districts in the Coast Range and the placer gold mining fields in the Sierra Nevada Mountains. The Coast Range is a region naturally enriched in mercury. Active geothermal vents and hot springs deposit mercury, sulfur, and other minerals at or near the earth's surface. Most of the mercury deposits in California occur within a portion of the Coast Range geomorphic province extending from Clear Lake in Lake County in the north to Santa Barbara County in the south. Approximately 90% of the mercury (roughly 104 million kilograms) used in the United States between 1846 and 1980 was mined in the Coast Range of California (Churchill, 2000). Much of the mining and extraction occurred prior to 1890 when mercury processing was crude and inefficient. The ore was processed at the mine sites, with about 35 million kilograms of mercury lost at the mine sites. As a result, high levels of mercury are present in sediment and fish tissue in Coast Range water bodies. Fish advisories have been posted for Clear Lake, Cache Creek, Lake Berryessa and Black Butte Reservoir (Stratton *et al.*, 1987; Brodberg and Klasing, 2003; Gassel *et al*., 2005). Mercury mine waste enters the Delta from mine-impacted Coast Range creeks such as Cache, Putah and Marsh Creeks.

Approximately 10 million kilograms of Coast Range mercury were transported across the valley and used as an amalgam in placer and lode gold mining in the Sierra Nevada Mountains between 1850 and 1890 (Churchill, 2000). Approximately six million kilograms of mercury were lost in Sierra Nevada rivers and streams during gold mining operations. Principal gold mining areas were in the Yuba River and Bear River (tributaries to the Sacramento River via the Feather River), the Cosumnes River (a tributary to the Mokelumne River), and the Stanislaus, Tuolumne and Merced Rivers (tributaries to the San Joaquin River). Elevated mercury concentrations are present in fish in all these Sierra Nevada waterways. Floured[6] elemental mercury enters the Delta from the Sacramento, Mokelumne and San Joaquin Rivers.

Evaluation of legacy mine sites, associated contaminated waterway reaches, and other methyl and total mercury sources that contribute to tributary inputs to the Delta is ongoing. More detailed source analyses for the tributary watersheds will be conducted by future mercury TMDL programs for those watersheds and by proposed implementation actions for the Delta mercury control program (see Chapter 4 in the draft Basin Plan Amendment staff report).

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[6] Flouring is the division of mercury into extremely small globules, which gives it a white, flour-like appearance. If the floured mercury has surface impurities such as oil, grease, clay or iron and base metal sulfides, it will not coalesce into larger drops or form an amalgam with gold (Beard, 1987). Mercury was used for gold recovery throughout the Sierra Nevada. Floured mercury was formed by the pounding of boulders and gravels over liquid mercury in hydraulic mining-related sluice boxes (Hunerlach *et al.*, 1999), as well by intense grinding in the hardrock milling systems, and was transported downstream with tailings.

2.4 Beneficial Uses, Applicable Standards & Extent of Impairment

2.4.1 Sacramento-San Joaquin Delta Estuary Beneficial Uses

The federal Clean Water Act and the State Water Code (Porter-Cologne Water Quality Control Act) require the State to identify and protect the beneficial uses of its waters. Table 2.3 lists the existing beneficial uses of the Delta. Human consumption of fish and shellfish (currently assumed under REC-1) and wildlife habitat (WILD) are impaired because of elevated mercury concentrations in fish throughout the Delta. The Basin Plan does not include a commercial and sport fishing (COMM) designation for the Delta, which includes uses of water for commercial or recreational collection of fish, shellfish, or other organisms intended for human consumption or bait purposes. However, as described in Appendix C, commercial and sport fishing take place in the Delta. Some sport and commercial species (e.g., striped bass and largemouth bass) are impaired by mercury, while others (e.g., salmon and clams) are not. The draft Basin Plan Amendment staff report considers adoption of a COMM beneficial use for the Delta.

The municipal and industrial supply (MUN) beneficial use is designated in the Basin Plan for all waterways within the legal Delta boundary except Marsh Creek and Yolo Bypass (e.g., Cache Creek Settling Basin outflow, Prospect Slough, and the downstream segment of Putah Creek within the Yolo Bypass). Staff evaluated whether levels of total mercury in water in Delta waterways support the MUN beneficial use. The California Toxics Rule (CTR) criterion for mercury protects humans from exposure to mercury through fish consumption and drinking water and is enforceable for all waters with a municipal and domestic water supply or aquatic beneficial use designation. As described in Sections 2.4.2 and 7.4.2, the CTR mercury criterion is exceeded in outflow from the Cache Creek Settling Basin and possibly in Prospect Slough, Putah Creek, and Marsh Creek; however, MUN is not designated for these waterways. Mercury reductions may be needed to meet the CTR in the Yolo Bypass downstream of the Cache Creek Settling Basin and in Marsh Creek, but these reductions will be addressed by the existing TMDL for Cache Creek and future TMDLs for the Marsh Creek and Putah Creek watersheds (see Section 7.4.2), in addition to actions designed to reduce fish methylmercury concentrations in the Delta/Yolo Bypass and total mercury exports to San Francisco Bay (see Section 8.2).

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Table 2.3: Beneficial Uses of the Delta and Yolo Bypass [(a)]

Beneficial Use	Delta Status	Yolo Bypass Status
Municipal and domestic supply (MUN)	Existing [(b)]	
Agriculture – irrigation and stock watering (AGR)	Existing	Existing
Industry – process (PROC) and service supply (IND)	Existing	
Contact recreation (REC-1) [(c)]	Existing [(b)]	Existing [(b)]
Non-contact recreation (REC-2) [(c)]	Existing	Existing
Freshwater habitat (warm water species)	Existing	Existing
Freshwater habitat (cold water species)	Existing	Potential
Spawning, reproduction and/or early development of fish (SPWN) (warm water species)	Existing	Existing
Wildlife habitat (WILD)	Existing [(b)]	Existing [(b)]
Migration of aquatic organisms (MIGR) (warm and cold water species)	Existing	Existing
Navigation (NAV)	Existing	

(a) This table lists the beneficial uses designated for the Delta and Yolo Bypass in Table II-1 of the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan) (CVRWQCB, 2009). The Yolo Bypass is a 73,300-acre floodplain on the west side of the lower Sacramento River. The lower two thirds of the Yolo Bypass are within the legal Delta, and waterways within the entire Delta are included in Clean Water Act 303(d) List. However, Table II 1 of the Basin Plan includes separate table rows for the Yolo Bypass and Delta.

(b) These are beneficial uses impaired by mercury in the Delta, including portions of the Yolo Bypass within the legal Delta boundary.

(c) REC-1 includes recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing and fishing. REC-2 includes recreational activities involving proximity to water, but where there is generally no body contact with water, nor any likelihood of ingestion of water. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, hunting and sightseeing.

2.4.2 Applicable Standards & Extent of Impairment

The narrative water quality objective for toxicity in the Basin Plan states, “All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life.” The narrative toxicity objective further says that “The Regional Water Board will also consider … numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the USEPA, and other appropriate organizations to evaluate compliance with this objective” (CVRWQCB, 2009). Four potential criteria were evaluated to determine whether the Delta was in compliance with the narrative objective. They are the USEPA and USFWS fish tissue criteria for protection of humans and wildlife, the USEPA aqueous methylmercury criterion for drinking water, the United Nations aqueous total mercury guidance level to protect livestock, and the California Toxic Rule (CTR) aqueous total mercury criterion for protection of human and wildlife health. Each is reviewed below and a determination made as to whether the recommended criteria or objective is met in the Delta.

2.4.2.1 Fish Tissue Criteria

In 1971, a human health advisory was issued for the Sacramento-San Joaquin Delta advising pregnant women and children not to consume striped bass. In 1994, an interim advisory was issued by the California Office of Environmental Health Hazard Assessment (OEHHA) for San Francisco Bay and Delta recommending no consumption of large striped bass and shark because of elevated concentrations of mercury and polychlorinated biphenyls (OEHHA, 1994). Additional monitoring indicates that several more species, including largemouth bass and white catfish (two commonly-caught local sport fish), also have elevated concentrations of mercury in their tissue (Davis *et al.*, 2003; Slotton *et al.*, 2003; LWA, 2003; SWRCB-DWQ, 2002).

In 2009, OEHHA issued updated safe eating guidelines for the Central and South Delta (including San Joaquin River from the Port of Stockton to Pittsburg), the San Joaquin River from Friant Dam to the Port of Stockton, the Sacramento River and Northern Delta, the lower Cosumnes River, and the lower Mokelumne River[7] (OEHHA, 2009). OEHHA advises that pregnant and nursing women and children avoid consuming bass (largemouth and striped) and Sacramento pikeminnow from the San Joaquin, Sacramento and lower Cosumnes and lower Mokelumne Rivers. In the Central and South Delta waterways, pregnant and nursing women and children should limit consumption of largemouth bass, carp, and crappie to 8 ounces uncooked fish (1 serving) per week and bluegill, catfish, and crayfish to 16 ounces uncooked (2 servings) per week. The new guidelines identify fish species that can safely be eaten in 2 or more servings per week.

The Delta was listed for mercury because of the 1971 and 1994 fish advisories and because some fish tissue concentrations exceeded the National Academy of Sciences (NAS) guidelines for protection of wildlife health. The NAS wildlife guideline is 0.5 mg/kg mercury in whole, freshwater fish (NAS, 1973). The USEPA has since published a recommended criterion for the protection of human health of 0.3 mg/kg mercury in fish tissue (USEPA, 2001). Similarly, the USFWS has provided guidance on safe methylmercury ingestion rates for sensitive wildlife species (USFWS, 2002, 2003 and 2004). The Delta TMDL cites the USEPA and USFWS recommended criteria for protection of human and wildlife health, as these are more protective.

Significant regional variations in fish tissue mercury concentrations are observed in the Delta. Elevated concentrations occur along the periphery of the Delta while lower body burdens are measured in the central Delta. A summary of fish tissue methylmercury concentrations by Delta subarea is provided in Chapter 4 (Tables 4.7 and 4.10) and Appendix C. Concentrations are greater than recommended as safe by the USEPA and USFWS at all locations except in the central Delta. Percent reductions in fish methylmercury levels ranging from 0% to 80% in the peripheral Delta subareas will be needed to meet the numeric targets for wildlife and human health protection.

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[7] OEHHA's recent advisories are in the form of safe eating guidelines that indicate which fish species may be eaten safely as well as those that should be avoided or eaten less frequently.

2.4.2.2 Aqueous Criteria & Guidance

The USEPA recommends a safe level of 70 ng/l methylmercury in drinking water to protect humans (USEPA, 1987). This level was released through USEPA's Integrated Risk Information System (IRIS) and was based on USEPA's recommended methylmercury reference dose for lifetime exposure. Methylmercury concentrations in the Delta typically range from 0.02 to 0.3 ng/l (Section 6.2.1). The maximum observed concentration in the Delta between March 2000 and April 2004 was 0.70 ng/l in Prospect Slough in March 2000 (Appendix L). The USEPA IRIS drinking water criterion is not expected to be exceeded in the Delta.

The United Nations recommends a guidance level of 10,000 ng/l unfiltered total mercury to protect livestock drinking water (Ayers and Westcot, 1985). Unfiltered mercury concentrations in the Delta typically range from 0.26 to 100 ng/l (Table 7.4 in Chapter 7). The maximum concentration ever observed in the Delta was 696 ng/l at Prospect Slough on January 10, 1995. The United Nations recommended livestock guidance level is not expected to be exceeded in the Delta.

The USEPA promulgated the CTR in April 2000 (USEPA, 2000b). The CTR mercury criterion is 0.05 µg/L (50 ng/l) total recoverable mercury for freshwater sources of drinking water. The CTR criterion was developed to protect humans from exposure to mercury in drinking water and in contaminated fish. It is enforceable for all waters with beneficial use designations of municipal and domestic water supply. This includes all subareas of the Delta except Yolo Bypass and Marsh Creek. As indicated earlier in Table 2.3, Basin Plan Table II-1 does not designate “MUN” for the Yolo Bypass and Marsh Creek; however, it does designate recreation (including fish consumption by humans). The CTR does not specify duration or frequency. The Central Valley Water Board has previously employed a 30-day-averaging period with an allowable exceedance frequency of once every three years.[8]

An evaluation of unfiltered total mercury concentrations demonstrates that the CTR mercury criterion is not exceeded anywhere in the Delta. Mercury concentrations are greater than the CTR criterion downstream of the Cache Creek Settling Basin in the Yolo Bypass and possibly in Putah Creek outflow to Yolo Bypass, Prospect Slough and Marsh Creek (Section 7.4.2). These water bodies are not designated for MUN. The mercury concentrations greater than the CTR criterion downstream of Cache Creek may be addressed by the Cache Creek mercury control program (Cooke and Morris, 2005) adopted in October 2005 and proposed upgrades of the Cache Creek Settling Basin described in Chapter 4 of the draft Basin Plan Amendment staff report. Prospect Slough is downstream of Cache Creek and potential exceedances of the CTR could be corrected with decreases in mercury loads from Cache Creek and its settling basin. Putah and Marsh Creeks are both on the 303(d) list because of elevated mercury concentrations. Potential exceedance of the CTR downstream of these water bodies will be addressed by load reductions to be determined by their TMDLs. Chapters 7 and 8 will provide additional evaluations of total mercury loads from these watersheds and potential reduction strategies.

Regardless of whether MUN is specifically designated by the Basin Plan (and the CTR criterion is enforceable), the numeric targets and mercury control actions in this and other TMDLs will

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[8] Personal communication from P. Woods (USEPA Region 9) to J. Marshack (CVRWQCB), 4 December 2001.

ensure that the CTR's level of human health protection is met throughout the Delta and Yolo Bypass. The CTR mercury criterion protects human health and is intended to be used where consumption of aquatic organisms occurs, which includes the Delta with the Marsh Creek subarea and Yolo Bypass. The proposed fish tissue objective will also apply to all of the Delta subareas and the Yolo Bypass. Since the proposed fish tissue objectives are more stringent than the CTR mercury criterion, attainment of the fish tissue objectives will also meet the aim of the CTR for protection of people that eat local fish.

The USFWS and the U.S. National Marine Fisheries Service are concerned that the mercury objective in the CTR may not protect threatened and endangered species and requested that the USEPA reevaluate the criterion. The USEPA has not released a reevaluation. Staff developed the TMDL's wildlife target evaluation and the Basin Plan amendments' proposed fish tissue objective for small fish with guidance from USFWS to ensure that threatened and endangered species will be protected.

2.4.2.3 San Francisco Bay Mercury TMDL's Allocation for Total Mercury in Central Valley Outflows

As a component of the mercury control program for the San Francisco Bay, San Francisco Water Board staff developed a target for San Francisco Bay sediment mercury concentration (particle-bound mercury mass divided by sediment mass) of 0.2 mg/kg and assigned the Central Valley a five-year average total mercury load allocation of 330 kg/yr at Mallard Island or a decrease of 110 kg/yr in mercury sources to the Delta (Johnson and Looker, 2004; SFBRWQCB, 2006). Compliance with the allocation can be assessed by one of two methods:

> "First, attainment may be demonstrated by documentation provided by the Central Valley Water Board that shows a net 110 kg/yr decrease in total mercury entering the Delta from within the Central Valley region. Alternatively, attainment of the load allocation may be demonstrated by multiplying the flow-weighted suspended sediment mercury concentration by the sediment load measured at the RMP Mallard Island monitoring station. If sediment load estimates are unavailable, the load shall be assumed to be 1,600 million kg of sediment per year. The mercury load fluxing past Mallard Island will be less than or equal to 330 kg/yr after attainment of the allocation."
> (San Francisco Bay Basin Plan, Chapter 7)

Central Valley Water Board staff will recommend to the Central Valley Water Board that the 110 kg total mercury reduction be met by reductions in total mercury entering the Delta from within the Central Valley. Initial reduction efforts should focus on the Cache Creek, Feather River, American River, Cosumnes River and Putah Creek watersheds because they export the largest volume of highly contaminated sediment (see Chapter 8 in this TMDL report and Chapter 4 in the draft Basin Plan Amendment staff report). Load calculation methods and strategies for reducing total mercury loading to San Francisco Bay are discussed more in Chapters 7 and 8 of this report and in the draft Basin Plan Amendment staff report.

Key Points

- The federal Clean Water Act (CWA) requires States to identify water bodies that do not meet their designated beneficial uses and to develop programs to eliminate impairments. States refer to the control program as a Total Maximum Daily Load (TMDL) program. A TMDL is the total maximum daily load of a pollutant that a water body can assimilate and still attain beneficial uses.
- The State of California Porter-Cologne Water Quality Control Act requires the Central Valley Water Board to develop a water quality control plan for each water body in the Central Valley that does not meet its designated beneficial uses. The Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (the Basin Plan) is the legal document that describes the beneficial uses of all water bodies in these basins, adopted water quality objectives to protect them, and, if the objectives are not being met, an implementation program to correct the impairment.
- This draft TMDL report addresses scientific peer review comments on the June 2006 draft TMDL report, Central Valley Water Board member comments and questions voiced during the March 2007 workshop, additional input from agencies and stakeholders during the 2008-2009 Stakeholder Process, and supplementary evaluations to support the Basin Planning effort described in the draft Basin Plan Amendment staff report. After staff has addressed any public comments on this draft TMDL and Basin Plan Amendment staff reports, the final draft Basin Plan Amendment staff report will be presented to the Central Valley Water Board for their consideration later in 2010.
- In 1990 the Central Valley Water Board identified the Delta as impaired by mercury because fish had elevated levels of mercury that posed a risk for human and wildlife consumers. In addition, the San Francisco Bay mercury control program identified Central Valley outflows via the Delta as one of the principal sources of total mercury to San Francisco Bay and assigned the Central Valley a load reduction of 110 kg/yr. Therefore, the final mercury TMDL control plan for the Delta must ensure protection of human and wildlife health in the Delta and meet the San Francisco Bay load allocation for the Central Valley.
- The scope of the Delta methylmercury TMDL includes all waterways within the legal Delta boundary and the Yolo Bypass north of the Delta. This TMDL addresses both methyl and total mercury. Reductions in methylmercury concentrations in ambient water are required to reduce methylmercury concentrations in fish. Reductions in total mercury loads are needed to maintain compliance with the USEPA's criterion of 50 ng/l; to prevent increases in total mercury discharges from causing increases in water and fish methylmercury in the Delta, thereby worsening the impairment; to meet the San Francisco Bay TMDL allocation to the Central Valley; and to reduce methylmercury production in Delta waterways.
- Elevated fish mercury concentrations occur along the periphery of the Delta while lower body burdens are measured in the central Delta. Concentrations are greater than recommended as safe by the USEPA and USFWS at all locations except in the central Delta. Percent reductions in fish methylmercury levels ranging from 0% to 80% in the peripheral Delta subareas will be needed to meet the numeric targets for wildlife and human health protection.

3 POTENTIALLY CONTROLLABLE METHYLATION PROCESSES IN THE DELTA

The primary problem with mercury in the Delta's aquatic ecosystems can be defined as biotic exposure to methylmercury (Wiener *et al.*, 2003a). Therefore, decreasing biotic exposure to methylmercury is the ultimate goal of the Delta methylmercury TMDL and implementation program. Several published papers provide comprehensive reviews of the current knowledge of the methylmercury cycle (e.g., Wiener *et al.*, 2003a and 2003b; Tetra Tech, Inc., 2005a; LWA, 2002). This chapter focuses on the processes that are potentially controllable in the Delta. The concepts summarized in this chapter guided the development of the methylmercury TMDL for the Delta, particularly the linkage analyses (Chapter 5), methyl and total mercury source analyses (Chapters 6 and 7), and recommended methylmercury allocations and total mercury limits (Chapter 8). Data gaps and uncertainties associated with each factor are identified in this chapter and then addressed further by recommendations for source characterization and control studies in Chapter 4 of the draft Basin Plan Amendment staff report.

Methylmercury concentrations in aquatic ecosystems are the result of two competing processes: methylation and demethylation. Methylation is the addition of a methyl group (CH_3) to an inorganic mercury molecule (Hg^{+2}). Sulfate reducing bacteria are the primary agents responsible for the methylation of mercury in aquatic ecosystems (Compeau and Bartha, 1985; Gilmour *et al.* 1992). Small amounts of methylmercury also may be produced abiotically in sediment (Falter and Wilken, 1998). Maximum methylmercury production occurs at the oxic-anoxic boundary in sediment, usually several centimeters below the surface. Although less common, methylmercury also may be formed in anaerobic water (Regnell *et al.*, 1996 and 2001). In this case, mercury-methylating microbes move from the sediment to the overlying water and the resulting methylmercury becomes available to the biotic community when aerobic and anaerobic waters mix. Methylmercury is a byproduct of the metabolism of sulfate-reducing bacteria. The amount of methylmercury produced is a function of the amount of active bacteria, their available food, and conditions that affect bacterial growth, such as temperature and pH. Given conditions and food positive for growth, sulfate-reducing bacteria will produce methylmercury even if methylmercury is present in the surrounding environment (i.e., methylmercury production is not controlled by chemical equilibrium).

Demethylation is both a biotic and abiotic process. Both sulfate reducing and methanogen-type bacteria have been reported to demethylate mercury in sediment with maximum demethylation co-occurring in the same zone where maximum methylmercury production is located (Marvin-DiPasquale *et al.*, 2000). Photodegradation of methylmercury in the water column also has been observed (Sellers *et al.*, 1996; Byington *et al.*, 2005; Gill, 2008a). While not well studied, the rates of both biotic and abiotic demethylation appear important in controlling net methylmercury concentrations in aquatic ecosystems (Sellers and Kelly, 2001; Marvin-DiPasquale *et al.*, 2000).

Factors controlling sediment methylmercury production have been the subject of intense scientific research (for reviews see Wiener *et al.*, 2003b and Benoit *et al.*, 2003). Sediment factors and landscape events important in net methylmercury production include:

- Sulfate and pH concentration of the overlying water (Gilmour *et al.*, 1998; Miskimmin *et al.*, 1992; Krabbenhoft *et al.*, 1999);

- Percent organic content of the sediment (Krabbenhoft *et al.*, 1999; Miskimmin *et al.*, 1992; Hurley *et al.*, 1998; Heim *et al.*, 2003; Slotton *et al.*, 2003);
- Creation of new water impoundments (Verdon *et al.*, 1991; Bodaly *et al.*, 1997);
- Amount and kind of inorganic mercury present in the sediment (Krabbenhoft *et al.*, 1999; Bloom, 2003); and
- Amount of permanent or seasonally flooded wetland in a watershed (Krabbenhoft *et al*., 1999; Brumbaugh *et al*., 2001; St Louis *et al*., 1994 and 1996; Hurley *et al*., 1995).

Sediment factors and landscape events important in net methylmercury loss in the Delta include:

- Deposition of particle-bound methylmercury in the water column; and
- Photodegradation of methylmercury in the water column.

The significance of deposition and photodegradation in the Delta were reported in the second set of CALFED mercury reports released in 2008 (Stephenson *et al.*, 2008; See Section 3.6)

The level of oxygenation in a water body also affects methylmercury production. The San Francisco Bay Regional Water Quality Control Board required the Santa Clara Water District to test methylmercury controls in three of its reservoirs and to report monitoring results (SFBRWQCB, 2008). Levels of methylmercury in the water column of Lake Almaden decreased significantly after the Santa Clara Valley Water District installed solar-powered water circulators (SCVWD IMC, 2009). Aeration has not been specifically tested in the Delta as a measure to reduce methylmercury concentrations, but may be effective in some situations, such as dredged material settling ponds.

The following sections focus on potentially controllable processes for within-channel methylmercury sources (e.g., wetlands and open-water habitat). Additional point and nonpoint sources are described in Chapters 6, 7 and 8. The organic content of the sediment and the pH of the overlying water are not discussed further as neither appears controllable in the Delta.

3.1 Sulfate

Sulfate is used by sulfate reducing bacteria as the terminal electron acceptor in the oxidation of organic material. Sulfate additions have been observed to both stimulate (Gilmour *et al.*, 1992; King *et al.*, 2002) and inhibit (Benoit *et al.*, 1999; Gilmour *et al.*, 1998) methylmercury production. Addition of sulfate is predicted to stimulate methylmercury production when it is limiting. In contrast, sulfate amendments may inhibit production when excess sulfide is present. Sulfide is the primary byproduct in the reduction of sulfate and increasing sulfide concentrations may cause inhibition by either decreasing the amount of neutrally charged dissolved mercury-sulfide complexes[9] (Benoit *et al.*, 1999 and 2001, but see Kelley *et al.*, 2003, for conflicting results) or by precipitating insoluble mercuric sulfide (Compeau and Bartha, 1985).

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[9] Dissolved, neutrally charged mercury is the only form that readily crosses microbial cell membranes.

Two factors influencing sulfate concentrations in the Delta are the water quality objectives for electrical conductivity (EC) and the ratio of San Joaquin River to Sacramento River water. Both are controllable water quality factors and result from water management decisions made by the State of California. Table 3 of Water Rights Decision 95-1WR stipulates maximum ambient electrical conductivity values for various locations in the Delta by month and water year type (SWRCB, 1995). Electrical conductivity in the Delta is primarily a function of freshwater outflow and seawater intrusion.[10] Water Right Decision 95-1WR regulates electrical conductivity by specifying both the amount of freshwater outflow and the amount of water exported to southern California. For example, during 2000-2001, the 2 o/oo salinity level[11] in ambient bottom water was located as far seaward as the City of Martinez in March 2000, but migrated as far upstream as Rio Vista in the summer of 2001 (Foe, 2003). The upstream movement of the salinity field had the effect of increasing sulfate concentrations in western Delta water by about ten-fold.

Sulfate concentrations are about seven times higher in the San Joaquin River than in the Sacramento River. At present, the San Joaquin River is almost entirely diverted out of the Delta by way of Old River and Grantline Canal for export to southern California via the state and federal pumping facilities near Tracy. This reduces the proportion of San Joaquin River water in much of the southern and central Delta and allows intrusion of Sacramento River water with lower sulfate concentrations. The Record of Decision for the CALFED Bay-Delta Program committed the State to evaluate and, if practical, begin construction of a series of permanent, operable barriers in the southern Delta to better control the routing of San Joaquin River water (CALFED Bay-Delta Program, 2004b). An indirect consequence of the permanent barriers is that their operation will determine sulfate concentrations in much of the central and southern Delta.

Sulfate amendment studies need to be undertaken with sediment collected throughout the year from the southern, central and western Delta to determine whether the sulfate concentration in the overlying water affect methylmercury production in sediment. Results of these experiments can be considered when evaluating how to manage the permanent, operable barriers in the southern Delta and when considering water right decisions to modify the location of the salinity field in the Delta.

3.2 New Water Impoundments

The creation of new water impoundments has been found to stimulate sediment microbial activity and to increase methylmercury concentrations in sediment, water and biota (Verdon *et al.*, 1991; Bodaly *et al.*, 1997). The State of California has a growing population and a limited water supply for municipal and agricultural use. One alternative under evaluation is the construction of additional reservoir storage. The Record of Decision for the CALFED Bay-Delta Program directs agencies and local interests to continue to evaluate five surface water storage options to improve water management (CALFED Bay-Delta Program, 2004a). These include north of Delta off-stream storage, in-Delta storage, Shasta Lake expansion, Los Vaqueros

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[10] Sulfate concentrations in the Sacramento and San Joaquin Rivers varied between 6-14 and 42-108 mg/l in 2000 and 2001 (Foe, 2003) while full strength seawater is 2,700 mg/l (Parsons and Takahashi, 1973).

[11] Salinity is generally reported in terms of parts per thousand (abbreviated o/oo), the number of pounds of salt per 1,000 pounds of water.

Reservoir expansion and upper San Joaquin storage. Environmental planning for each project is underway and should evaluate the potential of each new facility to increase downstream methylmercury concentrations in the Delta.

3.3 Sediment Mercury Concentrations

Methylmercury production has been found to be a function of the total mercury content of the sediment. Methylmercury concentrations[12] adjusted for the organic content of the sediment increased logarithmically with increasing total mercury concentration in a study of 106 sites from 21 basins across the United States (Krabbenhoft *et al.*, 1999). The slope of the relationship was linear to approximately 1 mg/kg total mercury before commencing to asymptote. Similar linear relationships have been observed in the Delta between methyl and total mercury concentrations in sediment (Table 3.1). The statistical significance of the correlation increases when data from one land use type (e.g., marshes) are used. This implies that methylation rates may also be a function of habitat type. The results are consistent with laboratory experiments where increasing concentrations of inorganic mercury were amended into sediment and the evolution of methylmercury monitored. The efficiency of the conversion of total to methylmercury was linear to about 1 mg/kg before commencing to level off (Bloom, 2003; Rudd *et al.*, 1983).

Mercury concentrations in fish at contaminated sites decline after control measures are instituted to reduce incoming mercury loads (Table 3.2). Most sites studied to date are industrial facilities that discharge to fresh water and have operated for relatively short periods.[13] The initial decrease in fish tissue concentration near the source of contamination is often fast with about a 50% decline in the first five to ten years. However, after a rapid initial decrease, concentrations tend to stabilize with little, if any, subsequent decline (Turner and Southworth, 1999; Takizawa, 2000; Lodenius, 1991; Lindestrom, 2001; Francesconi *et al*., 1997). The new equilibrium value is usually higher than in adjoining uncontaminated waterways and is also often greater than what is recommended as safe for human consumption (Turner and Southworth, 1999; Parks and Hamilton, 1987; Lodenius, 1991; Lindestrom, 2001; Francesconi *et al*., 1997; Becker and Bigham, 1995). The reasons are unclear but may be because small amounts of mercury are still entering from terrestrial sources (Turner and Southworth, 1999) or because of difficulties in bringing sediment concentrations down to background levels (Francesconi *et al*., 1997; Jernelov and Asell, 1975). If contamination has spread to areas more distant than the immediate facility, then reductions in fish tissue concentrations are much slower (Southworth *et al*., 2000). Absent from the literature are reports on remediation of pollution from mercury mining. The magnitude and duration of mercury and gold mining in California, coupled with the extensive distribution of contamination, will likely make recovery much slower than at industrial sites (Table 3.2).

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[12] Radiotracer experiments in Florida Everglade sediment demonstrate that methylmercury production is positively correlated with bulk sediment methylmercury concentrations (Gilmour *et al.*, 1998). Moreover, the spatial pattern of methylmercury production was strongly correlated with aqueous and biotic concentrations, suggesting that surficial sediment concentrations could be used as an analog for *in situ* methylmercury production and flux into the overlying water. Bulk methylmercury sediment concentrations are now widely used as an index of methylmercury production (Krabbenhoft *et al.*, 1999; Bloom *et al.*, 1999 and 2003; Heim *et al.*, 2003; Slotton *et al.*, 2003; Conaway *et al.*, 2003; Benoit *et al.*, 1999).

[13] One to two decades.

As part of the mercury control program for San Francisco Bay, San Francisco Water Board staff established a goal for Bay sediment of 0.2 mg/kg mercury and assigned Central Valley outflows a total mercury load reduction of 110 kg per year to achieve it (Johnson and Looker, 2004; SFBRWQCB, 2006). Waterborne mercury and total suspended sediment loads in the Delta's tributaries are summarized in Chapter 7. Initial management actions of the Delta methylmercury TMDL could consider controlling mercury from watersheds with high methylmercury concentrations in fish, high mercury to suspended sediment ratios and large areas of downstream marsh. The initial goal would be to meet the San Francisco Water Board's goal of 110 kg total mercury reduction per year, but additional load reductions eventually may be needed to achieve compliance with the recommended fish tissue methylmercury targets for the Delta (Chapter 4).

Table 3.1: Field Studies Demonstrating a Positive Correlation Between Total Mercury and Methylmercury in Freshwater Surficial Sediment

Location (a)	**R^2**	**P-Value**	**Comments**	**Author**
Sacramento-San Joaquin Delta Estuary	0.2	<0.01	All habitats in Delta combined.	Heim *et al.*, 2003
Sacramento-San Joaquin Delta Estuary	0.52	<0.001	Only marsh habitats.	Heim *et al.*, 2003
Sacramento-San Joaquin Delta Estuary	0.37	<0.001	Comparisons inside and outside of flooded Delta Islands.	Slotton *et al.*, 2003
Elbe River	0.69	<0.0001	Germany.	Hintelmann & Wilken, 1995
Patuxent River Estuary	0.61	<0.05	Sub embayment of Chesapeake Bay.	Benoit *et al.*, 1998
National Survey	0.62	<0.0001	Log/log relationship normalized to percent organic carbon at 106 sites in 21 basins across the United States.	Krabbenhoft *et al.*, 1999
Lake Levrasjon	0.64	<0.05	Southern Sweden.	Regnell & Ewald, 1997

(a) The majority of the sediment in each study had a mercury content less than 1 ppm.

Table 3.2: Change in Fish Tissue Mercury Concentration After Initiation of Source Control.

Location	Mercury Source	Biotic Change	Control Measures	References
Oak Ridge National Laboratory, Tennessee	Weapons Facility	Sunfish at discharge point declined from 2 to 1 mg/kg in 5 yrs; half mile downstream sunfish declined from 0.9 to 0.7 mg/kg in 9 yrs; no change in tissue 2 and 5 miles downstream.	Reduced discharge, excavated portion of flood plain.	Turner & Southworth, 1999; Southworth *et al.*, 2000
Lake St. Clair, Michigan	Two Chloralkali Plants	Walleye fish declined from 2.3 to 0.5 mg/kg in 25 yrs	Reduced/eliminated discharge	Turner & Southworth, 1999.
Abbotts Creek, North Carolina	Battery Manufacturing plant	Fish declined from 1 to 0.5 mg/kg in 11 yrs	Treated groundwater, reduced/eliminated discharge, removed contaminated soil, natural sediment burial	Turner & Southworth, 1999
Saltville, Virginia	Chloralkali Plant	Rockfish declined from 3.5 to 1 mg/kg in 20 yrs	River sediment dredged, rock bottom grouted, rip-rap river bank, pond seepage treated with activated carbon	Turner & Southworth, 1999
Howe Sound, British Columbia, Canada	Chloralkali Plant	Dungeness crab declined from 2 to 0.2 mg/kg in 5 yrs. No subsequent change	Reduced/eliminated discharge, treated groundwater	Turner & Southworth. 1999
Little Rock Lake, Wisconsin	Atmospheric deposition	Yellow Perch declined 30% in 6 yrs	Reduced atmospheric mercury input by 60%.	Hrabik & Watras, 2002.
Minimata, Japan	Chloralkali Plant	Fish declined from 9.0 to 0.4 mg/kg in 8 yrs; no further change.	Eliminated discharge; dredged and disposed of sediment.	Takizawa, 2000
Clay Lake, Ontario, Canada	A chloralkali plant and a wood pulp mill.	Walleye fish declined from 15.1 to 2.0 mg/kg in 20 yrs. Background concentration is 0.6 mg/kg.	Eliminated discharge; natural burial of contaminated sediment	Parks & Hamilton, 1987; Turner & Southworth, 1999.
Ball Lake, Ontario, Canada (downstream of Clay Lake)	Same as above	Walleye fish declined from 2.0 to 1.4 mg/kg in first 5 yrs. Northern Pike from 5.1 to 1.8 mg/kg. No change in Lake Whitefish.	Same as above	Armstrong & Scott, 1979
Lake Kirkkojarvi, Finland	Phenylmercury in slimicide in pulp mill	4 and 1-kg Northern Pike declined from 3.6 to 2.1 and from 1.5 to 0.8 mg/kg in 20 yrs. All reductions happened in first 10 yrs. Background concentration in 1-kg pike is 0.4 mg/kg.	Reduced discharge, natural burial	Lodenius, 1991
Lake Vanern, Sweden	Chloralkali Plant	5-yr old Northern Pike declined from 1.4 to 0.6 mg/kg in 25 yrs. Most of decrease occurred in first 10-15 yrs. Background concentrations in Pike are 0.4 mg/kg	Reduced/eliminated discharge, natural burial	Lindestrom, 2001
Princess Royal Harbor, Australia (Marine water)	Superphosphate Processing Plant	Mercury in 8 marine fish species declined by about 50% in 9-yrs. Most of decrease happened in first 4-yrs. Tissue concentrations are still about twice background.	Eliminated discharge, natural burial	Francesconi *et al.*, 1997
Onondaga Lake, New York	Municipal and industrial discharge	Mercury in six fish species declined by 60 to 80 % in 22 yrs. Tissue concentrations are still about twice background.	Eliminated discharge, natural burial	Becker & Bigham, 1995.
North Carolina, Quebec, Finland, Manitoba, Labrador and Newfoundland	Reservoir creation	Fish tissue levels declined to normal after 3 to 30 years.	None	As reviewed in French *et al.*, 1998.

3.4 Forms of Mercury

There are primarily two different forms of mercury transported into the Delta with potentially different methylation rates. The first form is mercury mine waste from the Coast Range. Most of this material is thought to be mercuric sulfide, cinnabar and metacinnabar (Bloom, 2003). Mercury mine waste enters the Delta from mine-impacted coast range creeks such as Putah and Cache Creeks. The second form is elemental mercury lost from placer and hardrock gold mining operations in the Sierra Nevada Mountains. Elemental mercury enters the Delta in Sacramento, Mokelumne and San Joaquin River water that drains from the northern and southern gold fields. [Additional sources of mercury are described in Chapter 7.]

Mercury from gold mining appears to be more biologically available than material from mercury mines. The evidence is twofold. First, Frontier Geosciences conducted a 1-year microcosm incubation study with both gold and mercury mine waste to determine the relative methylation efficiency of each (Bloom, 2003). Mercury from gold mining was found to have the higher methylation rate. Second, the ratio of methyl to total mercury in natural sediment is assumed to be a field measure of methylation efficiency (Gilmour *et al.*, 1998; Krabbenhoft *et al.*, 1999; Bloom *et al.*, 1999 and 2003). Heim and others (2003) collected sediment at multiple locations in Cache Creek (representative of mercury mine waste) and the Cosumnes River (representative of gold mine material) on three occasions (October 1999, May 2001 and October 2001) to determine methyl and total mercury concentrations and methylation efficiencies. The highest methyl to total mercury ratios were consistently observed in Cosumnes River material. These results are consistent with the conclusions of Bloom (2003) and suggest that floured elemental mercury from gold mining in the Sierra Nevada is more readily methylated than is cinnabar from the Coast Range.

Heim and others (2003) also collected sediment samples at multiple locations in Cache Creek. The ratio of methylmercury to total mercury increased with increasing distance from the mercury mining districts. The authors speculate that diagenic weathering-type processes are changing the form of the mercury and increasing its methylation efficiency as the material is slowly transported away from the mines. The precise mechanisms are not known but may include the formation of soluble polysulfide complexes (Paquette and Heltz, 1995) and dissolution of cinnabar by humic and fulvic acids (Wallschläger *et al.*, 1998; Ravichandran *et al.* 1998). Both processes should increase the efficiency of the conversion of inorganic to organic mercury. No similar weathering type experiments have been conducted on Sierra Nevada gold mine-derived mercury. The Cache Creek findings suggest that there is currently insufficient understanding of mercury weathering processes to justify developing control programs that preferentially target controlling gold-mine waste material.

3.5 Wetlands

Research in the Delta and elsewhere has found that wetlands are sites of efficient methylmercury production (Slotton *et al.*, 2003; Heim *et al.*, 2003; St. Louis *et al.*, 1994, 1996; Gilmour *et al.*, 1998). In fact, one of the best predictors of methylmercury concentrations in water and in biota is the amount of wetland present in upstream watersheds (Krabbenhoft *et al.*, 1999; Wiener *et al.*, 2003b). The Record of Decision for the CALFED Bay-Delta Program commits it to restore 30,000 to 45,000 acres of fresh, emergent tidal wetlands, 17,000 acres of fresh, emergent nontidal wetlands, and 28,000 acres of seasonal wetlands in the Delta by 2030 (CALFED Bay-Delta Program, 2000b). This is a total of 75,000 to 90,000 acres of additional seasonal and permanent wetlands in the Delta, which represents about a three to four times increase in wetland acreage from current conditions. Many of the proposed restoration sites are downstream of mercury-enriched watersheds. Marsh restoration efforts below mercury enriched watersheds are proposed for the following locations: Yolo Bypass downstream of Cache and Putah Creeks; Dutch Flats downstream of the Mount Diablo Mercury mine in the Marsh Creek watershed; and Staten Island and the Cosumnes River Wildlife Refuge near the confluence of the Cosumnes River and Mokelumne River. Extensive restoration efforts in the Delta have the potential to increase methylmercury exposure for people and wildlife. This potentially significant adverse environmental impact was identified in CALFED's programmatic ROD's CEQA evaluation.

Even though much of the research has found that wetlands act as sources of methylmercury, recent data indicate that some wetlands may act as net methylmercury sinks. Table 3.3 provides a summary of methylmercury production characteristics from different types of wetlands in the Delta region. In addition, a technical review of the June 2006 TMDL Report described a study conducted in southern Florida, in which different wetland and open water sites were found to contain varying levels of methylmercury (Tetra Tech, Inc., 2006). More research is needed to understand the processes that affect a wetland's methylmercury production, so that wetland restoration can occur with minimal methylmercury production increases.

Table 3.3: Summary of Wetland Methylmercury Production Characteristics.

Watershed	Site [(a)]	Wetland Type	MeHg Characteristics [(b)]
Delta	Twitchell Island (1)	2 Permanent (test ponds)	Both sources
	Browns Island (2)	Permanent, tidal	Small source
	Sycamore Slough (3)	Permanent, tidal	Sink
	Grizzly Island (Suisun Marsh) (4)	2 Seasonal	Source
Cache Creek	Anderson Marsh (5)	Permanent	Source
	Cache Creek Nature Preserve (6)	Permanent	Source
Mud Slough	San Luis Wildlife Refuge (7)	2 Permanent	Both neutral
		6 Seasonal	All sources
Suisun Marsh	First Mallard Branch (interior marsh) (3)	Permanent, tidal	Source
	Suisun Slough (mouth) (3)	Permanent, tidal	Sink

(a) Study citations: (1) Sassone *et al*., 2006; Sassone *et al*., 2008 (2) Fleck *et al*., 2007; (3) Heim et al., 2007; (4) Stephenson *et al*., 2008; (5) CVRWQCB, unpublished data; (6) Slotton and Ayers, 2001; (7) Stephenson *et al*., 2007.

(b) Wetlands that act as net producers of methylmercury are noted as "sources"; wetlands that act as sinks for methylmercury (e.g., more methylmercury is imported than exported) are noted as "sink"; and wetlands that apparently acted as neither a source nor sink for methylmercury are noted as "neutral".

3.6 Methylmercury Loss by Sedimentation and Photodemethylation

As water moves across the Delta from the Sacramento River to the pumps, settling of methylmercury bound to particles reduces aqueous methylmercury concentrations (Stephenson and Bonnema, 2008). Losses of methylmercury and particles were shown in samples collected as water from both the Sacramento and San Joaquin Rivers moved through the Delta (Heim *et al.*, 2008). The transect sampling by Heim and colleagues tracked the two largest sources of water entering the Delta and identified losses at two points: downstream of the convergence of the Sacramento River with Cache and Steamboat Sloughs and entry of San Joaquin River water into the San Joaquin Deep Water Ship Channel. The methylmercury loss in the San Joaquin River was not observed in some winter and spring sampling events. Data collected during the recent CalFed mercury project (Heim *et al.,* 2008; Foe *et al.*, 2008) were used in a particle transport model that demonstrated methylmercury movement in multiple flow paths across the Delta (Stephenson *et al*., 2008b). Methylmercury loss rates due to photodemethylation and particle settling varied by flow path and season.

Methylmercury loads from in-channel sources such as wetlands, ponds, and settling basins, as well as retention basins in urban areas, may be able to be controlled by enhancing their sediment trapping efficiency. During stakeholder meetings in 2009, entities responsible for methylmercury from managed wetlands and irrigated agriculture began gathering information and considering possible ways to enhance sedimentation of methylmercury. Ideas that could be investigated during studies in the first phase of the Delta mercury control program include: adding a sill or specific vegetation to trap sediment, creating small settling basins within drainage canals, and managing flow and depth within a pond or wetland system to maximize settling (Stephenson, 2009).

The results of the particle transport modeling (Stephenson *et al*., 2008b) could lead to changes in how the Delta subareas are delineated (see Section 2.2.2 in Chapter 2). For example, during a model run for August 2005 (Stephenson, 2009, video provided through pers. comm.), the particle tracking model indicates the San Joaquin River subarea could be re-delineated to include more of the Central Delta subarea, and the Sacramento River subarea could be re-delineated to include a portion of the southern Yolo Bypass subarea. If funding can be acquired, staff hopes to work with the particle transport model study authors to evaluate a variety of typical hydrographic periods and, if needed, re-delineate the Delta subareas to better reflect the water and sediment sources that drive water and fish methylmercury concentrations in different Delta areas.

Key Points

- The problem with mercury in the Delta’s aquatic ecosystems can be defined as biotic exposure to methylmercury. Therefore, decreasing biotic exposure to methylmercury is the ultimate goal of the Delta methylmercury TMDL and implementation program.
- The implementation plan should focus on sources and processes that are potentially controllable in the Delta. Potentially controllable sediment factors and landscape events important in net methylmercury production include: water rights salt standards in the Delta; creation of new water impoundments; amount of inorganic mercury present in the sediment; and management of permanent or seasonally flooded wetland in a watershed.

4 NUMERIC TARGETS

Water quality targets for mercury in fish were calculated to protect beneficial uses of the water and aquatic resources of the Delta. The targets are intended to reduce the risks to humans and wildlife that consume fish and other aquatic organisms from the Delta that contain methylmercury. This chapter first describes the derivation of species-specific targets based on a suite of fish types to protect humans and wildlife. The Central Valley Water Board staff proposes three targets for the protection of human and wildlife health: 0.24 mg/kg (wet weight) in muscle tissue of large trophic level four (TL4) fish such as bass and catfish; 0.08 mg/kg (wet weight) in muscle tissue of large TL3 fish such as carp and salmon; and 0.03 mg/kg (wet weight) in whole trophic level 2 and 3 fish less than 50 mm in length. In addition, staff proposes an implementation goal of 0.24 mg/kg methylmercury, wet weight, in standard 350-mm largemouth bass. As described in Chapter 5, this implementation goal can be linked to aqueous methylmercury to develop an implementation goal for methylmercury in unfiltered ambient water, which in turn can be used to determine methylmercury source reductions needed to achieve the proposed targets for methylmercury in fish.

In addition to addressing sources of methylmercury to the Delta, the Delta mercury control program addresses total mercury sources to the Delta and San Francisco Bay. The San Francisco Bay TMDL assigns a load reduction of 110 kg per year from the Central Valley (Johnson and Looker, 2004; SFBRWQCB, 2006). As described in later chapters of this report, the mercury control program for the Delta is designed to achieve the total mercury load reduction required by the San Francisco Water Board, as well as to maintain compliance with the USEPA's CTR for total mercury in freshwater sources and to limit total mercury sources to the Delta to ensure that methylmercury levels in fish do not increase in the future.

4.1 Definition of a Numeric Target

Numeric targets are the specific goals for the TMDL that will enable the protection of the beneficial uses of the Delta and San Francisco Bay. The development of numeric targets involves the following elements:

- Identification of the target media and the basis for using the selected target media to interpret or apply applicable water quality standards.
- Identification of target levels for the selected target media and the technical basis for the target levels.
- Comparison of historical or existing conditions and desired future conditions for the target media selected for the TMDL.

4.2 Clean Water Act 303(d) Listing and Beneficial Use Impairment

The Office of Environmental Health Hazard Assessment issued health advisories recommending that consumers limit their consumption of striped bass and sturgeon from the Delta and Bay because of high methylmercury tissue concentrations (Section 2.4.1). The fish advisory resulted in the Central Valley and San Francisco Water Boards listing the Bay-Delta Estuary as impaired.

By definition, an impaired water body does not support all of its designated beneficial uses. Existing and potential beneficial uses are listed in Table 2.3 in Chapter 2. The Delta provides habitat for warm and cold water species of fish and the aquatic communities associated with them. In addition, the Delta and associated riparian areas provide valuable wildlife habitat. Beneficial uses that are impaired due to high mercury levels include commercial and sport fishing and wildlife habitat.

4.3 Selection of the Type of Target for the Delta

4.3.1 Fish Tissue

Measurements of mercury in the target media should be able to assess fairly directly whether beneficial uses are being met. Several media for numeric targets were considered, including sediment, water column and biota. The major beneficial use of the Delta that is currently unmet is its use as a safe fishery for humans and wildlife. A target of mercury in fish tissue was determined to be the most appropriate because it provides the most direct assessment of fishery conditions and improvement. Fish tissue data have been collected between 1969 and 2002 in the Delta. Existing data for fish species consumed by humans and wildlife provide a baseline against which future improvements can be measured.

Targets are developed for **methylmercury** in fish tissue because it is the most toxic form of mercury. It is also the form to which humans and wildlife may be exposed in the Delta at levels sufficient to cause adverse effects. The cost for methylmercury analysis is greater than that for total mercury; therefore, most data available are for total mercury in fish tissue. Independent research demonstrates that most mercury (85-100%) in fish muscle is methylmercury (Becker and Bigham, 1995; Slotton *et al.*, 2004). For the purposes of the TMDL, Central Valley Water Board staff assumes that all the mercury measured in Delta fish is methylmercury.

4.3.2 San Francisco Bay Numeric Target

The Delta TMDL is structured to meet the San Francisco Bay mercury TMDL's total mercury allocation for Central Valley outflows to the Bay. San Francisco Water Board staff developed a target for San Francisco Bay sediment mercury concentration of 0.2 mg/kg and assigned the Central Valley a five-year average total mercury load allocation of 330 kg/yr at Mallard Island or a decrease of 110 kg/yr in mercury sources to the Delta. The 2004 San Francisco Bay mercury TMDL staff report provides a detailed derivation of the San Francisco Bay sediment target and allocation for the Central Valley (Johnson and Looker, 2004; SFBRWQCB, 2006). Strategies for reducing the total mercury loading to San Francisco Bay are discussed in Chapter 8 in this TMDL report and Chapter 4 in the draft Basin Plan Amendment staff report.

4.3.3 Water Criteria

The California Toxics Rule (CTR) mercury criterion applies to the Delta (see Section 2.3.2.2). This criterion of 50 ng/l total recoverable mercury in water is intended to protect the health of humans consuming contaminated organisms and drinking water. The CTR value may not be sufficiently protective of humans consuming fish from the Delta because of the low bioconcentration factors used to derive the CTR value. Central Valley Water Board staff considers fish tissue targets to be more stringent than the CTR criterion.[14] Although the CTR criterion may be less protective than the fish tissue targets discussed below, the TMDL was designed to comply with the CTR mercury criterion. Compliance with the CTR criterion through the TMDL is discussed in the total mercury source assessment (Chapter 7) and total mercury limits (Chapter 8) sections of this report.

4.4 Fish Tissue Target Equation and Development

Key variables that are incorporated into the calculation of fish tissue targets are:

- Acceptable daily dose level of methylmercury;
- Body weight (bwt) of the consumer;
- Trophic level or size of fish consumed; and
- Rate of fish consumption.

These components can be related using a basic equation (OEHHA, 2000; USEPA, 1995c) as follows.

Equation 4.1:

$$\frac{\text{Safe daily intake} * \text{Consumer's body weight}}{\text{Consumption rate}} = \text{Acceptable level of mercury in fish tissue}$$

At or below the safe daily intake of methylmercury, consumers are expected to be protected from adverse effects. An acceptable intake level is also called a reference dose (RfD). An RfD is expressed as an average daily rate (micrograms of mercury per kilogram body weight per day) of mercury intake. In general, an RfD is calculated by using studies of exposure in specific populations to determine a threshold level of exposure below which adverse effects did not occur. The threshold level is then divided by uncertainty factors that lower the value to the final reference dose. Uncertainty factors account for differences in metabolism and sensitivity between individuals, lack of toxicity information in available studies, or other unknowns.

In the calculation of its recommended methylmercury criterion to protect human health, USEPA added a relative source contribution (RSC) component to the equation to account for methylmercury from other sources (USEPA, 2001). Humans are exposed to methylmercury

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[14] The weighted average practical bioconcentration factor (PBCF) used to develop the CTR mercury criterion is 7342.6 (USEPA, 2000b). For the Delta, bioaccumulation factors (BAF) for large trophic 4 fish are in the range of 50,000 to 300,000. These BAFs are the ratios of mercury in fish to the concentration of total recoverable mercury in water. The Delta bioaccumulation factors indicate that piscivorous fish species in the Delta accumulate higher concentrations of mercury than USEPA's PBCF.

from commercial fish as well as locally caught fish. Human intakes of methylmercury from all other sources (air, drinking water, soil, and foods other than fish and seafood) are considered negligible. The RSC represents that portion of methylmercury exposure that will not be controlled by cleanup actions directed to a particular water body. Because piscivorous wildlife species are assumed to obtain all of their fish or other aquatic prey from the local water body, no RSC adjustment is used for the wildlife calculations. As with humans, the direct intake of methylmercury by piscivorous wildlife from air or water is negligible relative to intake from fish and aquatic organisms (USEPA, 1997a).

The consumption rate can be separated into rates of consumption of fish from each trophic level. Adjusting for multiple consumption rates and the RSC, the basic equation appears as follows.

Equation 4.2:

$$\frac{(\text{Safe intake} - \text{RSC}) * \text{body weight}}{(\text{CRate}_{TL2} + \text{CRate}_{TL3} + \text{CRate}_{TL4})} = \begin{array}{c}\text{Acceptable level of mercury} \\ \text{in Delta fish tissue}\end{array}$$

Where: CRate_{TL2} = consumption rate of fish from Trophic Level 2

CRate_{TL3} = consumption rate of fish from Trophic Level 3

CRate_{TL4} = consumption rate of fish from Trophic Level 4

Safe levels of methylmercury in fish tissue that protect wildlife are presented first in this report, followed by the human health targets. The order of presentation and in-depth discussion of wildlife methodology are not intended to suggest greater importance of wildlife targets relative to human health targets. Rather, wildlife targets are discussed first because the safe fish tissue levels are based on average consumption rates that are assumed to be constant. Human consumption rates, however, vary widely by individual. For targets to protect human consumers, consumption rate options are incorporated into the calculations.

4.5 Wildlife Health Targets

Birds and mammals most likely at risk for mercury toxicity are primarily or exclusively piscivorous. Those identified for the Delta are: American mink, river otter, bald eagle, kingfisher, osprey, western grebe, common merganser, peregrine falcon, double crested cormorant, California least tern, and western snowy plover[15] (USEPA, 1997a; CDFG, 2002). Bald eagles, California least terns and peregrine falcons are listed by the State of California or by the USFWS as either threatened or endangered species. The Delta is a foraging and possible wintering habitat for bald eagles (USFWS, 2004). California least terns also forage in the Delta. There is at least one nesting colony of these terns within the Delta (USFWS, 2004).

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[15] The CDFG *California Wildlife Habitat Relationships* database also reports observations of brown pelicans and clapper rails in the Delta. Both of these species are federally listed as endangered and depend on the aquatic food web. However, it has been confirmed that brown pelicans and clapper rails prefer saltwater habitats and are only occasional visitors to the Delta regions as discussed in this TMDL (Schwarzbach, 2003; CDFG, 2005). Peregrine falcon are included because they consume piscivorous waterfowl.

Although most of the Delta habitat is unlike that preferred by peregrine falcons for nesting, several peregrine falcon pairs have nested on bridges in the area (Linthicum, 2003).

Acceptable fish tissue mercury levels for wildlife species can be calculated using daily intake levels, body weights and consumption rates. Parameters needed to estimate daily methylmercury exposures and safe levels of methylmercury in prey for wildlife are given in Table 4.1. Mercury studies conducted in the laboratory and field are used to derive RfD for birds and mammalian wildlife. The following section uses these RfDs to calculate fish tissue targets to protect the health of wildlife in the Delta.

4.5.1 Reference Doses, Body Weights & Consumption Rates

The reference dose for mammalian wildlife species of 0.018 mg methylmercury/kg bwt/day is based on studies in which mink were fed methylmercury at varying doses and evaluated for neurological damage, growth and survival (USEPA, 1995a; USEPA, 1997b). Studies of mallard growth and reproduction following methylmercury exposure were used to determine a methylmercury reference dose for birds of 0.021 mg/kg bwt/day (USEPA, 1997b). For each of reference doses, the lowest toxic dose was divided by three (uncertainty factor) to account for differences in species' and individuals' reactions to mercury and produce a dose level at which harmful effects are not expected (USFWS, 2003).

Average body weights of adult females are used because the most sensitive endpoints of methylmercury toxicity are related to reproductive success. The USFWS provided guidance to Central Valley Water Board staff regarding the species of concern and their exposure parameters (USFWS, 2002, 2003 and 2004).

4.5.2 Safe Methylmercury Levels in Total Diet

Fish tissue mercury levels that would result in methylmercury intakes by piscivorous wildlife at or below safe intake levels are calculated in two steps. First, safe levels of methylmercury in the total diet of each wildlife species are calculated (Table 4.2). The total diet safe level represents the concentration of methylmercury, as an average in all prey consumed, needed to keep the organism's daily intake of methylmercury below the reference dose. Total diet safe levels were calculated using the exposure parameters for wildlife species and Equation 4.1. In the second step, the total diet safe level is translated into protective levels of methylmercury in various components of an organism's diet (Table 4.3). An example calculation of the total safe diet level for mink is shown below:

$$\frac{\text{Mammalian reference dose * Mink body weight}}{\text{Mink fish consumption rate}} = \text{Total diet safe level}$$

$$\frac{18\ \mu\text{g MeHg/kg day * 0.60 kg}}{140\ \text{g/day}} = 0.077\ \mu\text{g MeHg/g total diet (0.077 mg/kg)}$$

Table 4.1: Exposure Parameters for Fish-Eating Wildlife

Species (a)	**Body weight** (b)	**Total Food Ingestion Rate** (c)	**Trophic Level 2 Aquatic Prey**	**Trophic Level 3 Aquatic Prey**	**Trophic Level 4 Aquatic Prey**	**Piscivorous Bird Prey**	**Omnivorous Bird Prey**	**Other Foods** (d)	**Size of Prey**
	kg	g/day, wet wt	g/day, as % of diet	g/day, as % of diet	g/day, as % of diet	g/day, as % of diet	g/day, as % of diet	g/day, as % of diet	
Mink	0.60	140	-	140 (100%)	-	-	-	-	most prey 50-150mm; females catch smaller prey than males (USEPA, 1995b)
River otter	6.70	1124	-	899 (80%)	225 (20%)	-	-	-	heterogeneous, 20-500 mm (USEPA, 1995b); majority <150 mm but commonly catch large TL4 fish.
California least tern	0.045	31	-	31 (100%)	-	-	-	-	mostly < 50 cm, nearly all fish
Western snowy plover	0.041	33.3	8.3 (25%)	-	-	-	-	25 (75%)	mainly aquatic and terrestrial invertebrates. Assume TL2 aquatic prey is 25% of diet (USFWS, 2003)
Belted kingfisher	0.15	68	-	68 (100%)	-	-		-	generally less than 105 mm; up to 180 mm (Hamas, 1994)
Common merganser (e)	1.23	302	-	302(100%)	-	-	-	-	most prey <150 mm (USEPA, 1995b; Hatch & Weseloh, 1999)
Double-crested cormorant (f)	1.74	390	-	390 (100%)	-	-	-	-	generally 100-300 mm length; up to 360mm (Mallory & Metz, 1999)
Western grebe (g)	1.19	296	-	296 (100%)	-	-	-	-	USFWS assumed similar to merganser (USFWS, 2004)
Bald eagle (h)	5.25	566	-	328 (58%)	74 (13%)	28 (5%)	74 (13%)	62 (11%)	fish 75-500+ mm; most will be >150 mm (Jackman *et al.*, 1999; USEPA, 1995b).
Osprey (i)	1.75	350	-	315 (90%)	35 (10%)	-	-	-	fish 100-450 mm; most will be >200 mm.
Peregrine falcon (j)	0.89	134	-	-	-	6.7 (5%)	13.4 (10%)	114 (85%)	Does not eat fish.

Table 4.1 Footnotes:

(a) Italics denote species listed as threatened or endangered by state or federal authorities.

(b) Average female body weights are from *Trophic Level and Exposure Analyses for Selected Piscivorous Birds and Mammals Volume II* (USEPA, 1995b), USFWS (2003, 2004), and as noted below.

(c) Total food ingestion rates are from USEPA (1995b) and USFWS (2003; 2004) and as noted below.

(d) Other foods are mainly terrestrial mammal, bird, reptile and invertebrate prey that are presumed to provide negligible amounts of methylmercury.

(e) Merganser body weight and ingestion rate from Schwarzbach and others (2001).

(f) Cormorant body weight is the average for female birds cited in Hatch and Weseloh (1999). This paper also reports daily consumption at 20-25% of body mass. Total ingestion rate of 390 g/day is 22.5% of average female bodyweight.

(g) Female western grebe body weight from Storer and Nuechterlein (1992).

(h) Bald eagle parameters provided by the USFWS (2004). Diet of bald eagles in northern California includes fish, mammals and birds. Using dietary data from Jackman and others (1999), the USFWS estimated the average proportions of prey types. TL3 and TL4 fish comprised 58% and 13% of the total bald eagle diet, respectively. Piscivorous birds, such as gulls, grebes, and mergansers, comprised approximately 5% of the total diet. An additional 13% of the total diet was comprised of other aquatic birds, such as coots, that feed mainly on TL2 organisms. Bald eagles are scavengers and thus consume fish of large sizes (Jackman *et al.*, 1999).

(i) Osprey catch and eat large fish, the majority of which are >200 mm (USEPA, 1995b). In a water body where TL4 sport fish are readily available, osprey diet is assumed to be 10% TL4 fish (USFWS, 2002). Prey size is limited to the maximum size that an osprey can lift out of water.

(j) Peregrine falcons eat a wide variety of birds, including grebes, herons, shorebirds, mergansers, gulls and other birds that accumulate methylmercury from the aquatic food web. USFWS (2004) supports the assumption by Central Valley Water Board staff that approximately 15% of peregrine prey in the Delta area is comprised of piscivorous birds. See the appendices of the Cache Creek TMDL for Mercury staff report for further analysis of peregrine prey and habitat.

Table 4.2: Concentrations of Methylmercury in Total Diet to Protect Delta Wildlife Species

Species	**RfD** (µg/kg bwt-day)	**Body Weight** (kg)	**Total Food Ingestion Rate** (g/day)	**Safe Methylmercury Concentration in Total Diet** (mg/kg in diet)
Mink	18	0.60	140	0.077
River otter	18	6.70	1124	0.11
California least tern	21	0.045	31	0.030
Western snowy plover	21	0.041	33.3	0.026
Belted kingfisher	21	0.15	68	0.046
Common merganser	21	1.23	302	0.086
Double-crested cormorant	21	1.74	390	0.094
Western grebe	21	1.19	296	0.084
Bald eagle	21	5.25	566	0.20
Osprey	21	1.75	350	0.11
Peregrine falcon	21	0.89	134	0.14

Table 4.3: Safe Concentrations of Methylmercury in Fish (mg/kg) by Trophic Level to Protect Wildlife

Species [(a)]	TL 2, < 50 mm	TL 2-3, 50-150 mm	TL 3, 150-350 mm	TL 4, 150-350 mm	TL 3, >150 mm	TL 4, >150 mm
Mink		0.08				
River otter		0.04		0.36		
California least tern	0.03					
Western snowy plover [(b)]	0.10					
Belted kingfisher		0.05				
Double-crested cormorant		0.09				
Common merganser			0.09			
Western grebe			0.08			
Osprey			0.09	0.26		
Bald eagle [(c)]					0.11	0.31
Peregrine falcon [(d)]			(0.17)			

(a) Italics denote species that are listed as threatened or endangered by federal or state authorities.

(b) The snowy plover safe level should be applied to TL2/3 aquatic invertebrates, such as small clams, crabs, polychaetes and amphipods.

(c) To avoid exceeding the bald eagle wildlife value, safe concentrations must be attained in birds as well as fish eaten by bald eagles. The safe levels for average mercury concentrations in omnivorous and piscivorous bird prey are 0.19 and 1.35 mg/kg, respectively. Because bald eagles are scavengers, there is no upper size limit on fish eaten by these birds.

(d) Parentheses denote the TL3 fish level corresponding to the piscivorous bird safe concentration for peregrines. For birds eaten by peregrine falcons, the average concentrations should not exceed 2.2 mg/kg in piscivorous bird prey, respectively.

4.5.3 Calculation of Safe Fish Tissue Levels from Total Diet Values

Wildlife species consume fish and other aquatic prey from various size ranges and trophic levels. In the second step of wildlife target development, safe fish tissue levels are identified for different prey classifications. These classifications are termed “trophic level food groups”. Table 4.3 shows safe fish tissue concentrations needed by the wildlife species and developed for prey within the following trophic level food groups: TL2 fish less than 50 mm in length, 50-150 mm TL2 and 3 fish, 150-350 mm TL3 fish, and TL4 fish greater than 150 mm.

In cases in which an organism’s prey is fairly uniform and from one trophic level, the total diet safe level becomes the average, safe tissue mercury concentration. For organisms that feed from different trophic levels, the proportions of each trophic level in the diet (Table 4.1) are used to determine safe tissue mercury levels for each component of the diet. The species whose prey falls generally into one size category are mink, California least tern, western snowy plover, double crested cormorant, western grebe, kingfisher and common merganser. For these species, the total diet safe level becomes the safe fish tissue level matched to the size and trophic level of prey consumed.

Average, safe fish tissue concentrations for kingfisher, cormorant and mink were determined for the food group size range of 50-150 mm. Although kingfishers typically consume fish less than 105 mm in length, they can eat fish as long as 180 mm (Hamas, 1994; USEPA, 1995b). The range for cormorant prey is 30 to 400 mm, with most fish eaten being less than 150 mm (Hatch and Weseloh, 1999). Most fish caught by mink are in the range of 50-150 mm (USEPA, 1995b).

As the size ranges of prey caught by these three species are similar, one category of TL2/3 fish is appropriate for their protection (USFWS, 2004).

A second food group of TL3 fish in the range of 150-350 mm incorporates safe fish tissue mercury concentrations for prey of common mergansers and western grebes. Most prey caught by mergansers is in the range of 100-300 mm, with catches of fish up to 360 mm observed (Mallory and Metz, 1999). Because body size and foraging strategy of western grebes are similar to those of the merganser, staff assumed the same size range for grebe prey (USFWS, 2004).

Otter, bald eagle and osprey eat fish from multiple trophic level food groups. Methylmercury concentrations vary as a function of size and trophic level of prey. Therefore, different trophic levels of prey will have different acceptable concentrations of methylmercury. For these wildlife species, the total diet safe level (TDSL) can be described as:

Equation 4.3:

$$\text{TDSL} = (\%\text{ diet TL}_2 * \text{TL2}_{\text{conc}}) + (\%\text{ diet TL}_3 * \text{TL3}_{\text{conc}}) + (\%\text{ diet TL}_4 * \text{TL4}_{\text{conc}})$$

Where: $\%\text{ diet TL}_2$ = percent of trophic level 2 biota in diet
$\%\text{ diet TL}_3$ = percent of trophic level 3 biota in diet
$\%\text{ diet TL}_4$ = percent of trophic level 4 biota in diet
TL2_{conc} = concentration of methylmercury in TL2 biota
TL3_{conc} = concentration of methylmercury in TL3 biota
TL4_{conc} = concentration of methylmercury in TL4 biota

In order to solve the above equation for the desired concentrations in TL2, TL3 and TL4 biota, concentrations in two trophic levels are put in terms of the concentration in the lowest trophic level. Equation 4.3 is then rearranged to solve for the lowest trophic level concentration.

In order to express the concentration in a higher trophic level (i.e., TL4) in terms of TL2 concentrations, staff used two types of translators: food chain multipliers (FCM) and trophic level ratios (TLR).[16] FCM and TLR used in the calculation of Delta wildlife targets are shown in Table 4.4. Where possible, site-specific, existing fish concentration data was used to develop the ratios. A similar table of safe fish tissue concentrations to protect wildlife species using a national average bioaccumulation factor (BAF) between TL3 and TL4 of five is presented in Chapter 6 of Mercury Study Report to Congress Vol. 7 (USEPA, 1997b). Details regarding the calculation of the translators and their use were provided by the USFWS (2003 and 2004).

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[16] A food chain multiplier (FCM) is the ratio of methylmercury concentrations in fish of different trophic levels. A FCM represents the biomagnification of mercury between 2 successive levels of the food chain. The FCM is determined using mercury concentration data in fish in a predator-prey relationship. Example: the FCM for trophic level 4 fish is the ratio of methylmercury in large TL4 fish to methylmercury in small TL3 fish.

A trophic level ratio (TLR) is the ratio of methylmercury concentrations in fish of different trophic levels, but is derived using data for fish in the same size classification. For example, an osprey may consume sunfish (TL3) and bass (TL4). A 350 mm sunfish, though, is too large to be preyed upon by an equivalently-sized smallmouth bass. Therefore, the ratio of mercury concentration in TL4 to TL3 fish eaten by osprey is termed a TLR rather than a FCM.

Table 4.4: Food Chain Multipliers and Trophic Level Ratios for Delta Wildlife Target Development

Translator	Value	Source	Relevant Wildlife Species [(a)]
Trophic Level Ratio (TLR)			
TLR 4/3	3.0	Ratio between existing MeHg concentrations in large TL4 fish (150-350 mm length) and large TL3 fish (150-350 mm length). Calculated from Delta-wide average fish tissue levels; see Appendix B.	Bald eagle, osprey
Food Chain Multipliers (FCM)			
FCM 4/3	8.1	Ratio between existing MeHg concentrations in large TL4 fish (150-350 mm length) and small TL3 fish (50-150 mm). Calculated from Delta-wide average fish tissue levels; see Appendix B.	River otter
FCM 3/2	5.7	Ratio between MeHg concentrations in large TL3 fish and small TL2 fish. From USFWS (2004) based on national averages.	Bald eagle, peregrine falcon
FCM piscivorous birds (FCM PB)	12.5	Ratio between MeHg in piscivorous bird tissue and in small TL3 prey fish. From USFWS (2003).	Bald eagle, peregrine falcon
FCM omnivorous birds (FCM OB)	10	Ratio between MeHg in omnivorous bird tissue and in small, TL2/3 prey fish and other aquatic organisms. From USFWS (2003).	Bald eagle, peregrine falcon

(a) Wildlife species for which the translator is used to determine safe tissue levels.

4.5.3.1 River Otter Safe Tissue Levels

To calculate the safe concentrations for otter, the safe concentrations in TL3 and TL4 fish need to be determined. In order to solve for these two variables using Equation 4.3, the TL4 fish concentration is expressed in terms of the TL3 fish concentration. River otters eat a wide range of prey sizes. Large fish in the otter diet likely prey on small fish that otter also eat. Therefore, the TL4 variable is expressed using the TL3 concentration and a food chain multiplier (FCM 4/3). From the Delta field data, staff determined that the methylmercury concentration in large TL4 fish is 8.1 times the concentration in small TL3 fish. Safe tissue levels in TL3 and TL4 fish for otter are determined by:

$$TDSL_{otter} = (\%\ dietTL_3 * TL3_{conc}) + (\%\ dietTL_4 * TL4_{conc})$$

Where:

$$TL4_{conc} = TL3_{conc} * FCM\ 4/3$$

$$0.107\ mg/kg = (0.80 * TL3_{conc}) + (0.20 * 8.1 * TL3_{conc})$$

Solving for $TL3_{conc}$:

$$TL3_{conc} = 0.044\ mg\ MeHg/kg\ fish$$

$$TL4_{conc} = 0.044\ mg/kg * 8.1 = 0.36\ mg\ MeHg/kg\ fish$$

This equation produces safe levels of 0.04 and 0.36 mg/kg in small TL3 and large TL4 fish, respectively, which are shown in Table 4.3.

4.5.3.2 Osprey safe tissue levels

Safe methylmercury tissue levels for osprey are calculated like those for river otter, with the exception of the trophic level translator. Trophic level 3 and 4 fish eaten by osprey tend to be of similar sizes. Because there is not a food chain relationship between similarly sized fish, the osprey values are calculated using a trophic level ratio (TLR 4/3). On average in the Delta, methylmercury levels in large TL4 fish are 3.0 times the levels in large TL3 fish.

$$TDSL_{osprey} = (\%\ dietTL_3 * TL3_{conc}) + (\%\ dietTL_4 * TL4_{conc})$$

Where:

$$TL4_{conc} = TL3_{conc} * TLR\ 4/3$$

$$0.105\ mg/kg = (0.90 * TL3_{conc}) + (0.10 * 3.0 * TL3_{conc})$$

Solving for $TL3_{conc}$:

$$TL3_{conc} = 0.088\ mg\ MeHg/kg\ fish$$

$$TL4_{conc} = 0.088\ mg/kg * 3.0 = 0.26\ mg\ MeHg/kg\ fish$$

4.5.3.3 Bald Eagle Safe Tissue Levels

Calculation of methylmercury tissue levels for bald eagle is slightly more complicated because bald eagles consume omnivorous birds (OB), piscivorous birds (PB), and fish. The omnivorous birds of concern in the bald eagle diet feed on trophic level 2 aquatic prey (mostly invertebrates). To solve the equation, safe tissue concentrations in the other eagle prey types are expressed in terms of the lowest food chain level (TL2) common to all prey types (USFWS, 2004). To translate the TL2 concentration into the piscivorous bird safe level, staff used the food chain multiplier for TL3 small fish (FCM 3/2) and the food chain multiplier relating piscivorous birds and small TL3 fish (FCM PB). Like osprey, bald eagles tend to eat TL3 and TL4 fish of similar size, hence the use of the TL4/3 ratio.

$$TDSL_{bald\ eagle} = (\%\ dietTL_3 * TL3_{conc}) + (\%\ dietTL_4 * TL4_{conc}) + (\%diet_{OB} * OB_{conc}) + (\%diet_{PB} * PB_{conc})$$

Where:

$$TL3_{conc\ large\ fish} = TL2_{conc} * FCM\ 3/2$$

$$TL4_{conc\ large\ fish} = TL2_{conc} * FCM\ 3/2 * TL\ 4/3$$

$$OB_{conc} = TL2_{conc} * FCM\ OB$$

$$PB_{conc} = TL2_{conc} * FCM\ 3/2 * FCM\ PB$$

$$0.195\ mg/kg = (0.58*5.7*TL2_{conc}) + (0.13*5.7*3.0*TL2_{conc}) + (0.13*10*TL2_{conc}) + (0.05*5.7*12.5*TL2_{conc})$$

Solving for $TL2_{conc}$:

$TL2_{conc}$ = 0.019 mg MeHg/kg fish *(not eaten by eagles; used to determine other safe levels)*

$TL3_{conc\ large\ fish}$ = 0.019 * 5.7 = 0.11 mg MeHg/kg fish

$TL4_{conc\ large\ fish}$ = 0.019 * 5.7 * 3.0 = 0.31 mg MeHg/kg fish

OB_{conc} = 0.019 * 10 = 0.19 mg MeHg/kg omnivorous birds

PB_{conc} = 0.019 * 5.7 * 12.5 = 1.35 mg MeHg/kg piscivorous birds

4.5.3.4 Peregrine Falcon Safe Tissue Levels

Peregrine falcons consume almost exclusively avian prey, some of which is aquatic-dependent. To solve for safe concentrations in omnivorous and piscivorous bird prey, these terms are expressed as functions of the lowest trophic level common to the birds' food web, which is TL2 aquatic prey (USFWS, 2004).

$$\text{TDSL}_{\text{peregrine}} = (\%\text{diet}_{\text{OB}} * \text{OB}_{\text{conc}}) + (\%\text{diet}_{\text{PB}} * \text{PB}_{\text{conc}})$$

Where: $\text{OB}_{\text{conc}} = \text{TL2}_{\text{conc}} * \text{FCM OB}$

$\text{PB}_{\text{conc}} = \text{TL2}_{\text{conc}} * \text{FCM 3/2} * \text{FCM PB}$

$0.139\ \text{mg/kg} = (0.10 * 10 * \text{TL2}_{\text{conc}}) + (0.05 * 5.7 * 12.5 * \text{TL2}_{\text{conc}})$

Solving for $\textit{TL2}_{\textit{conc}}$*:*

$\text{TL2}_{\text{conc}} = 0.030$ mg MeHg/kg fish *(not eaten by peregrines; used to determine other safe levels)*

$\text{OB}_{\text{conc}} = 0.030 * 10 = 0.30$ mg MeHg/kg omnivorous birds

$\text{PB}_{\text{conc}} = 0.030 * 5.7 * 12.5 = 2.2$ mg MeHg/kg piscivorous birds

Note that the safe fish tissue levels in Table 4.3 are partially watershed-dependent and are specific to the Delta. The acceptable, average fish tissue concentrations for wildlife consuming from one trophic level will be consistent across different water bodies. This is because all of the parameters used to calculate the safe fish levels (species body weight, consumption rate and reference dose) were obtained from published literature and apply on a national or regional scale (Table 4.2). For species consuming fish from two trophic level classifications or piscivorous birds, translators (FCM or TLR) were used to calculate the safe concentrations in prey fish and piscivorous birds. These translators should be derived from site-specific data when possible and may differ between watersheds. For the Delta targets, the TLR and FCM between trophic level 4 and 3 fish were specific to the Delta. The FCMs for piscivorous birds, omnivorous birds and trophic level 3 fish were literature-derived average values.

Central Valley Water Board staff is not proposing safe tissue levels in piscivorous or omnivorous birds as TMDL targets. Data are lacking to compare safe levels in bird prey with existing conditions. By lowering methylmercury concentrations in fish and aquatic prey to safe levels shown in Table 4.3, staff anticipates that concentrations in birds feeding in the aquatic food web will decline to safe levels as well. In particular for peregrine falcon, the desired safe level in piscivorous birds is 2.2 mg/kg. Dividing the safe piscivorous bird level by 12.5 (FCM PB) results in a safe level in TL3 prey fish (150-350 mm length) of 0.17 mg/kg, which is above the proposed target for large TL3 fish.

Wildlife targets for TL3 and TL4 fish greater than 150 mm in length may be directly compared with targets developed to protect human consumers, as discussed in the following section. In Section 4.7, the wildlife and human targets that are trophic level and size-specific are incorporated into a single target based on largemouth bass that is protective of humans and all wildlife species of concern.

4.6 Human Health Targets

Numeric targets can be developed to protect humans in a manner analogous to targets for wildlife. A reference dose, average body weight and consumption rates are used along with Equations 4.1 and 4.3 to calculate safe fish tissue levels. In this section, the human health exposure parameters are discussed.

4.6.1 Acceptable Daily Intake Level

Central Valley Water Board staff used the USEPA RfD for methylmercury (USEPA, 2001) in Delta target calculations. The lowest level of methylmercury exposure that caused harm was determined in tests of neuropsychological function in children in the Faroe Islands and other sites exposed to methylmercury in fish. The USEPA divided the lowest effect level by ten to calculate a final RfD of 0.1 µg methylmercury/kg bwt/day (USEPA, 2001). The USEPA describes its RfD an exposure level that is not expected to cause harm over a lifetime of exposure on a daily basis. The ten-fold uncertainty factor accounts for differences in the extent to which individuals absorb, metabolize, and react to methylmercury. The USEPA RfD is applied to the general population.[17]

4.6.2 Body Weight & Consumption Rate

This report uses the USEPA's standard adult bodyweight of 70 kg. Using an average pregnant female bodyweight (65 or 67 kg) would have very little difference on the calculation of mercury targets in fish.

Consumption rate is the most difficult of the fish tissue target variables to select because human consumption is variable. The amount of methylmercury ingested is highly dependent on the amount of fish and the sizes and species of fish consumed. The preferred level of Delta fish consumption is bounded by the limited amount recommended in the existing fish advisory and the rate of a very high consumer. People could eat unlimited quantities of Delta fish if the fish mercury concentration was zero. Human health is best protected by both cleanup and education. Education is needed until the effects of mercury reduction are seen in fish tissue levels. During the TMDL implementation period, consumers should be encouraged to eat smaller fish and species with lower mercury concentrations.

A comprehensive survey of consumption of Delta fish has not been conducted. Thus, staff examined San Francisco Bay and national fish consumption studies, as well as several localized and pilot studies in the Delta, to develop Delta-specific consumption scenarios and ultimately recommend targets for human protection.

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[17] "In the studies so far published on subtle neuropsychological effects in children, there has been no definitive separation of prenatal and postnatal exposure that would permit dose-response modeling. That is, there are currently no data that would support the derivation of a child (versus general population) RfD. This RfD is applicable to the lifetime daily exposure for all populations, including sensitive subgroups. It is not a developmental RfD per se, and its use is not restricted to pregnancy or developmental periods" *Water Quality Criterion for Methylmercury, Section 4-6* (USEPA, 2001).

The USEPA recommends default consumption rates for the general population and some subpopulations (USEPA, 2000a). Default consumption rates are derived from data collected nationwide as part of the 1994-96 USDA Continuing Survey of Food Intake by Individuals (CFSII). The USEPA reports rates separately for consumption of freshwater and marine fish. The USEPA recommends a fish intake rate of 17.5 g/day (about one 8-ounce uncooked fish meal every two weeks[18]) to protect the general population consuming freshwater and estuarine fish. This value represents the 90th percentile consumption rate for all survey participants, including those who do not eat fish. In selecting the 90th percentile, rather than the mean or median, the USEPA intended to recommend a consumption rate that is protective of the majority of the entire population. The USEPA recommended a consumption rate of 142.4 g/day (four to five 8-ounce, uncooked, portions per week) of local fish to represent anglers who use locally caught fish as a main source of protein. This value represents the 99th percentile consumption rate for all survey participants.

A detailed survey of consumption by anglers in San Francisco Bay was conducted in 1998 and 1999 (SFEI, 2000). The consumption rates for the 90th and 95th percentiles of anglers that were "consumers" (consumed Bay fish at least once prior to the interview) were 16 and 32 g/day, respectively. The San Francisco Bay Mercury TMDL selected the consumption rate for the 95th percentile of anglers (32 g/day) for calculation of the San Francisco Bay fish mercury target (0.2 mg/kg) to protect people who choose to eat San Francisco Bay fish on a regular basis (Johnson and Looker, 2004; SFBRWQCB, 2006).

California Department of Public Health staff interviewed members of communities thought to have high consumption rates (CDHS, 2004) and conducted several pilot fish consumption surveys in the Delta (CDHS, 2005 and 2006; Ujihara, 2006). From the interviews, CDPH learned that being able to safely eat Delta fish is important to many people. Members of all races and many ethnic groups fish in the Delta. Preferences for angling location, language spoken, and fish species are important for developing education and outreach programs.

The CDPH conducted small surveys of anglers in three parts of the Delta (CDHS, 2005 and 2006; Ujihara, 2006). Of boaters docking in Contra Costa County surveyed in 2005, 50% reported never eating Delta fish; 3% ate it more than once per week. Of boat and shore anglers on the Sacramento River between Rio Vista and the American River interviewed during salmon season in 2003, 17% ate Delta fish more than once per week. Shore anglers at two southern Delta and two San Joaquin River sites outside the Delta were interviewed in October/November 2005. Of the total respondents who ate any fish in the 30-day period prior to the survey, the geometric mean consumption rates were 22, 17, and 27 grams uncooked fish per day for locally caught, commercial, and total fish, respectively; these rates are less than one 8-ounce meal per week. Anglers were typically male. Many respondents in the Sacramento River and Delta/San Joaquin River angler surveys said that women and children in their households eat Delta fish.

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[18] Although the target calculations use bodyweights and consumption rates for adult humans, the resulting fish tissue levels protect children as well. Children's bodyweights and smaller portion sizes can also be fitted into Equations 4.1 and 4.3. The OEHHA has published a table of sizes of typical meals of fish that correspond to smaller bodyweights (OEHHA, 1999). Children would only be at risk of mercury toxicity if they consumed more than the average portion for their body size.

A recent fish consumption and advisory awareness survey of low-income women at a WIC[19] clinic in Stockton found that 32% of the 500 survey participants ate Delta fish and 95% ate commercial fish (Silver *et al*., 2007). For participants who ate any fish in the 30-day period prior to the survey, the geometric mean consumption rates equaled 13, 33, and 35 grams uncooked fish per day for Delta, commercial, and total fish, respectively.[20] Cambodian, Asian/Pacific Islander, and African American participants had the highest mean consumption rates (24, 22, and 18 grams uncooked fish per day, respectively).

In 2005-2008, researchers from University of California Davis interviewed anglers and community members in the Delta about eating fish (Shilling, 2009). The study area included the Sacramento River between Rio Vista and the American River and the Sacramento Deep Water Ship Channel. The average and 95th percentile rates of consumption of locally caught fish were 11 and 52 g/day uncooked fish/day, respectively. Women and men ate fish at similar rates. Average consumption rates of locally caught fish were highest for Lao, African American, and Vietnamese participants.

4.6.3 Consumption of Fish from Various Trophic Levels & Sources

Species and size of fish as well as consumption rate affect methylmercury intake. It is difficult to estimate amounts of various species of sport fish that might be consumed from the Delta. Based on the CSFII national survey, the USEPA assumed that humans eat freshwater and estuarine fish from trophic levels two (3.8 g/day), three (8.0 g/day) and four (5.7 g/day) (USEPA, 2001). These rates are 21.7, 45.7, and 32.6% of the total 17.5 g/day, respectively. Trophic level 2 species, such as clams, crayfish, shrimp and shimofuri goby, are harvested from the Delta for human consumption (Appendix C). However, CDFG creel surveys (CDFG, 2000-2001) and anecdotal information provided by CDFG staff (Schroyer, 2003) indicate that many Delta anglers do not take home TL2 species. As described in Figure C.1 in Appendix C, the creel surveys indicate that Delta anglers may target an almost even mix of TL3 (American shad, salmon, sunfish, splittail) and TL4 (catfish and striped bass) fish in the Sacramento and Mokelumne Rivers subareas of the Delta, and primarily TL4 species (striped bass and catfish) throughout the rest of the Delta. Anecdotal information provided by CDFG staff (Schroyer, 2003) indicates that even in the rest of the Delta, many anglers take home a mix of TL3 and TL4 fish species. In the Delta consumption surveys described in previous paragraphs, anglers reported taking home catfish, striped bass, carp, bluegill, salmon, largemouth bass, crappie, sturgeon, and crayfish (CDHS, 2005 and 2006; Ujihara, 2006).

When evaluating potential fish tissue targets, staff considered five different tropic level distributions of locally caught fish (Table 4.5). Staff considered the TL2/3/4 mixture used by the USEPA for one distribution and Delta-specific information to develop four other distributions: 100% TL4, even mix of TL3 and 4, and an even mix of TL3 and 4 with small amounts of TL2 species (e.g., clams and shrimp).

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[19] Special Supplemental Nutrition program for Women, Infants, and Children (WIC).

[20] This study reported consumption in grams of cooked fish. In order to compare the studies, Central Valley Water Board staff converted units of cooked fish to uncooked fish by multiplying by 1.25.

When determining safe levels of Delta fish consumption, staff also considered the intake of methylmercury from commercial fish (see definition of RSC in Section 4.4). Many fish consumers eat a combination of locally caught and commercially bought fish. Based on the national CFSII survey, the USEPA assumes an average consumption rate of commercial fish of 12.46 g/day, which results in an average daily intake of 0.027 µg methylmercury/kg bwt-day (USEPA, 2001). For people eating fish from commercial markets and the Delta, the safe intake level of methylmercury from Delta fish is the reference dose minus the methylmercury from commercial fish (0.1 µg/kg-day minus 0.027 µg/kg-day equals 0.073 µg/kg-day).[21]

4.6.4 Safe Rates of Consumption of Delta Fish

The USEPA issued a recommended criterion of 0.3 mg/kg methylmercury in locally caught fish consumed by humans (USEPA, 2001) [22]. The USEPA human health criterion was calculated using a default consumption rate of freshwater/estuarine fish of 17.5 g/day (about one meal every two weeks) and commercial (marine) fish of 12.46 g/day. The criterion assumed that humans eat freshwater and estuarine fish from TL2 (21.7%), TL3 (45.7%) and TL4 (32.6%). However, the USEPA's Water Quality Criterion report noted that the criterion can be adjusted on a site-specific basis to reflect regional or local consumption patterns and/or specific populations of concern. These include the consumption rates of local fish and the RSC estimate. For example, the San Francisco Bay mercury fish tissue objective of 0.2 mg/kg was calculated using a consumption rate of 32 g/day (about one meal per week) derived from a San Francisco Bay consumption survey. The San Francisco Bay objective is applied to the average mercury concentration in the five most commonly consumed Bay fish species: striped bass, California halibut, jacksmelt, white sturgeon, and white croaker (three TL4 species and two TL3 fish species; SFBRWQCB, 2006).

In the absence of Delta-specific consumption rates, the USEPA default consumption rate (17.5 g/day), San Francisco Bay consumption rate (32 g/day), and USEPA recommended consumption rate for anglers whose main source of protein is from locally caught fish (142.4 g/day) were used in Equation 4.1 to estimate the safe methylmercury level in the total diet for humans consuming Delta fish (Table 4.5). In addition, scenarios were developed for anglers who consume Delta and commercial fish, and for anglers who consume only Delta fish. For each of the total diet safe levels associated with the different consumption rates, different distributions of locally caught fish were considered. Because some Delta consumers eat TL2 species, two scenarios assume Delta consumers eat small proportions of TL2 species.

Equation 4.3 was used to develop safe levels for each trophic level of Delta fish. In order to solve Equation 4.3 for the desired concentrations in TL2, TL3 and TL4 biota, concentrations in the higher trophic levels are put in terms of the concentration in the lowest trophic level.

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[21] Most commercial fish do not come from the Delta. The most popular fish and seafood bought in commercial markets are marine species such as scallops, shrimp, and tuna. The average consumption rate of marine fish reported by all respondents in the national CFSII survey was 12.46 g/day (three meals every two months; USEPA, 2001). The average concentration of methylmercury in commercial species weighted by frequency of consumption is 0.16 mg/kg (USEPA, 2001)

[22] The USEPA rounded from 0.288 mg/kg to 0.3 mg/kg for use as its recommended methylmercury criterion. Central Valley Water Board staff's calculations throughout the rest of this report are rounded to two decimal places, e.g., 0.29 mg/kg.

Equation 4.3 is then rearranged to solve for the lowest trophic level concentration. In order to express the concentration in a higher trophic level, trophic level ratios were used. The TLRs used in the calculation of Delta human targets are shown in Table 4.6. Existing Delta fish concentration data were used to develop the ratios. The following example illustrates how the trophic level fish targets were developed for Scenario A.1 in Table 4.5 using Equations 4.1 and 4.3.

Per Equation 4.1:

$$\begin{array}{c}\text{Safe MeHg in total diet}\\ \text{of Delta fish}\end{array} = \frac{\text{(Human RfD - Relative source contribution) * Body weight}}{\text{Consumption rate}}$$

$$0.29\text{ mg/kg} = \frac{0.073\ \mu\text{g MeHg/kg-day} * 70\text{ kg}}{17.5\text{ g/day}}$$

Per Equation 4.3:

$$0.29\text{ mg/kg} = (\%\ \text{dietTL}_2 * \text{TL3}_{\text{conc}}) + (\%\ \text{dietTL}_3 * \text{TL3}_{\text{conc}}) + (\%\ \text{dietTL}_4 * \text{TL4}_{\text{conc}})$$

Where: $\text{TL3}_{\text{conc}} = \text{TL2}_{\text{conc}} * \text{TLR } 3/2$

$\text{TL4}_{\text{conc}} = \text{TL2}_{\text{conc}} * \text{TLR } 3/2 * \text{TLR } 4/3$

$$0.29\text{ mg/kg} = (21\% * \text{TL2}_{\text{conc}}) + (46\% * \text{TL2}_{\text{conc}} * 4.5) + (33\% * \text{TL2}_{\text{conc}} * 4.5 * 2.9)$$

Solving for TL2_{conc}:

$\text{TL2}_{\text{conc}} = 0.30 / (0.21 + (0.45*4.5) + (0.33*4.5*2.9)) = 0.046$ mg/kg in shrimp & clams

$\text{TL3}_{\text{conc}} = 0.046$ mg/kg $* 4.5 = 0.20$ mg/kg in 150-500 mm fish

$\text{TL4}_{\text{conc}} = 0.046$ mg/kg $* 4.5 * 2.9 = 0.45$ mg/kg in 150-500 mm fish

The highlighted safe levels for TL3 and TL4 fish in Scenarios A.1, A.4, B.4 and E.3 are evaluated as fish tissue objective alternatives in Chapter 3 of the draft Basin Plan Amendment staff report. As indicated by Table 4.5, potential safe levels of mercury in large Delta TL4 fish range from 0.05 to 0.80 mg/kg. Safe methylmercury concentrations can be higher when consumers of Delta fish do not eat commercial fish. However, in interviews of local community based groups and pilot surveys, most respondents who eat Delta fish consume commercial fish as well (CDHS, 2004; Silver 2007; and Ujihara, 2006). Staff therefore narrowed the options for further consideration by assuming Delta fish consumers eat commercial fish unless consumers are highly dependent on Delta fish (Scenario E).

Including small amounts of TL2 species into the diet distribution (Scenarios A.2, A.3, B.2, and B.3) makes little difference in the safe methylmercury concentrations in TL3 and TL4 fish, relative to an even mix of just TL3 and TL4 fish. To protect the many Delta anglers who likely do not eat TL2 species, staff proceeded with consideration of TL3 and 4 fish only.

To further assess the feasibility of attaining the targets, staff compared them to regional background conditions defined by a recent study by the USEPA and Oregon State University (Peterson *et al.*, 2007). This study included the collection and analysis of 2,707 large TL3 and TL4 fish from 626 streams and river segments in the western United States, including California, using a probability design. The purpose of the study was to assess the distribution of mercury in fish across the western United States. Central Valley Water Board staff evaluated the study results in terms of the existing fish mercury levels in the Delta and alternative fish tissue targets (Foe, 2007).

Only about 1 to 3% of the waterways evaluated by the regional study had fish mercury concentrations higher than those observed in the Mokelumne/Cosumnes subarea of the Delta. Likewise, fish mercury concentrations in the Sacramento, San Joaquin, and Yolo Bypass subareas were in the top 20 to 25% of fish mercury concentrations observed throughout the western United States. This confirms that Delta fish have elevated concentrations in comparison to regional background levels and suggests that the Delta and its tributary watersheds contain mercury sources in addition to atmospheric deposition, e.g., abandoned mines and sites where the mercury is efficiently converted to methylmercury that bioaccumulates in the aquatic food web (Foe, 2007). Of the sampled waterways in the western United States, none supported a fish population with mercury concentrations as low as Scenario E.3 (0.05 mg/kg in large TL4 fish) (Peterson *et al.*, 2007; Foe, 2007). Therefore, this target may not be attainable. In contrast, about 30% to 40% of the sampled waterways supported a fish population with mercury concentrations lower than Scenarios A.1, A.4, and B.4, suggesting that these scenarios may be attainable with implementation of a vigorous control program.

As discussed in the draft Basin Plan Amendment staff report, the TL3 and TL4 targets produced by Scenario B.4 of 0.08 mg/kg and 0.24 mg/kg, respectively, are recommended by Central Valley Water Board staff for the protection of humans for several reasons:

- They fully protect wildlife species consume large fish, including threatened and endangered species as required by the Endangered Species Act.
- They reasonably protect people who eat Delta fish by safely allowing the consumption of one eight-ounce meal per week of Delta fish, a consumption rate greater than the USEPA default rate used in Scenarios A and C. These objectives are therefore more protective of people who by custom, need, or enjoyment, more frequently eat Delta fish.
- They incorporate local consumption patterns, which show that Delta anglers commonly target fish like salmon (TL3) and striped bass (TL4).
- They are consistent with the fish tissue objectives approved by the State Water Board for San Francisco Bay (SFBRWQCB, 2006; SWRCB, 2007). Like the Scenario B.4 targets, the methylmercury objective recommended for the Bay is based on protecting people who eat 32 g/day of local fish. Scenario B.4 takes into consideration that people, fish-eating wildlife and their prey (e.g., anadromous species) travel between the Delta and San Francisco Bay.
- They are attainable because they are not less than background fish mercury levels in the western United States and they can be reliably measured (given current analytical methods for water and fish; see Section 5.2 in Chapter 5).

These targets are carried forward throughout the rest of this report for use in the food web evaluation, linkage analysis and development of methylmercury source allocations.

Table 4.5: Safe Concentrations of Methylmercury in Delta Fish by Trophic Level (TL) to Protect Humans Calculated Using Varying Assumptions about Consumption Rates and Trophic Level Distribution.

Scenario	Body Weight (kg)	Acceptable Daily Delta Fish MeHg Intake Level (µg/kg-day) (a)	Total Consumption Rate of Delta Fish (g/day) (b)	Safe MeHg Level in Total Diet of Delta Fish (mg/kg) (c)	Distribution of Locally Caught Fish by TL			Safe Concentration of MeHg in Fish by TL (mg/kg) (d)		
					TL2	TL3	TL4	TL2	TL3	TL4
For people eating commercial and Delta fish:										
A.1	70	0.073	17.5	0.29	21.7%	45.7%	32.6%	0.04	**0.20**	**0.58**
A.2					10%	45%	45%	0.04	0.16	0.47
A.3					5.0%	47.5%	47.5%	0.03	0.16	0.45
A.4					---	50%	50%		0.15	0.43
A.5					---	---	100%			**0.29**
B.1	70	0.073	32	0.16	21.7%	45.7%	32.6%	0.02	0.11	0.32
B.2					10%	45%	45%	0.02	0.09	0.26
B.3					5.0%	47.5%	47.5%	0.02	0.09	0.25
B.4					---	50%	50%		**0.08**	**0.24**
B.5					---	---	100%			0.16
For people eating only Delta fish:										
C.1	70	0.1	17.5	0.40	21.7%	45.7%	32.6%	0.06	0.28	0.80
C.2					---	50%	50%		0.21	0.59
C.3					---	---	100%			0.40
D.1	70	0.1	32	0.22	21.7%	45.7%	32.6%	0.03	0.15	0.44
D.2					---	50%	50%		0.11	0.33
D.3					---	---	100%			0.22
E.1	70	0.1	142.4	0.05	21.7%	45.7%	32.6%	0.01	0.03	0.10
E.2					---	50%	50%		0.03	0.07
E.3					---	---	100%			**0.05**

(a) For people eating fish from commercial markets and the Delta, the safe intake level of methylmercury from Delta fish is the USEPA reference dose minus the methylmercury from commercial fish (0.1 µg/kg-day minus 0.027 µg/kg-day = 0.073 µg/kg-day). Scenarios C through E assume no commercial fish are consumed.

(b) The USEPA human health criterion was calculated using a default consumption rate of freshwater/estuarine fish of 17.5 g/day and of commercial (marine) fish of 12.46 g/day, as derived from national dietary surveys (USEPA, 2001). The criterion assumed that humans eat freshwater and estuarine fish from TL2 (21.7%), TL3 (45.7%) and TL4 (32.6%).

(c) The USEPA criterion calculations yielded a methylmercury value of 0.288 mg methylmercury/kg fish, which the USEPA rounded to one significant digit. The Region 2 San Francisco Bay Mercury TMDL target calculations yielded a methylmercury value of 0.16 mg methylmercury/kg fish, which Region 2 also rounded to one significant digit in the San Francisco Bay Mercury TMDL report (Johnson and Looker, 2004).

(d) Values were calculated using Equation 4.3 and trophic level ratios presented in Table 4.6. Values were rounded to two decimal places. The highlighted targets (Scenarios A.1, A.4, B.4 and E.3) are evaluated as fish tissue objective alternatives in the draft Basin Plan Amendment staff report. The TL3 and TL4 targets produced by Scenario B.4 are recommended for the protection of humans that consume fish from throughout the Delta and are carried forward throughout the rest of this report for use in the linkage analysis and development of allocations.

Table 4.6: Trophic Level Ratios for Delta Human Target Development

Translator	Value	Source
TLR 4/3	2.9	Ratio between existing MeHg concentrations in large TL4 fish (150 mm [or legal catch limit] to 500 mm length) and large TL3 fish (150 mm [or legal catch limit] to 500 mm length). Calculated from Delta-wide average fish tissue levels; see Appendix B.
TLR 3/2	4.5	Ratio between existing MeHg concentrations in large TL3 fish (150-500 mm length) and TL2 species potentially consumed by humans (shrimp and clams). Calculated from Delta-wide average fish tissue levels; see Appendices B, C and K.

4.7 Trophic Level Food Group Evaluation

As noted in the previous section, Central Valley Water Board staff recommends targets of 0.08 and 0.24 mg/kg in large TL3 and TL4 fish, respectively, for the protection of humans that consume fish from throughout the Delta. In this section, the relationships between methylmercury concentrations in large TL4 fish and the other trophic level food groups are examined. The purpose of this analysis is to determine whether consistent relationships might exist between the assemblages of fish and, if so, whether it might be possible to describe safe mercury ingestion rates for humans and wildlife species in terms of large TL4 fish. This analysis enables staff to determine whether a water quality objective based on methylmercury in large fish developed for the protection of humans may or may not be protective of wildlife species that consume smaller or lower trophic level fish.

4.7.1 Data Used in Trophic Level Food Group Evaluation

Mercury concentrations for each trophic level food group sampled in the Delta are presented in Appendix K and summarized in Table 4.7. Values presented are average concentrations, weighted by the number of individual fish in composite samples. The trophic level food group concentrations are the result of analyzing 1,048 composite samples of 4,578 fish from 23 species in the Delta (Table B.2 and B.3 in Appendix B and Appendix K). Figure 4.1 illustrates the fish sampling locations used in the trophic level food group evaluation. The sampling was conducted by CDFG, SFEI, University of California, Davis, the Toxic Substances Monitoring Program, and the Sacramento River Watershed Program (Davis *et al.*, 2000; Davis *et al*., 2003; Slotton *et al.*, 2003; LWA, 2003; SWRCB-DWQ, 2002).

The data for each food group were assembled after considering four general rules. First, the data were restricted to samples collected between 1998 and 2001, the period with the most comprehensive sampling across the Delta. Second, migratory species (salmon, American shad, steelhead, sturgeon, and striped bass) were excluded. These species likely do not reside year-round at the locations in the Delta where they were caught and their tissue mercury levels may not show a positive relationship with the mercury levels in resident animals. In addition, data for migratory species are not available for all Delta subareas, precluding an analysis to determine whether such a relationship might exist. A review of data available for several commercial species (striped bass, salmon, blackfish and crayfish) is provided in Appendix C.[23] Third, fish samples with lengths greater than 500 mm were not included. Data for fish larger than 500 mm are available for only some subareas. Capping the size at 500 mm allows comparable data for all Delta subareas. Finally, only fish fillet data were used in the human and eagle trophic level food group analysis. Humans typically consume fish fillets, while wildlife species, including eagles, eat whole fish. However, all the data for large fish typically consumed by eagles and other large wildlife species are from fillet samples, making it necessary to use fillet information for these species.[24] Whole fish data were used for the smaller wildlife species food groups.

Of the eight Delta subareas identified in Section 2.2.2 and Figure 2.2, three of the subareas were not included in the trophic level food group evaluation due to inadequate information. No fish were sampled from the Marsh Creek subarea between 1998 and 2001. In addition, small fish were sampled throughout the Yolo Bypass-South subarea between 1998 and 2001, but large fish were sampled only in the southernmost area; hence, the mercury levels in the trophic level food groups are not geospatially comparable. The only fish sampling conducted in the Yolo Bypass-North subarea took place in Greens Lake, which is not considered representative of the entire subarea. In addition, only large TL4 fish were sampled; no small fish were sampled.

Table 4.8 provides a comparison of the average mercury concentrations for each trophic level food group sampled in the Delta (Table 4.7) to the recommended targets for the species with the lowest safe fish methylmercury levels within each trophic level food group. The comparison indicates that the recommended targets for wildlife protection are already met in the Central and West Delta subareas. In addition, the comparison indicates that greater reductions may be required to achieve the recommended target for large TL4 fish developed for human protection than for the recommended targets for smaller and lower trophic level fish developed for wildlife protection. The following section describes a more direct method for comparing the level of protection provided by the different trophic level food group targets.

4.7.2 Trophic Level Food Group Comparisons

Regressions between methylmercury concentrations in large TL4 fish and the other TL food groups are presented in Figure 4.2. The relationships were evaluated using linear, exponential, logarithmic, and power curves; in each case the type of curve that provided the highest R^2 value was selected. All of the correlations were statistically significant ($P<0.05$ or less). The regressions demonstrate that there are predictable relationships between mercury concentrations in large TL4 fish and the other trophic level food groups in the Delta.

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[23] Methylmercury concentrations in salmon and striped bass are important to human risk assessment because people frequently attempt to catch these two species. Average mercury concentrations in striped bass are similar to mercury levels in largemouth bass. The available mercury data for salmon indicate that their tissue concentrations are much lower that the mercury levels in bass (0.04 to 0.12 mg/kg). See Appendix C for more information about striped bass and salmon.

[24] Researchers in New York found that concentrations in whole body and muscle of large TL3 and TL4 fish were not significantly different (Becker and Bigham, 1995), suggesting that it is appropriate to use fillet data to evaluate exposure to wildlife species.

Table 4.9 presents the predicted safe dietary mercury concentrations for each target species in terms of large TL4 fish calculated from the regression equations in Figure 4.2. The recommended target of 0.24 mg/kg in large TL4 fish developed for the protection of humans is lower than the corresponding safe large TL4 fish mercury concentrations predicted for the other TL food groups, which ranged from 0.30 mg/kg for Western grebe to 1.12 mg/kg for Western snowy plover. This indicates that the recommended targets for large TL3 and TL4 fish developed for protection of humans are most likely protective of wildlife species that consume smaller or lower trophic level fish. In other words, reductions in methylmercury levels needed to achieve the recommended targets for large TL3 and TL4 fish are expected to produce reductions in smaller fish sufficient to fully protect wildlife species. To ensure that wildlife species dining only on small fish are protected, staff proposes an additional target of 0.03 mg/kg methylmercury in TL2 and 3 fish less than 50 mm in length. This target represents the safe level for prey consumed by the California least tern, a piscivorous species listed by the federal government as endangered. As shown in Table 4.9, such a target for small fish also would protect the Western snowy plover.

Table 4.7: Mercury Concentrations in Trophic Level Food Groups Sampled in the Delta

Trophic Level Food Group	**Hg Concentrations (mg/kg) by Delta Subarea** [(a)]				
	Central Delta	Mokelumne River	Sacramento River	San Joaquin River	West Delta
TL4 Fish (150-500 mm)	0.26	0.92	0.56	0.50	0.32
TL3 Fish (150-500 mm)	0.08	0.28	0.21	0.11	0.11
TL4 Fish (150-350 mm)	0.20	0.75	0.46	0.42	0.24
TL3 Fish (150-350 mm)	0.08	0.29	0.17	0.12	0.08
TL3 Fish (50-150 mm)	0.03	0.09	0.04	0.04	0.03
TL3 Fish (<50 mm)	0.02	0.07	0.03	0.04	0.03

(a) The trophic level food group mercury levels are weighted averages of mercury levels for resident fish within each food group collected in each Delta subarea between 1998 and 2001. These food groups correspond to the proposed numeric targets developed earlier in Chapter 4. Weighted average mercury concentration is based on the number of fish in the composite samples analyzed, rather than the number of samples.

Table 4.8: Percent Reductions in Fish Methylmercury Levels Needed to Meet Numeric Targets

Trophic Level Food Group	**Target Species** [(a)]	**Target** (mg/kg)	**Delta Subareas**				
			Central Delta	Mokelumne River	Sacramento River	San Joaquin River	West Delta
TL4 Fish (150-500 mm)	Human	0.24	8%	74%	57%	52%	25%
TL3 Fish (150-500 mm)	Human	0.08	0%	71%	62%	27%	27%
TL4 Fish (150-350 mm)	Osprey	0.26	0%	65%	43%	38%	0%
TL3 Fish (150-350 mm)	Grebe	0.08	0%	72%	53%	33%	0%
TL3 Fish (50-150 mm)	Kingfisher	0.05	0%	44%	0%	0%	0%
TL3 Fish (<50 mm)	Least Tern	0.03	0%	57%	0%	25%	0%

(a) Only the recommended targets for the wildlife species with the lowest safe methylmercury concentrations in fish diet (Table 4.3) within each trophic level food group are evaluated. The proposed large TL3 and TL4 fish targets for human protection are lower than the targets proposed for protection of eagles.

Table 4.9: Predicted Safe Concentrations of Methylmercury in 150-500 mm TL4 Fish and Standard 350-mm Largemouth Bass Corresponding to Trophic Level Food Group (TLFG) Targets for the Protection of Piscivorous Species.

Trophic Level Food Group / Species	**TLFG Target** (mg/kg) (a)	**Predicted 150-500 mm TL4 Fish Safe Level** (mg/kg)	**Predicted Standard 350-mm Largemouth Bass Safe Level** (mg/kg) (b)
TL4 Fish (150-500 mm)			
Human	0.24	(c)	0.28
Bald eagle	0.31	(c)	0.36
TL3 Fish (150-500 mm)			
Human	0.08	0.24	0.24
Bald eagle	0.11	0.37	0.43
TL4 Fish (150-350 mm)			
Osprey	0.26	0.33	0.36
River otter	0.36	0.45	0.57
TL3 Fish (150-350 mm)			
Western grebe	0.08	0.30	0.31
Common merganser	0.09	0.35	0.38
Osprey	0.09	0.35	0.38
TL3 Fish (50-150 mm)			
Kingfisher	0.05	0.62	0.73
Mink	0.08	0.90	1.06
River otter	0.04	0.50	0.57
Double-crested cormorant	0.09	0.96	1.15
TL3 (<50 mm)			
California least tern	0.03	0.38	0.42
Western snowy plover	0.10	1.12	1.34

(a) The TLFG targets developed for bald eagle, osprey and river otter were developed using site-specific TLRs and/or FCMs combined with information provided in published literature. All other TLFG targets were entirely developed using information provided in published literature.

(b) The calculation and purpose of the standard 350-mm largemouth bass mercury concentrations are described in the following section (Section 4.8).

(c) The TL4 Goals are same as the TLFG Targets for human and eagle protection.

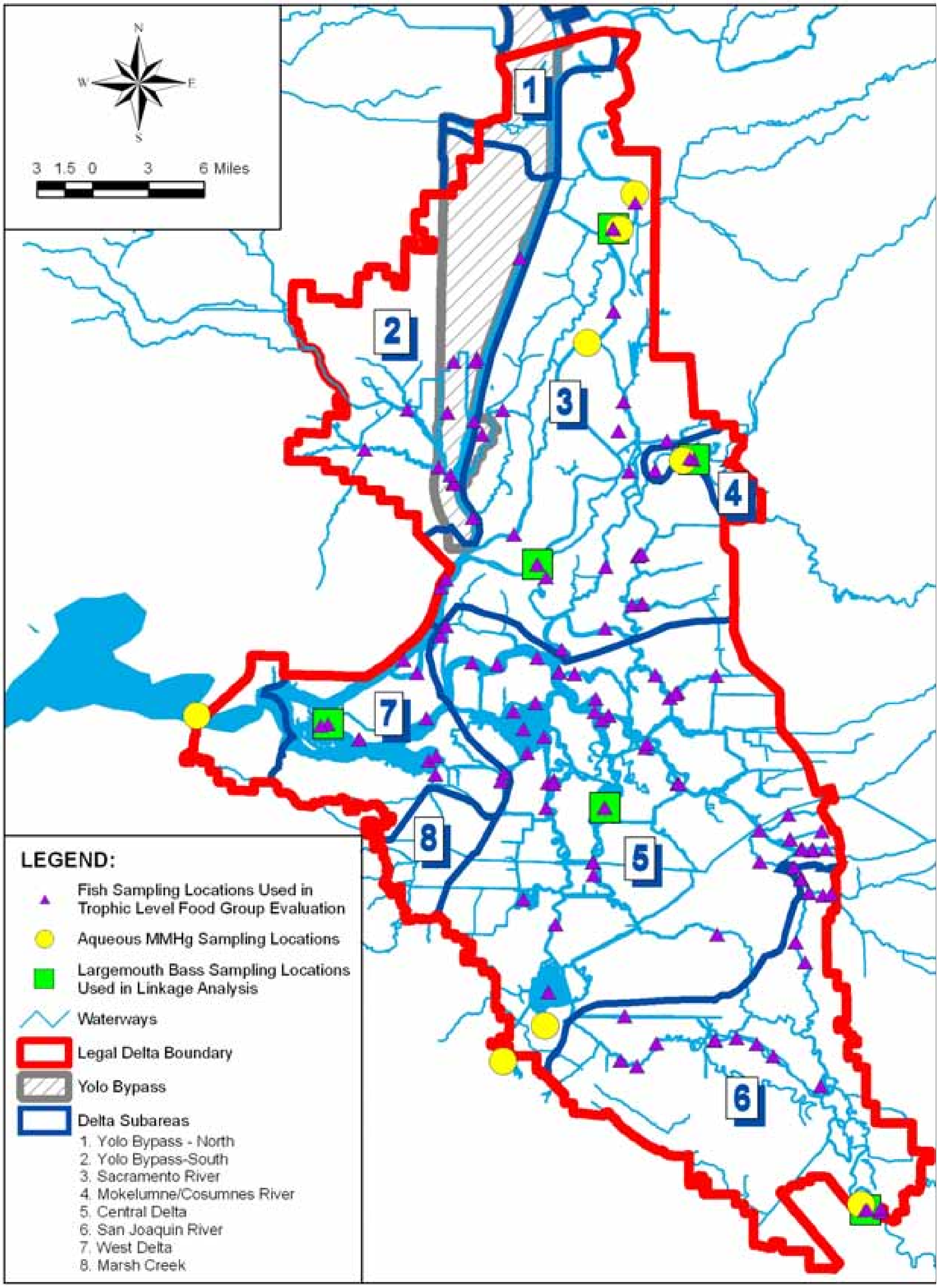

Figure 4.1: Fish and Water Sampling Locations Included in the Trophic Level Food Group and Largemouth Bass Evaluations.

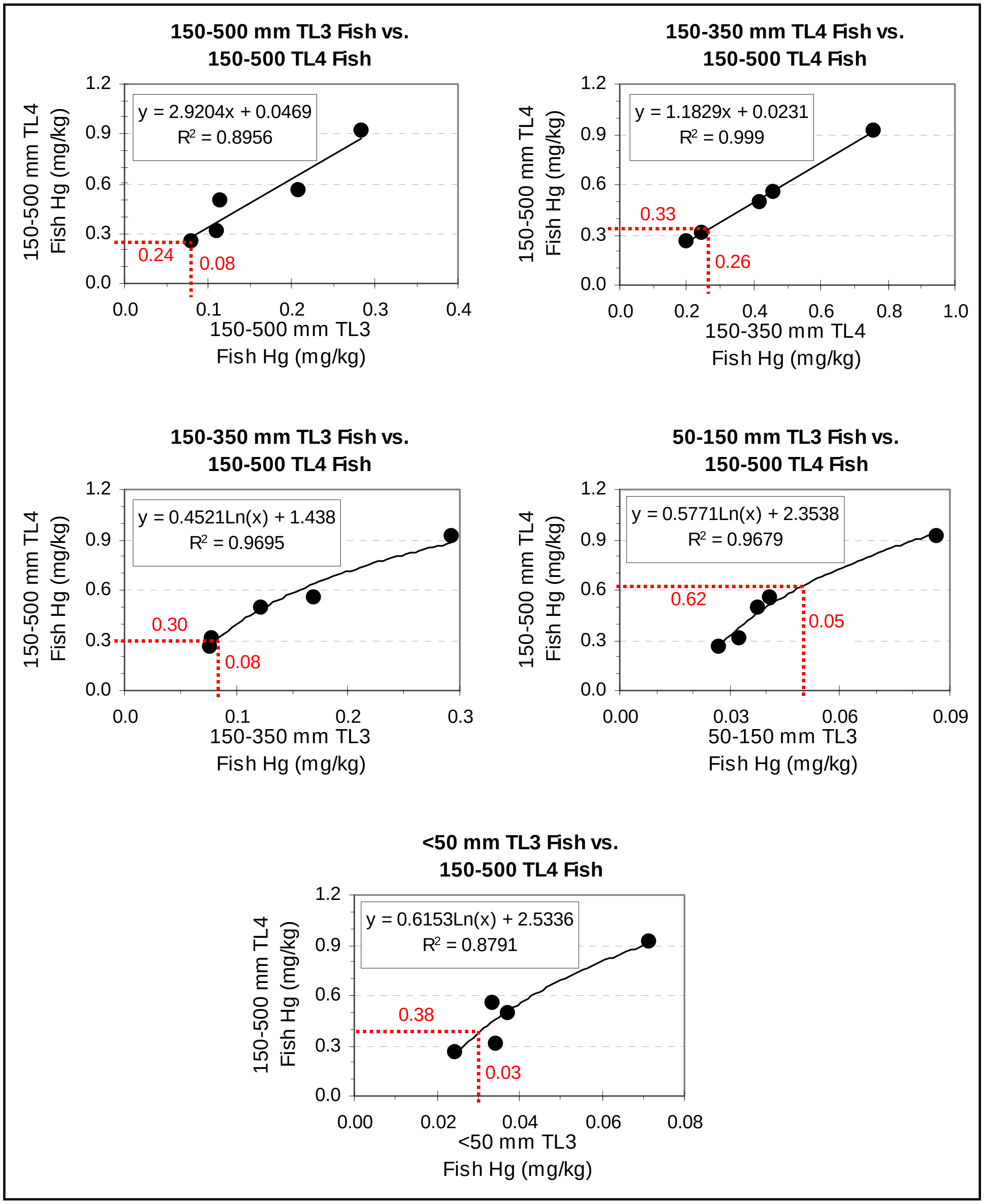

Figure 4.2: Comparison of Methylmercury Concentrations in Large (150-500 mm) TL4 Fish and Other Trophic Level (TL) Food Groups. The regressions are used to predict safe diets for target species listed in Table 4.9 in terms of large TL4 fish.

4.8 Largemouth Bass Evaluation

A goal of the TMDL is to link target methylmercury concentrations in fish to methylmercury concentrations in water to develop a goal for aqueous methylmercury that could then be used in development of an implementation plan. Chapter 5 (Linkage Analysis) describes the relationships between methylmercury in water and in largemouth bass in the Delta. Largemouth bass were selected for the linkage analysis for several reasons. Largemouth bass are a good bioindicator species. In addition, only largemouth bass data are available for the same sampling period and locations as the methylmercury water data (Figure 4.1). Largemouth bass, however, constitute only a portion of the diet of some of the human and wildlife consumers of Delta fish. The methylmercury targets determined above assume that humans and wildlife species consume a variety of sizes and species of fish from the Delta. In this section, the relationships between methylmercury concentrations in largemouth bass and the trophic level food groups were examined so that an implementation goal could be developed in terms of largemouth bass and, ultimately, linked to aqueous methylmercury.

Most of the information on mercury concentrations in the various trophic level food groups in the Delta was collected as species-specific composite samples between 1998 and 2001. Therefore, the largemouth bass evaluation was conducted in four parts. First, the methylmercury concentrations in largemouth bass of a standard size were estimated for each Delta subarea using the relationships between length and methylmercury tissue concentration[25] in samples collected in 2000. Second, correlations were run between standard 350-mm largemouth bass collected in 2000 and average concentrations of 300-400 mm largemouth bass (composite and individual samples) collected between 1998 and 2000. The year 2000 is significant because (1) aqueous methylmercury sampling began in March 2000 and (2) largemouth bass sampling adequate for the length/concentration regressions took place only in September/October 2000. The monthly March-October 2000 subset of the aqueous data has the greatest overlap with the lifespan of the largemouth bass sampled in September/October 2000. As these correlations were highly significant, the third step was to examine correlations between mercury concentrations in standard 350-mm largemouth bass and composites of all trophic level food groups collected in the Delta between 1998 and 2001. The purpose of this analysis was to determine whether consistent relationships might exist between the different assemblages of fish and, if so, whether it might be possible to describe safe mercury ingestion rates for humans and wildlife species in terms of the methylmercury concentration in a standard 350-mm largemouth bass. The final step was to determine a safe methylmercury concentration for each species in terms of the methylmercury concentration in 350-mm largemouth bass (Table 4.9).

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[25] Determining the methylmercury concentration in a specific or “standard” size fish is a typical method of data analysis that allows comparison between sites and years. For largemouth bass from one site or subarea, mercury concentration is well correlated with length (Davis *et al*., 2003; data in Figure 4.3 in this report). This correlation is also useful in monitoring, as concentrations in fish in a range of lengths can be used to predict the concentration in a standard size. Hereafter, the mercury concentration in a “standard 350 mm largemouth bass” refers to the concentration obtained through a regression analysis as in Figure 4.3.

4.8.1 Largemouth Bass Standardization

The methylmercury content of a standard 350-mm length largemouth bass was determined at all sites where both water and fish tissue data were available (Figure 4.1) by regressing fish length against mercury body burden (Figure 4.3). Appendix K provides the concentration and length data for largemouth bass sampled in the Delta. Table 4.10 presents the predicted mercury values for 350 mm bass at each location where both water and fish tissue data were available. The predicted mercury concentration in standard 350 mm largemouth bass varied by a factor of five across the Delta (0.19 mg/kg in the Central Delta to 1.04 mg/kg in the Mokelumne River). Mercury concentration in a standard length 350 mm largemouth bass was selected because the length is near the middle of the size range collected at each site and therefore maximizes the predictive capability of the regression (Davis *et al*., 2003). Three hundred and fifty mm is slightly larger than CDFG's legal size limit of 305 mm (12 inches). A 350 mm bass is three to five years old (Schaffter, 1998; Moyle, 2002).

4.8.2 Correlations between Standard 350 mm and All Largemouth Bass Data

Figure 4.4 presents the regression between mercury levels in standard 350-mm largemouth bass collected in year 2000 and weighted-average concentrations in 300-400 mm largemouth bass collected between 1998 and 2000 in five delta subareas[26] (Table 4.10). Each data point represents one subarea. The correlation is statistically significant (P<0.01) and has a slope of 0.8, suggesting that mercury concentrations do not vary appreciably between the two groups. The results suggest that year 2000 standard 350-mm bass mercury levels are representative of mercury concentrations in largemouth bass collected between 1998 and 2000.

4.8.3 Largemouth Bass/Trophic Level Food Group Comparisons

Regressions between mercury concentrations in standard 350-mm largemouth bass and TL3 and TL4 food groups are presented in Figure 4.5. The purpose of this analysis was to determine whether consistent relationships might exist between the different assemblages of fish and, if so, whether it might be possible to describe safe mercury ingestion rates for wildlife species and humans in terms of the mercury concentration in a standard 350-mm largemouth bass. The relationships were evaluated using linear, exponential, logarithmic, and power curves; in each but one case the type of curve that provided the highest R^2 value was selected.[27] All of the correlations were statistically significant (P<0.05 or less). The regressions

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[26] Data collected in 1998-2000 contained individual and composite samples. Mercury concentrations in the composite samples were weighted by number of individual fish in the composite and then averaged with individual results.

[27] A logarithmic curve best fits the points comparing standard 350-mm largemouth bass mercury concentrations to 150-500 mm TL4 fish (Figure 4.3). However, the curve intercepts the x-axis well above zero, preventing the prediction of standard largemouth bass mercury concentrations that corresponds to the range of alternative large TL4 fish mercury targets developed for human protection (0.58, 0.29, 0.24 and 0.05 mg/kg). This is also true of a linear curve: it intercepts the x-axis above zero. Therefore, a linear equation with the intercept set to zero was used to estimate standard 350-mm largemouth bass mercury concentrations that correspond to the preferred and alternative large TL4 fish targets. All three regressions are statistically significant (P<0.01). Use of either the linear or logarithmic curves to predict safe levels for largemouth bass that correspond to the TL4 target alternatives has additional uncertainty because two of the alternatives (0.24 and 0.05 mg/kg) are lower than the lowest of observed values (0.26 mg/kg in the Central Delta subarea) upon which the curves are based.

demonstrate that there are predictable relationships between mercury concentrations in standard 350-mm largemouth bass and all trophic level food groups in the Delta.

Table 4.9 presents the predicted safe dietary mercury concentrations for each TLFG target in terms of standard 350-mm bass. The safe largemouth bass mercury levels were calculated from the regression equations in Figure 4.5. The lowest largemouth bass mercury value (0.24 mg/kg) corresponds to 0.08 mg/kg in 150-500 mm TL3 fish. This is the most conservative of all the calculated largemouth bass safe levels and, if attained, should fully protect all listed beneficial uses in the Delta. Staff recommends that **0.24 mg/kg, wet weight, in a standard 350-mm largemouth bass** be used as an **implementation goal** in the linkage analysis (Chapter 5) and determination of methylmercury allocations (Chapter 8).

As described in Tables 4.8 and 4.11, percent reductions in fish methylmercury levels ranging between 0 and 77% will be needed to meet the recommended numeric targets for large and small TL3 and TL4 fish and the implementation goal for standard 350-mm largemouth bass in the different Delta subareas. Staff expects that when methylmercury concentrations in largemouth bass reach the recommended implementation goal for standard 350-mm largemouth bass, then concentrations in other aquatic organisms also will have declined sufficiently to protect human and wildlife consumers. Monitoring should be conducted in all trophic level food groups at that time to verify that the expected decreases have occurred.

Key points and options to consider for the numeric targets are listed after Figure 4.5.

Table 4.10: Mercury Concentrations in Standard 350-mm and 300-400 mm Largemouth Bass

	Hg Concentrations (mg/kg) by Delta Subarea				
	Central Delta	Mokelumne River	Sacramento River	San Joaquin River	West Delta
Year 2000 Standard 350-mm largemouth bass collected in September/October 2000 [(a)]	0.19	1.04	0.72	0.68	0.31
300-400 mm largemouth bass collected between 1998 and 2000 [(b)]	0.31	0.94	0.76	0.64	0.30

(a) The standard 350-mm largemouth bass mercury concentrations are predicted values derived using the regressions in Figure 4.3.

(b) The values for the 300-400 mm bass are weighted-average concentrations in 300-400 mm largemouth bass collected between 1998 and 2000 from multiple locations within each of the five delta subareas.

Table 4.11: Percent Reductions in Standard 350-mm Largemouth Bass Methylmercury Levels Needed to Meet the Recommended Implementation Goal of 0.24 mg/kg in Each Delta Subarea.

Central Delta	**Mokelumne River**	**Sacramento River**	**San Joaquin River**	**West Delta**
0%	77%	67%	65%	23%

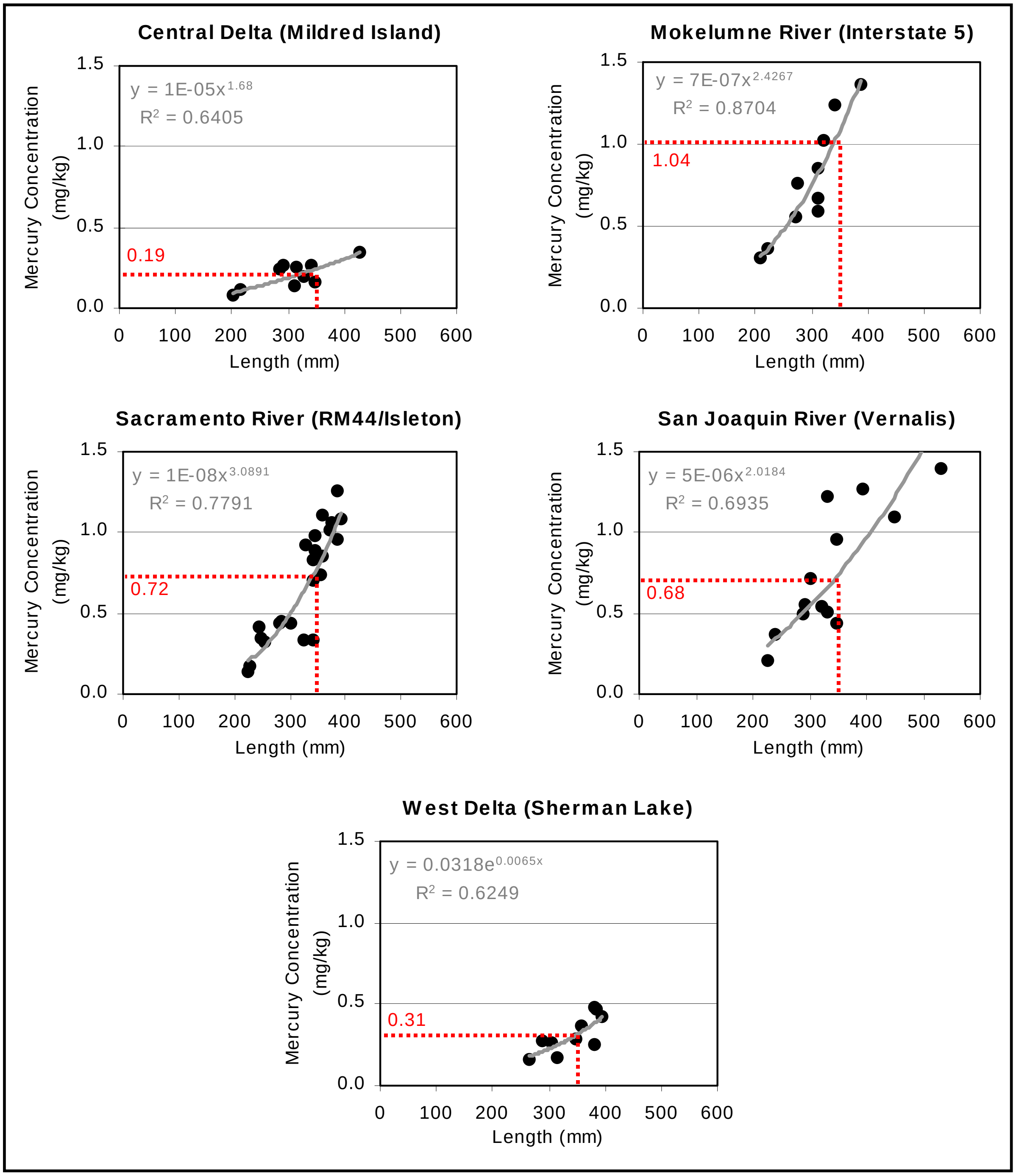

Figure 4.3: Site-specific Relationship between Largemouth Bass Length and Mercury Concentrations in the Delta. The relationships were used to predict the mercury content of a standard, 350-mm length bass sampled in September/October 2000, as indicated by the dashed lines. All relationships were significant at least at $P<0.05$.

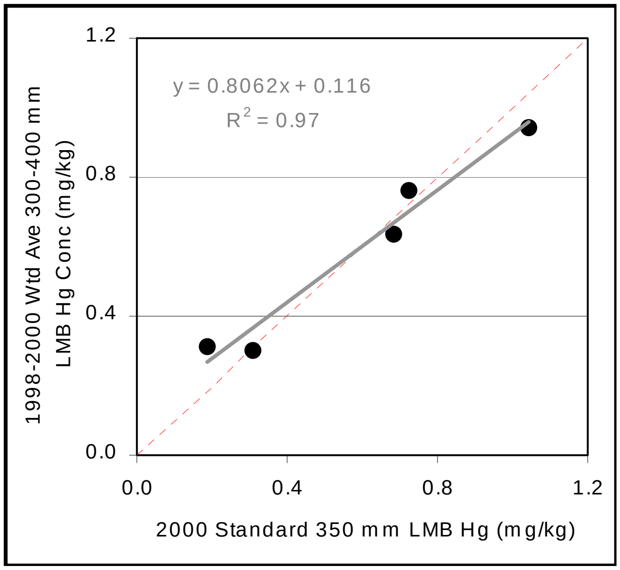

Figure 4.4: Comparison of Mercury Levels in Standard 350 mm Largemouth Bass (LMB) Collected at Linkage Sites in 2000 and Mercury Levels in 300-400 mm LMB Collected throughout Each Subarea in 1998-2000.

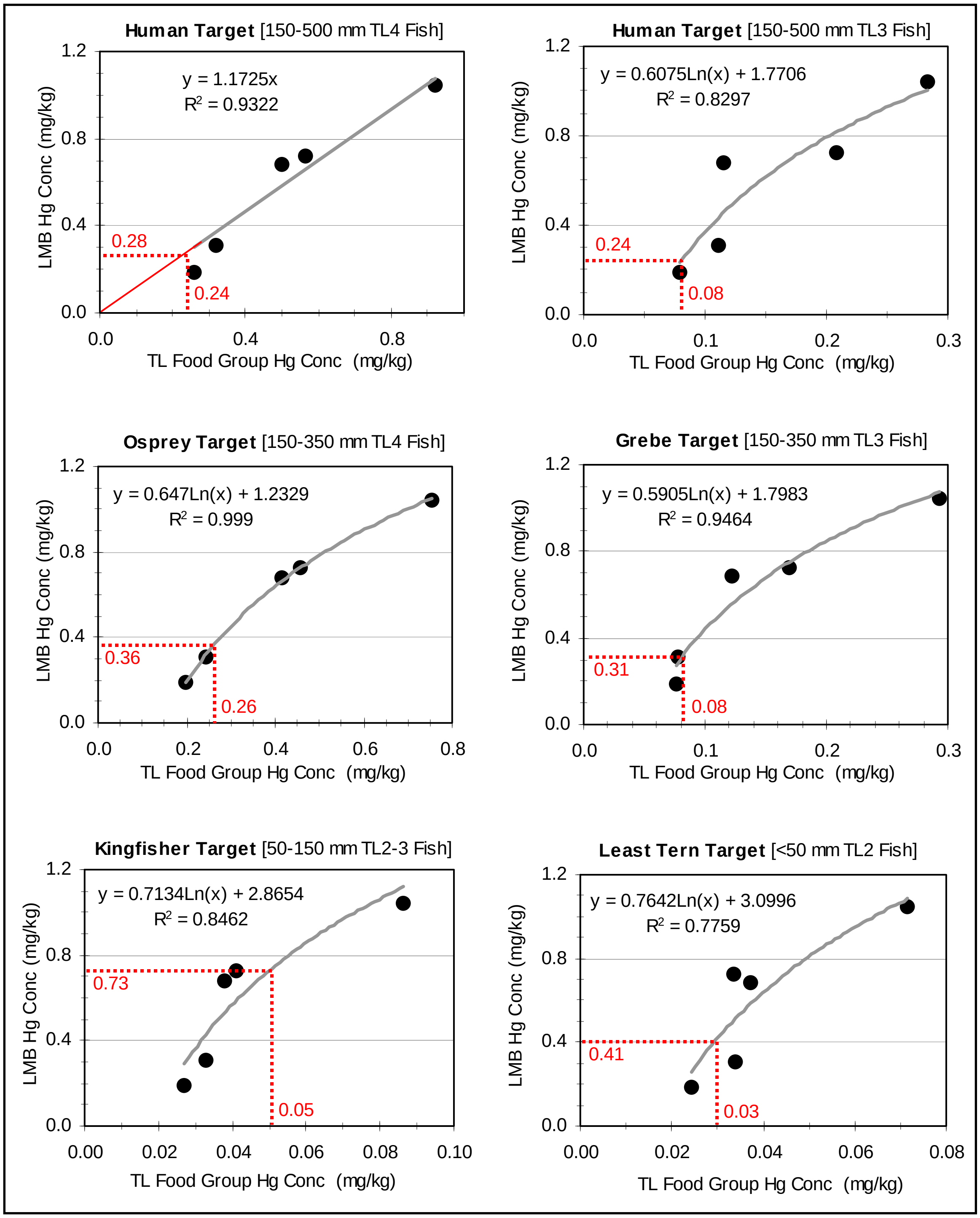

Figure 4.5: Comparison of Mercury Concentrations in Standard 350-mm Largemouth Bass (LMB) Caught in September/October 2000 and Composites of Fish from Various Trophic Level (TL) Food Groups Caught between 1998 and 2001.
The regressions are used to predict safe diets for target species listed in Table 4.9 in terms of largemouth bass mercury concentrations. Note, the recommended target for large TL4 fish (0.24 mg/kg) developed for human protection is lower than average mercury levels observed in the Delta, resulting in a corresponding standard 350-mm largemouth bass concentration that falls slightly below the regression curve based on observed values.

Key Points

- The concentration of methylmercury in fish tissue is the numeric target selected for the Delta methylmercury TMDL. Measurements of mercury in fish should be able to assess whether beneficial uses are being met because fish-eating (piscivorous) birds and mammals are most likely at risk for mercury toxicity.
- Piscivorous species identified in the Delta are: American mink, river otter, bald eagle, kingfisher, osprey, western grebe, common merganser, peregrine falcon, double crested cormorant, California least tern, and western snowy plover. Bald eagles, California least terns and peregrine falcons are listed by the State of California or by USFWS as either threatened or endangered species.
- Acceptable fish tissue levels of mercury for the trophic level food groups consumed by each wildlife species were calculated using the method developed by USFWS that addresses daily intake levels, body weights and consumption rates. Numeric targets were developed to protect humans in a manner analogous to targets for wildlife using USEPA-approved methods and regional information.
- Central Valley Water Board staff recommends two numeric targets for large fish: 0.24 mg/kg (wet weight) in muscle tissue of large trophic level four (TL4) fish such as bass and catfish and 0.08 mg/kg (wet weight) in muscle tissue of large TL3 fish such as carp and salmon. These targets are protective of (a) humans eating 32 g/day (1 meal/week) of commonly consumed, large fish; and (b) all wildlife species that consume large fish. The evaluation of the relationships between methylmercury concentrations in large TL4 fish and the other trophic level food groups indicated that wildlife species that consume smaller or lower trophic level fish would be protected by the large TL3 and TL4 fish targets developed for human protection.
- To ensure that wildlife species dining only on small fish are protected, staff proposes an additional target of 0.03 mg/kg methylmercury in whole TL2 and 3 fish less than 50 mm in length. This target represents the safe mercury level for prey consumed by the California least tern, a piscivorous species listed by the federal government as endangered. Such a target for small fish also would protect the Western snowy plover and other species that consume small fish.
- Elevated fish mercury concentrations occur along the periphery of the Delta while lower body burdens are measured in the central Delta. Percent reductions in fish methylmercury levels ranging from 0% to 74% will be needed to meet the numeric targets for wildlife and human health protection in all subareas of the Delta.
- The relationships between methylmercury concentrations in largemouth bass and the trophic level food groups also were examined because largemouth bass are a good bioindicator species and only largemouth bass data are available for the same sampling period and locations as the methylmercury water data available for the linkage analysis (next chapter). It was possible to describe safe mercury ingestion rates for wildlife species and humans in terms of the mercury concentration in a standard 350-mm largemouth bass. A methylmercury concentration of 0.24 mg/kg in 350-mm length largemouth bass would fully protect humans and piscivorous wildlife species and is proposed as an implementation goal for use in the linkage analysis and determination of methylmercury allocations for point and nonpoint sources.

Options to Consider

- A variety of assumptions can be made to calculate safe fish mercury levels for humans. For example, staff recommended targets of 0.08 mg/kg and 0.24 mg/kg for large TL3 and TL4 fish, respectively, because such targets are protective of a higher consumption rate (~1 meal per week) than that used to develop the USEPA criterion (~1 meal per 2 weeks) and because available information indicates that anglers take home a mixture of TL3 and TL4 species. Application of the USEPA criterion to large TL4 fish results in a target of 0.29 mg/kg. Use of the USEPA default consumption rates of fish from TL2 (21.7%), TL3 (45.7%) and TL4 (32.6%) produces a much higher target of 0.58 mg/kg for large TL4 fish. However, as the evaluations of trophic level food group and standard 350-mm largemouth bass mercury levels indicate, a target of 0.58 mg/kg for large TL4 fish would not protect several piscivorous wildlife species, such as bald eagle, osprey, river otter, grebe, merganser, and least tern. Large TL4 fish targets of 0.29, 0.24, or 0.05 mg/kg would be protective of these species. However, a large TL4 fish target of 0.05 mg/kg may not be attainable because it is well below regional background fish mercury levels observed in the western United States.

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5 LINKAGE ANALYSIS

The Delta linkage analysis focuses on the comparison of methylmercury concentrations in water and biota. As discussed in Chapter 2, methylmercury is the form of mercury that bioaccumulates in the food web. The relationship has not previously been evaluated in the Delta, but statistically significant, positive correlations have been reported between aqueous methylmercury and aquatic biota elsewhere (Brumbaugh *et al.*, 2001; Foe *et al.*, 2002; Slotton *et al.*, 2003; Tetra Tech, Inc., 2005a; Sveinsdottir and Mason, 2005), indicating that methylmercury concentrations in water are one of the primary factors determining methylmercury concentrations in fish. This linkage analysis develops a Delta-specific mathematical relationship between aqueous and biotic methylmercury concentrations. The relationship is used to determine an aqueous methylmercury goal that, if met, is predicted to produce safe fish tissue levels for both human and wildlife consumption (Chapter 4). The aqueous methylmercury goal is then used to allocate methylmercury reductions for within-Delta and tributary sources (Chapter 8).

The linkage analysis has three sections. The first section describes the available fish and aqueous methylmercury data. The second section illustrates the mathematical relationship between unfiltered water and largemouth bass methylmercury levels. The mathematical relationship is used to develop an unfiltered aqueous methylmercury goal of 0.06 ng/l that corresponds to the recommended fish tissue targets that are protective of humans and wildlife that consume Delta fish. The final section provides an alternate linkage using 0.45 μ filtered methylmercury water data. Results of these correlation-based linkages are comparable to results of more empirical linkage methods, such as the evaluation of Delta areas that currently achieve the implementation goal for largemouth bass, and the use of bioaccumulation factors to calculate an aqueous methylmercury goal.

5.1 Data Used in Linkage Analysis

Fish. Water and fish have not been sampled in the Delta for the specific purpose of developing a linkage analysis. As a result, there is an acceptable overlap for only a portion of the available fish and water data. This linkage analysis focuses on recently collected largemouth bass data for several reasons. First, largemouth bass was the only species systematically collected near many of the aqueous methylmercury sampling locations used to develop the methylmercury mass balance for the Delta (next section). Second, largemouth bass are piscivorous and have some of the highest mercury levels of any fish species evaluated in the Delta. Third, bass are abundant and widely distributed throughout the Delta. Fourth, bass have high site fidelity. That is, largemouth bass maintain a localized home range; most stay within a mile of a given waterway (Davis *et al.*, 2003). Such high site fidelity makes them useful bioindicators of spatial variation in mercury accumulation in the aquatic food chain. Finally, spatial trends across the Delta in standard 350-mm largemouth bass mercury levels are representative of spatial trends in the trophic level food group mercury levels (Section 4.7). Largemouth bass were collected from 19 locations in the Delta in August/September 1998, 26 locations in September/October 1999, and 22 locations in September/October 2000 (Davis *et al.*, 2000; Davis *et al*., 2003; LWA, 2003). The year 2000 largemouth bass data were used in the linkage analysis because the exposure period of these fish had the greatest overlap with the available water data. Monthly water data were collected during the last eight months of the life of the fish. Figure 5.1 shows the water and largemouth bass methylmercury sampling locations used in the linkage analysis. The mercury concentrations in standard 350-mm largemouth bass and the corresponding water data for each sampling location are presented in Table 5.1. Section 4.8 in Chapter 4 describes the method used to calculate standard 350-mm largemouth bass mercury concentrations.

Water. Unfiltered methylmercury water samples were collected periodically between March 2000 and April 2004 at multiple Delta locations (Figure 5.1, Tables D.1 and D.3 in Appendix D). The monthly March-October 2000[28] subset of this data has the greatest overlap with the lifespan of the largemouth bass sampled in September/October 2000. The March-October 2000 and March 2000 to April 2004 data were pooled by Delta subarea to calculate monthly averages (Tables D.2 and D.3).[29] These values were used to estimate average and median methylmercury concentrations for the March-October 2000 period and annual and seasonal average and median concentrations for the March 2000 to April 2004 period (Table 5.1).[30]

Table 5.1: Fish and Water Methylmercury Values by Delta Subarea.

	Delta Subarea (a)				
	Sacramento River	Mokelumne River	Central Delta	San Joaquin River	West Delta
FISH [Sampled in September/October 2000] (mg/kg)					
Standardized 350-mm Largemouth Bass	0.72	1.04	0.19	0.68	0.31
WATER [Sampled between March and October 2000] (ng/l)					
Average	0.120	0.140	0.055	0.147	0.087
Median	0.086	0.142	0.032	0.144	0.053
WATER [Sampled between March 2000 and April 2004] (ng/l)					
Annual Average	0.108	0.166	0.060	0.160	0.083
Annual Median	0.101	0.161	0.051	0.165	0.061
Cool Season Average (b)	0.137	0.221	0.087	0.172	0.106
Cool Season Median	0.138	0.246	0.077	0.175	0.095
Warm Season Average	0.094	0.146	0.050	0.156	0.075
Warm Season Median	0.089	0.146	0.040	0.162	0.055

(a) See Figure 5.1 for the location of each water and fish collection site.
(b) For this analysis, “cool season” is defined as November through February and “warm season” is defined as March through October.

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[28] Coincidentally, March through October defines the season with warmer water temperatures. Aquatic biota may be more metabolically active and have a higher methylmercury bioaccumulation rate in summer. In addition, sulfate-reducing bacteria may have higher methylmercury production rates making this a critical bioaccumulation period.

[29] The methylmercury concentrations for two periods – (a) March-October 2000 and (b) September 2000 to April 2004 – were compared at each sampling location in Figure 5.1 with a paired t-test to determine whether the mean concentrations for the two time periods were different. The tests indicated no significant difference ($P \leq 0.05$) for any location. Therefore, the data for March 2000 to April 2004 (a substantially larger database than that for March-October 2000) were also evaluated in the linkage analysis.

[30] Monthly averages were used to ensure that the seasonal and annual values were not biased by months with different sample sizes.

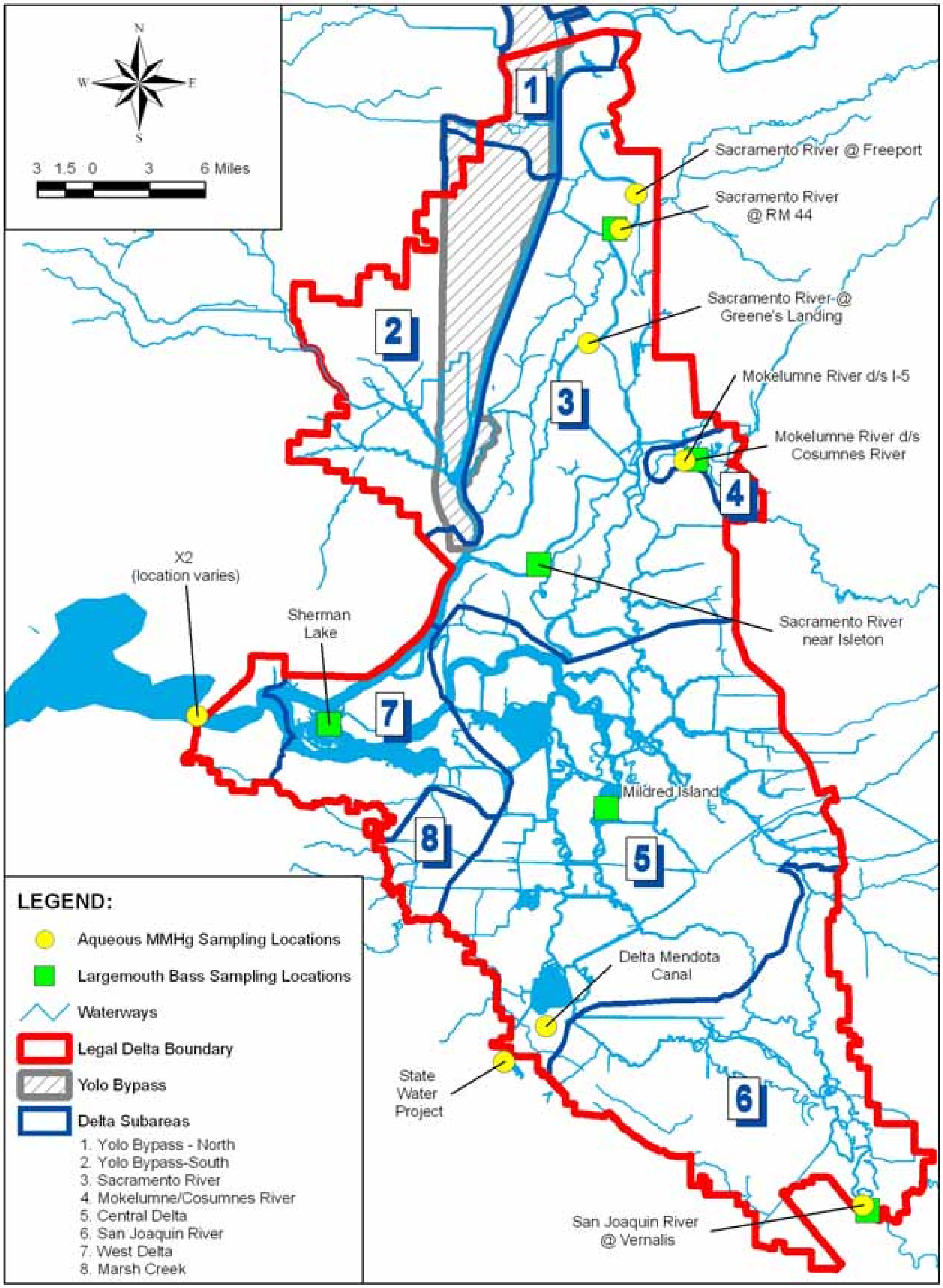

Figure 5.1: Aqueous and Largemouth Bass Methylmercury Sampling Locations Used in the Linkage Analysis.

5.2 Bass/Water Methylmercury Regressions & Calculation of Aqueous Methylmercury Goal

The mercury concentrations in standard 350-mm largemouth bass for each Delta subarea were regressed against the average and median unfiltered aqueous methylmercury levels for the March to October 2000 and March 2000 to April 2004 periods to determine whether relationships might exist (Figure 5.2, Table 5.2, and Figure D.1 in Appendix D). The regressions were evaluated using linear, exponential, logarithmic, and power curves. Power curves provided the best fit, although all the regression types demonstrated a positive relationship between aqueous and biotic methylmercury concentrations. In each scenario described by Table 5.2, increasing the aqueous methylmercury concentration results in increasing fish tissue levels. The recommended implementation goal for fish methylmercury in the Delta is 0.24 mg/kg (wet weight) in a standard 350-mm largemouth bass (Chapter 4). Substitution of 0.24 mg/kg into the equations in Table 5.2 results in predicted average and median safe water methylmercury values that range from 0.04 to 0.09 ng/l. The lowest concentration is predicted by the regression based on median March to October 2000 water values (Scenario 1B) while the highest concentration is predicted by the regression based on average cool season water concentrations (Scenario 3A).

Staff recommends that **0.06 ng/l methylmercury in unfiltered water** be used as an **implementation goal** for the determination of load allocations (Chapter 8). This recommendation is based on Scenario 1A in Table 5.2 and incorporates an explicit margin of safety of about 10%. The goal could be applied as an annual average methylmercury concentration. Staff recommends this value because only the March to October 2000 period overlapped the lifespan of the largemouth bass analyzed for mercury body burden. Also, little is known about the seasonal exposure regime controlling methylmercury concentrations in aquatic biota. Therefore, an annual average was selected as it weights all seasons equally.

The recommended implementation goals for largemouth bass and ambient water methylmercury in the Delta are based on Scenario B.4 from Table 4.5 in Chapter 4. Scenarios A.1, A.4, B.4 and E.3 are evaluated as fish tissue objective alternatives in the draft Basin Plan Amendment staff report. Table 5.3 shows the ambient water methylmercury levels that correspond to all the objective alternatives.

Progress towards attaining Alternative 5 in Table 5.3 would be difficult to track. This is because Alternative 5 (0.05 mg/kg in large TL4 fish) is substantially below existing conditions anywhere in the Delta, thus making it difficult to accurately extrapolate from methylmercury in fish to corresponding methylmercury in water. Such extrapolation for Alternative 5 produces a concentration of 0.028 ng/l methylmercury in water, which is below the current minimum reporting level for laboratory analyses for methylmercury. (Minimum reporting levels are equivalent to the lowest calibration standard for methylmercury, which is currently 0.05 ng/l.) Though water methylmercury concentrations below the minimum reporting level can be detected, they cannot be quantified accurately; thus, Alternative 5 progress would be difficult to quantify and track. The other fish tissue objective alternatives correspond to water methylmercury concentrations above the minimum reporting level of 0.05 ng/l and thus can be quantified accurately.

To evaluate the bass/water methylmercury relationship, staff used measures of central tendency for the fish and water concentration variables. Because a fish integrates methylmercury that is taken in over its lifetime, it is not valid biologically to match individual fish and water samples for the purposes of graphing them, when other data are available. An average of the aqueous methylmercury concentrations collected over an eight-month period better represents aqueous methylmercury available to the fish, than do single water samples. The fish tissue concentrations used in Figures 5.2 and 5.3 are the methylmercury concentrations in a single-size (standard 350 mm) largemouth bass that staff calculated using data from bass of various sizes in each subarea. Because methylmercury concentrations vary with size of fish, calculating the expected methylmercury fish level in a single length of fish is a common practice for comparing fish methylmercury concentrations between locations without the confounding effect of size difference (see Chapter 4 for a description of the standardization method).

The linkage analysis for the Delta relies upon sequential correlations to determine the numerical aqueous methylmercury goal. A potential problem with the analysis is that each correlation has an associated error term. No attempt has been made to estimate these errors and propagate them from one correlation to the next when calculating the recommended aqueous methylmercury goal.

Staff determined the statistical strength of each regression equation (shown on Figures 5.2 and 5.3) for the purpose of selecting the variables that exhibited the strongest relationship (average versus median aqueous methylmercury and filtered versus unfiltered methylmercury). Staff noted that the regression for standard 350 mm largemouth bass and average unfiltered methylmercury has the highest R^2 value. However, staff did not rely on the statistical significance to support the fish/methylmercury linkage analysis. Multiple studies assert that the supply of aqueous methylmercury is a key determining factor in the concentrations of methylmercury in biota (Brumbaugh *et al.,* 2001; Paterson *et al*., 1998; SFBRWQCB, 2008; Slotton *et al.*, 2004; Stewart *et al.*, 2008; St. Louis *et al*, 2004; Wiener *et al*., 2003). As described below, staff evaluated two other approaches to determining an aqueous methylmercury goal and obtained results similar to that produced by the quantitative relationship in Figure 5.2.

There are two alternate, more empirical, approaches. The first approach is to compare existing largemouth bass and aqueous methylmercury levels to the proposed implementation goals. The average March-October 2000 methylmercury concentration in the Central Delta (0.055 ng/l, Table 5.1) is less than the proposed aqueous goal of 0.06 ng/l while concentrations in the West Delta (0.087 ng/l) are higher. Similarly, the methylmercury concentration in standard 350-mm bass in the Central Delta is 0.19 mg/kg while the concentration in the West Delta is 0.31 mg/kg (Table 4.10). The recommended implementation goal is 0.24 mg/kg in standard 350-mm largemouth bass. Therefore, empirical observations suggest that the “correct” aqueous methylmercury goal to achieve safe mercury levels in the various trophic level food groups must lie between 0.055 and 0.087 ng/l. If the aqueous methylmercury goal of 0.06 ng/l is attained in the Delta, then methylmercury concentrations in all trophic level food groups are predicted to fall within the safe tissue concentration range.

A second linkage approach that does not rely on the correlation between largemouth bass and water methylmercury concentrations to derive an implementation goal for water makes use of bioaccumulation factors (BAFs), an approach used in numerous USEPA-approved TMDLs across the country.[31] A BAF is the ratio of the concentration of a chemical in fish tissue to the concentration of the chemical in the water column. As defined in the Mercury Study Report to Congress (USEPA, 1997a), the BAF is the concentration of the methylmercury in fish divided by the concentration of dissolved methylmercury in water. A total BAF based on the total concentration of a chemical in water also can be used (USEPA, 2003). By definition, BAFs imply a linear relationship between methylmercury in the water column and in fish. Section D.2 in Appendix D describes the method used to develop BAF-based implementation goals for the Delta and its subareas using standard 350-mm largemouth bass and average aqueous methylmercury concentrations. The resulting safe aqueous methylmercury levels ranged from 0.029 to 0.069 ng/l, and averaged 0.052 ng/l:

- Central Delta subarea: 0.069 ng/l;
- Mokelumne River subarea: 0.032 ng/l;
- Sacramento River subarea: 0.040 ng/l;
- San Joaquin River subarea: 0.052 ng/l; and
- West Delta subarea: 0.067 ng/l.

These levels are slightly less than but comparable to the safe levels produced using the regression-based approach. The similarity most likely occurs because both methods used the same fish and water data, and because the regression described in Figure 5.2(A) is nearly linear at low fish and water methylmercury levels. This approach has the benefit that it does not assume identical bioaccumulation rates across the Delta. However, unlike the regression-based method, the BAFs inherently assume a linear relationship between fish and water methylmercury levels.

The points on the graphs in Figures 5.2 and 5.3 essentially represent methylmercury bioaccumulation factors (BAFs) for each Delta subarea. The regression equations demonstrate that for all of the Delta subareas, the average aqueous methylmercury concentration accounts for a very large part of the difference between fish mercury concentrations. The strong correlation shown in Figure 5.2 between Delta subarea BAFs is a strength of this TMDL's linkage analysis approach and underlies the feasibility of reaching the fish tissue targets.

The safe aqueous methylmercury concentrations predicted for the Delta are comparable to analysis results for Cache Creek and nationwide studies. Brumbaugh and others (2001) found in a national survey of 106 stations from 21 basins that one-time unfiltered methylmercury water samples collected during the fall season were also positively correlated with largemouth bass tissue levels. An aqueous methylmercury concentration of 0.058 ng/l was predicted to produce three-year old largemouth bass (262-mm average length fish) with 0.3 mg/kg mercury tissue concentration. In the Cache Creek watershed, an unfiltered methylmercury concentration of 0.14 ng/l corresponded with the production of 0.23 mg/kg mercury in large fish (Cooke *et al.*, 2004). Predicted safe methylmercury water values for the Delta are bracketed by safe water concentrations determined by the national and Cache Creek studies.

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[31] Refer to: http://www.epa.gov/OWOW/tmdl/index.html.

Additional fish and methylmercury water studies that address uncertainties in the linkage analysis are planned. These include additional evaluations of standard 350-mm largemouth bass tissue concentrations at more locations in the Delta and elsewhere in the Central Valley after multiple years of aqueous methylmercury data have been obtained. Studies also are planned to better determine the seasonal exposure regime when most of the methylmercury is sequestered in the aquatic food chain. Board staff will work with a statistician to develop a more powerful statistical analysis of the linkage during the study period. The results of these studies may lead to future revisions in the proposed aqueous methylmercury goal.

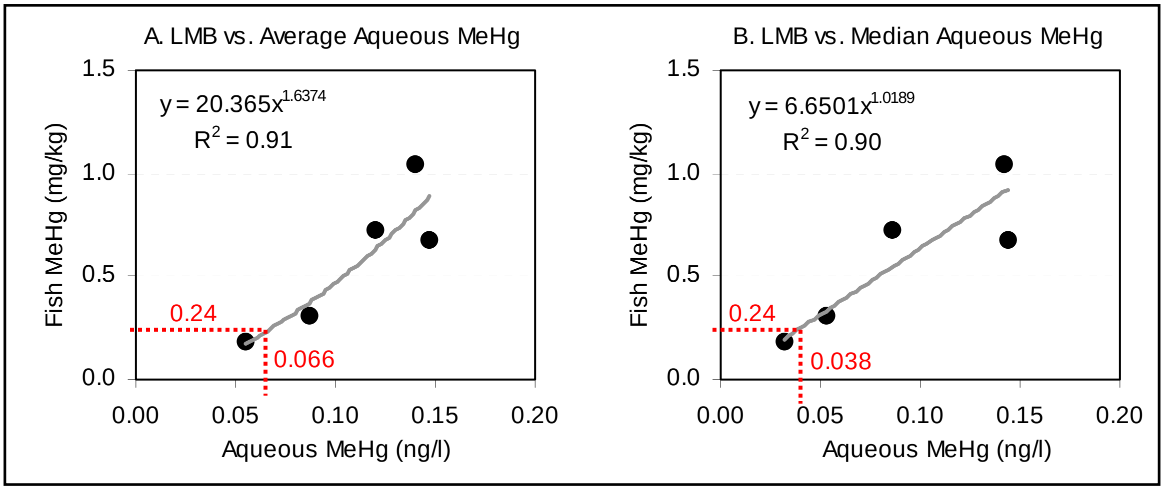

Figure 5.2: Relationships between Standard 350-mm Largemouth Bass Methylmercury and March to October 2000 Unfiltered Aqueous Methylmercury.
The proposed implementation goal for standard 350-mm largemouth bass is 0.24 mg/kg.

Table 5.2: Relationships between Methylmercury Concentrations in Water and Standard 350-mm Largemouth Bass

Aqueous MeHg Data Period	Scenario	Regression Equation	$R^{2\,(a)}$	Aqueous MeHg Conc. (ng/l) Corresponding to LMB value of 0.24 mg/kg
1. March to October 2000	A. Average Aqueous MeHg	$y = 20.365x^{1.6374}$	0.91	0.066
	B. Median Aqueous MeHg	$y = 6.6501x^{1.0189}$	0.90	0.038
2. March 2000 to April 2004 - Annual -	A. Average Aqueous MeHg	$y = 14.381x^{1.51}$	0.88	0.066
	B. Median Aqueous MeHg	$y = 8.0903x^{1.1926}$	0.86	0.052
3. March 2000 to April 2004 - Cool Season -	A. Average Aqueous MeHg	$y = 17.795x^{1.8007}$	0.90	0.092
	B. Median Aqueous MeHg	$y = 8.8725x^{1.4347}$	0.92	0.081
4. March 2000 to April 2004 - Warm Season -	A. Average Aqueous MeHg	$y = 11.528x^{1.339}$	0.83	0.055
	B. Median Aqueous MeHg	$y = 6.8941x^{1.0723}$	0.85	0.044

(a) All R^2 values are statistically significant at $P<0.05$. Regression graphs are provided in Figure 5.2 and Appendix D.

Table 5.3. Ambient Water Methylmercury Concentrations that Correspond to Alternative Fish Tissue Objectives Evaluated in the Basin Plan Amendment Staff Report.

Fish Tissue Objective Alternative [(a)]	**Scenario # from Table 4.5**	**150-500 mm TL3 Fish Tissue Target** (mg/kg)	**150-500 mm TL4 Fish Tissue Target** (mg/kg)	**Predicted Standard 350-mm Largemouth Bass (LMB) MeHg Concentration for TL3 Fish Target** (mg/kg) [(b)]	**Predicted Standard 350-mm LMB MeHg Concentration for TL3 Fish Target** (mg/kg) [(b)]	**Ambient Water MeHg Concentration that Corresponds to the Lowest Predicted LMB Concentration for the Alternative** (ng/l) [(b)]
2	A.1	0.20	0.58	0.79	0.68	0.125
3	A.5	- - -	0.29		0.34	0.082
4	B.4	0.08	0.24	0.24	0.28	0.066
5	E.3	- - -	0.05		0.06	0.028

(a) Alternative numbers from Table 3.1 in the Basin Plan Amendment Staff Report. “Alternative 1” is the “no action” alternative and has a narrative objective rather than a numeric objective.

(b) Predicted standard 350-mm largemouth bass methylmercury concentrations that correspond to the TL3 fish targets were calculated using the equation provided in Figure 4.5 for “Human Target [150-500 TL3 Fish]”. Predicted standard 350-mm largemouth bass methylmercury concentrations that correspond to the TL4 fish targets are based on the equation provided in Figure 4.5 for “Human Target [150-500 TL4 Fish]”.

(c) Ambient water methylmercury concentrations that correspond to the predicted largemouth bass concentrations were calculated using the equation for Scenario 1A in Table 5.2.

5.3 Evaluation of a Filtered Aqueous Methylmercury Linkage Analysis

This section presents an alternate linkage analysis based on filter-passing[32] aqueous methylmercury data. Methylmercury concentrations in standard 350-mm largemouth bass for each Delta subarea (Table 5.1) were regressed against the average and median filtered aqueous methylmercury levels for March-October 2000 (Table 5.4 and Table D.4 in Appendix D). Figure 5.3 demonstrates that there is a statistically significant positive correlation between filter-passing aqueous and largemouth bass tissue methylmercury levels. However, average and median filter-passing methylmercury water values for the Central Delta and Western Delta, regions that define the lower end of the regression, are determined mainly by values lower than the method detection limit (0.022 ng/l). Furthermore, substitution of the recommended implementation goal of 0.24 mg/kg mercury for 350 mm largemouth bass in the equations in Figure 5.3 results in predicted average and median safe water values (0.016 ng/l and 0.010 ng/l, respectively) below the method detection limit. Similarly low levels resulted when the BAF-based linkage method was used (see Section D.2 in Appendix D). Staff does not recommend adoption of a methylmercury goal that is unquantifiable with present analytical methods.

Key points to consider for the linkage analysis are listed after Table 5.4 and Figure 5.3.

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[32] Water samples were filtered using 0.45-micrometer capsule filters. Much of the methylmercury measured in filtered samples is colloidal (Choe, 2002). Hence the results are called “filter-passing” rather than “dissolved”.

Table 5.4: Average and Median Filtered Methylmercury Concentrations (ng/l) for March 2000 to October 2000 for Each Delta Subarea.

	Delta Subarea [(a)]				
	Sacramento River	Mokelumne River	Central Delta	San Joaquin River	West Delta
Average	0.043	0.078	0.029	0.037	0.019
Median	0.039	0.069	0.014	0.036	0.011

(a) See Figure 5.1 for the location of each water and fish collection site. See Appendix L for raw data and Table D.4 in Appendix D for monthly averages, upon which these average and median values are based.

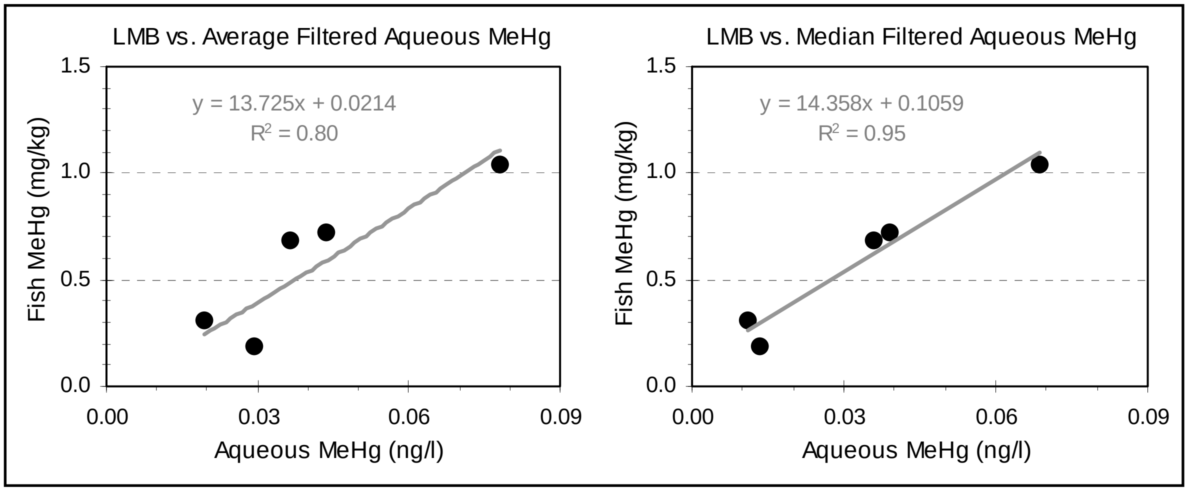

Figure 5.3: Relationships between Standard 350-mm Largemouth Bass Mercury Levels and March to October 2000 Filtered Aqueous Methylmercury.

Key Points

- Statistically significant mathematical relationships exist between unfiltered and filter-passing methylmercury concentrations in water and fish tissue.
- Based on the relationship between average March to October 2000 unfiltered methylmercury concentrations in water and methylmercury in standard 350-mm largemouth bass tissue, staff recommends an implementation goal for ambient Delta waters of 0.06 ng/l unfiltered methylmercury. The proposed goal incorporates an explicit margin of safety of about 10%. Staff recommends that the goal be applied as an annual average methylmercury concentration.
- More empirical linkage methods, such as the evaluation of Delta areas that currently achieve the implementation goal for largemouth bass and the use of bioaccumulation factors to calculate an aqueous methylmercury goal, predict safe aqueous methylmercury levels comparable to the correlation-based linkage method.

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6 SOURCE ASSESSMENT – METHYLMERCURY

The Delta mercury TMDL program addresses the sources of two constituents, methyl and total mercury. The program focuses on methylmercury because, as described in Chapters 2 and 5, methylmercury is the form of mercury that bioaccumulates in the Delta food web and statistically significant, positive correlations have been found between aqueous methylmercury and aquatic biota in the Delta and elsewhere, indicating that methylmercury concentrations in water are one of the primary factors determining methylmercury concentrations in fish. The program also addresses total mercury for several reasons: methylmercury production has been found to be a function of the total mercury content of sediment (Chapter 3); the mercury control program for the Delta must maintain compliance with the USEPA's CTR criterion for total recoverable mercury in freshwater sources; and the mercury control program for San Francisco Bay has assigned a total mercury load reduction of 110 kg/yr to the Central Valley (Johnson and Looker, 2004; SFBRWQCB, 2006). Sources and losses of methylmercury are described in this chapter. Sources and losses of total mercury and suspended sediment are described in Chapter 7. All of the mass load calculations are based on Equation 6.1:

Equation 6.1:

$$M_x = C_x * V$$

Where: M_x = Mass of constituent, X
C_x = Concentration of constituent, X, in mass per volume
V = Volume of water

Average annual methylmercury loads were estimated for water years (WY) 2000 to 2003, a relatively dry period that encompasses the methyl and total mercury concentration data for the major Delta inputs and exports available at the time the TMDL was developed. As described in the draft Basin Plan Amendment staff report, staff recommends that a Delta mercury control program review take place after additional Delta-specific studies are completed, during which the TMDL source analysis can be updated. Staff will use data from recently completed studies, as well as additional information that becomes available during the next seven years, to revise the methylmercury source analyses as part of the program review. Although some methylmercury load estimates would change with incorporation of data from recent studies, the first implementation activities (methylmercury control studies and total mercury reductions) proposed for the control program (see Chapter 4 in the draft Basin Plan Amendment staff report) would not change. Stakeholders participating in Stakeholder Group meetings in 2009 accepted this approach to using data that became available after the TMDL was developed.

Section 6.1 and Appendix E describe the water volumes upon which the loads are based. Sections 6.2 and 6.3 describe the methylmercury concentration data for all major sources and sinks and identify data gaps and uncertainties. Section 6.4 reviews the results and potential implications of the methylmercury mass balance. Mass balances are useful because the difference between the sum of known inputs and exports is a measure of the uncertainty of the measurements and of the importance of other unknown processes at work in the Delta.

6.1 Water Budget

Water inputs and losses were evaluated for the WY2000-2003 period, a relatively dry period that encompasses the methylmercury concentration data for the major Delta inputs and exports available at the time the TMDL was developed (Section 6.2). In addition, the WY1984-2003 period was evaluated to illustrate the importance of wet years, particularly for total mercury and sediment loading from the Yolo Bypass (Chapter 7). This 20-year period includes a mix of wet and dry years that is statistically similar to what has occurred in the Sacramento Basin over the last 100 years. An assessment of a typical distribution of wet and dry water years is critical to the understanding of mercury and sediment sources because, given the interannual variability in Sacramento Basin flows and mercury loads, and high daily loads associated with large storm events, the load transported by several high flow days may be equivalent to the annual load from the Sacramento River Basin during a dry year (see Figure E.1 and Table I.2 in Appendices E and I, respectively).

Water volume information for Delta inputs and exports was obtained from a variety of sources. USGS and DWR gages provided daily flows for the major tributaries to the Delta. The Dayflow model was used to estimate daily flow to San Francisco Bay, the Delta Mendota Canal (DMC), and the State Water Project (SWP). The Delta Island Consumptive Use Model was used to estimate Delta agricultural diversion and return flows. Average annual precipitation and land use acreages were used to estimate wet weather inputs from urban areas, atmospheric deposition, and tributaries without flow gages. Project files were reviewed to determine average annual discharges from NPDES-permitted facilities in the Delta and annual average volumes removed by dredging projects. Appendix E provides a detailed description of the methods used to estimate annual average flow for the different water sources.

The WY2000-2003 water budget balances within about 5%, and the WY1984-2003 water budget balances to within about 1% (Table 6.1). This indicates that all major water inputs and exports have been identified. The Sacramento River, San Joaquin River and Yolo Bypass are the primary water sources, with the Sacramento River providing the majority of flow. The primary sinks are San Francisco Bay and the state and federal pumps that transport water to the southern part of the State. The majority of water movement in the Delta is down the Sacramento River to San Francisco Bay and through a series of interconnecting channels to the state and federal pumps. Most of the water in winter and spring flows to San Francisco Bay, while in summer and fall the state and federal pumps export a larger fraction south of the Delta (DWR, 1995).

6.2 Methylmercury Sources

The following were identified as sources of methylmercury to the Delta/Yolo Bypass: tributary inflows from upstream watersheds, sediment flux, municipal wastewater, agricultural drainage, and urban runoff. Table 6.2 lists the average methylmercury concentrations and estimated average annual loads for each for WY2000-2003. The following sections illustrate the locations of the sources, describe the available methylmercury concentration data, and identify data gaps and uncertainties associated with the load estimates. Figures and tables cited in the text are arranged at the end of each source-specific section in the order in which they were mentioned.

Table 6.1: Average Annual Water Volumes for Delta/Yolo Bypass Inputs and Losses

Inputs & Exports	**WY2000-2003**		**WY1984-2003**	
	Water Volume (M acre-feet/yr)	% All Water	Water Volume (M acre-feet/yr)	% All Water
Tributary Sources (% of All Inputs)				
Sacramento River	15.1	75%	16.1	68%
San Joaquin River	1.8	9.0%	3.0	13%
Fremont Weir Spills to Yolo Bypass	1.1	5.5%	1.9	8.0%
Mokelumne-Cosumnes River	0.43	2.4%	0.69	2.9%
Knights Landing Ridge Cut	0.27	1.3%	0.33	1.4%
Cache Creek Settling Basin	0.22	1.1%	0.38	1.6%
Calaveras River	0.15	0.75%	0.16	0.68%
French Camp Slough	0.064	0.32%	0.067	0.28%
Willow Slough & Bypass	0.062	0.31%	0.068	0.29%
Morrison Creek	0.061	0.30%	0.064	0.27%
Putah Creek	0.041	0.20%	0.11	0.47%
Ulatis Creek	0.032	0.16%	0.033	0.14%
Bear/Mosher Creeks	0.029	0.14%	0.030	0.13%
Dixon Area	0.012	0.06%	0.012	0.05%
Marsh Creek (a)	0.006	0.03%	0.006	0.03%
Other Small Drainages to Delta (b)	0.082	0.41%	0.082	0.35%
Sum of Tributary Inputs	**19.51**	**97.1%**	**23.03**	**97.5%**
Within-Delta Sources (% of All Inputs)				
Wastewater (Municipal & Industrial)	0.27	1.4%	0.27	1.1%
Atmospheric (Direct)	0.089	0.45%	0.092	0.39%
Atmospheric (Indirect)	0.16	0.80%	0.17	0.72%
Urban	0.059	0.30%	0.061	0.26%
Sum of Within-Delta Inputs	**0.58**	**2.9%**	**0.59**	**2.5%**
Exports (% of All Exports)				
Outflows to San Francisco Bay [X2]	12	63%	17	73%
State Water Project	3.2	17%	2.6	11%
Delta Mendota Canal	2.5	13%	2.4	10%
Agricultural Diversions (a)	0.99	5%	0.99	4.2%
Evaporation	0.30	2%	0.3	1.3%
Dredging (a)	0.00024	0.001%	0.00024	0.001%
Sum of Inputs	**20.09 M acre-feet**		**23.63 M acre-feet**	
Sum of Exports	**18.99 M acre-feet**		**23.29 M acre-feet**	
Input - Export	**1.10 M acre-feet**		**0.33 M acre-feet**	
Exports / Inputs	**95%**		**99%**	

(a) Only WY2001-2003 flow data were available for Marsh Creek. Agricultural diversion volume is based on WY1999. The water volume removed by dredging is a 10-year average. The same water volumes for these inputs and exports, and for the Wastewater input, were used in both water budget periods.

(b) "Other Small Drainages to Delta" include the following areas shown on Figure 6.1, for which methylmercury, total mercury and TSS concentration data are not available: Manteca-Escalon, Bethany Reservoir, Antioch, and Montezuma Hills areas.

Table 6.2: Methylmercury Concentrations and Loads to the Delta/Yolo Bypass for WY2000-2003.

	Average Annual Load (g/yr)	**% All MeHg**	**Average Aqueous Concentration** (ng/l)
Tributary Sources			
Sacramento River @ Freeport	2,026	39%	0.10
San Joaquin River near Vernalis	356	6.8%	0.16
Fremont Weir Spills to Yolo Bypass	177	3.4%	0.10
Cache Creek Settling Basin	137	2.6%	0.50
Mokelumne River near I-5	108	2.1%	0.17
Knights Landing Ridge Cut	100	1.9%	0.19
Calaveras River (b)	26	0.50%	0.14
Willow Slough & Bypass (a)	18	0.34%	0.24
Putah Creek	11	0.21%	0.18
Bear/Mosher Creeks (b)	11	0.21%	0.31
French Camp Slough (b)	11	0.21%	0.14
Ulatis Creek (b)	9.5	0.18%	0.24
Morrison Creek (b)	7.5	0.14%	0.10
Dixon Area (a)	3.6	0.07%	0.24
Marsh Creek @ Highway 4 (c)	1.9	0.04%	0.25
Other Small Drainages to Delta	*unknown*		
Sum of Tributary Sources	**3,004**	**58%**	**- - -**
Within-Delta Sources			
Wetland Habitats	983	19%	- - -
Open Water Habitats	861	17%	- - -
Wastewater	205	3.9%	<0.02 to 1.7
Agricultural Lands	123	2.4%	- - -
Atmospheric Deposition	23	0.44%	- - -
Urban	20	0.38%	0.24
Sum of Within-Delta/Yolo Bypass Sources	**2,215**	**42%**	**- - -**
TOTAL MeHg INPUTS:	**5,219 g/yr (5.2 kg/yr)**		

(a) Methylmercury data were not available for Willow Slough, Willow Slough Bypass, and Dixon Area runoff. The average methylmercury concentration for Ulatis Creek was used to estimate their inputs to the Yolo Bypass because they have similar land uses as the Ulatis Creek watershed.

(b) Average wet weather methylmercury concentrations are shown for the small watersheds rather than average annual concentrations.

(c) Only WY2001-2003 flow data were available for Marsh Creek.

6.2.1 Tributary Inputs

Tributaries contribute almost 60% of Delta methylmercury inputs (Table 6.2) during the relatively dry WY2000-2003 period. Figure 6.1 illustrates the tributary watersheds that drain directly or indirectly to the Delta within its legal boundary. The following watershed areas drain directly to the Delta:

- Calaveras, Mokelumne, Sacramento, and San Joaquin Rivers;
- Bear, Marsh, Mosher, Morrison, and Ulatis Creeks;
- Prospect and Shag Sloughs, which drain the Yolo Bypass;
- French Camp Slough and Upper Lindsay/Cache Slough area; and
- Manteca-Escalon, Bethany Reservoir, Antioch, and Montezuma Hills areas.

The primary drainage in the Yolo Bypass is the Toe Drain, which drains southward to Prospect Slough in the legal Delta. However, depending on the level of inundation in the Yolo Bypass, about 20% of the incoming water may drain to the Delta by way of Shag Slough (Foe *et al*., 2008). The following watershed areas drain to the Yolo Bypass upstream of Prospect and Shag Sloughs:

- Cache Creek Settling Basin
- Fremont and Sacramento Weirs
- Knights Landing Ridge Cut
- Putah Creek
- Willow Slough and Willow Slough Bypass
- Dixon Area

Putah Creek drains to the Yolo Bypass downstream of the legal Delta boundary, while the rest of the watershed areas drain to it upstream of the legal Delta boundary. Fremont and Sacramento Weirs convey floodwaters from the Sacramento and Feather Rivers, Sutter Bypass and their associated tributary watersheds. The Knights Landing Ridge Cut is an overflow channel that connects the Colusa Basin Drain to the Yolo Bypass (see Figure 6.1 and Figure E.2 in Appendix E).

Several sampling efforts have taken place to characterize tributary inputs to the Delta and Yolo Bypass. Figure 6.2 shows the tributary methylmercury monitoring locations. Appendix L provides the methylmercury concentration data collected at each tributary location and Table 6.3 and Figure 6.3 summarize the data.

Central Valley Water Board staff conducted monthly aqueous methylmercury sampling in the four major tributaries – Sacramento River, San Joaquin River, Mokelumne River, and Prospect Slough – from March 2000 to September 2001 (Foe, 2003). In addition, other programs conducted periodic aqueous methylmercury sampling on the Sacramento River between July 2000 and June 2003 (SRWP, 2004; CMP, 2004; Stephenson *et al.*, 2002). Monthly sampling of the major tributaries and periodic sampling of other tributaries by Central Valley Water Board staff resumed in April 2003. Of the three Sacramento River sampling locations included in the linkage analysis (Chapter 5) – Freeport, River Mile 44 and Greene's Landing – Freeport is the most upstream location and is used to characterize loads from the Sacramento River watershed[33] (Table 6.2).

The Sacramento Weir did not spill to the Yolo Bypass during WY2000-2003; hence, no methylmercury load estimate was made for Sacramento Weir inputs. Methylmercury loads contributed by Fremont Weir spills were estimated using methylmercury concentration data collected from the Sacramento River at Colusa because field observations indicate that Fremont Weir spills are typically comprised of flows from the Sacramento River upstream of the Feather River confluence (Foe, pers. comm.). Methylmercury loads contributed by the Knights Landing Ridge Cut were estimated using methylmercury concentration data collected from the Colusa Basin Drain at Knights Landing.

Methylmercury data were not available for several of the small watersheds and drainage areas that discharge to the Delta and Yolo Bypass. The average methylmercury concentration for Ulatis Creek was used to estimate Willow Slough/Bypass, Upper Lindsay/Cache Slough, and Dixon area inputs because they have similar land uses as the Ulatis Creek watershed and are adjacent to each other. No methylmercury load estimates were made for the other small drainage areas (Manteca-Escalon, Bethany Reservoir, Antioch, and Montezuma Hills areas); given that these areas contribute only about one third of a percent of all water inputs to the Delta/Yolo Bypass, methylmercury loads from these areas are not expected to be substantial.

Regressions between methylmercury concentration and daily flow were evaluated for each tributary input with available flow gage records to determine whether concentrations could be predicted from flow (Appendix F). Only the regression for the Sacramento River was significant ($P<0.05$). The Sacramento River regression explained 12% of the variation in methylmercury concentrations. Lack of a relationship between methylmercury concentrations and flow at all sites except the Sacramento River suggests that flow is unlikely to be a useful surrogate for methylmercury concentrations. The relationship at Freeport may be a statistical anomaly. Therefore, average methylmercury concentrations were used to estimate all tributary loads. For tributary inputs with a monthly sampling frequency (Table 6.3), concentration data were pooled by month to calculate monthly average concentrations for WY2000-2003 (Table F.1 in Appendix F). The monthly average concentrations were multiplied by monthly average flow volumes (Table F.2) to estimate loads; monthly loads were summed to calculate an annual average methylmercury load for WY2000-2003. For all the tributaries with less frequent sampling, loads were estimated by multiplying average annual water volume for WY2000-2003 (Table 6.1) by the average wet weather methylmercury concentration for each tributary input (Table 6.3).

Methylmercury loads in Yolo Bypass outflows at Prospect Slough were evaluated for comparison to Yolo Bypass inputs and other major tributaries (e.g., the Sacramento and San Joaquin Rivers). Methylmercury concentration data for Shag Slough outflows were not available at the time the TMDL was developed. Although sampling took place on a regular

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[33] The Delta area that drains to the 13-mile reach of the Sacramento River between Freeport (near river mile 46) and the I Street Bridge (the northernmost legal Delta boundary, near river mile 59) is predominantly urban and is encompassed by the urban load estimate described in Section 6.2.5. No attempt was made to subtract this area from the Sacramento River watershed load estimate. Therefore, the Sacramento River load noted in Table 6.2 incorporates a small portion of the within-Delta urban runoff loading.

basis at Prospect Slough in the Yolo Bypass, only six sampling events occurred when there was net advective outflow at the Lisbon Weir (Appendix E, Section E.2.2). Dispersive or tidal flows also transport loads from the Bypass below the Lisbon Weir during almost all times; however, the actual amount is unknown at present. Therefore, annual methylmercury loading from Prospect Slough was estimated by multiplying average methylmercury concentrations observed when the slough had net outflow (0.346 ng/l) by the annual average net advective outflow from the Yolo Bypass (1.0 M acre-ft/yr for WY2000-2003, see Appendix E, Section E.2.2).

The resulting Yolo Bypass load (443 g/yr) is comparable to the sum of watershed inputs to the Yolo Bypass (440 g/yr). However, this load estimate probably underestimates export from the Bypass because, although it is based on the estimated total outflow from the Bypass, it uses methylmercury concentrations observed at Prospect Slough, and does not include outflows from Shag Slough. Recent data indicate that Shag Slough has elevated methylmercury concentrations (Foe *et al*., 2008), possibly due to its proximity to mercury-contaminated inputs from Cache and Putah Creeks. Even so, this uncertainty is unlikely to substantially affect the load estimates for WY2000-2003, a relatively dry period (Appendix E, Section E.1). For example, the Fremont Weir and Cache Creek Settling Basin weir, the primary tributary water sources to the Yolo Bypass, did not spill at all during WY2001 (see Appendix E, Figure E.4). Foe and others (2007) found the Yolo Bypass to be a net producer of methylmercury, when conveying floodwaters. Additional evaluation is needed to determine how much methylmercury is produced within the Yolo Bypass and how much is delivered from upstream watersheds during both wet and dry years. Central Valley Water Board staff recently completed a study that found that *in situ* methylmercury production within the Yolo Bypass averaged 40% of the methylmercury loading to the Delta from the entire Sacramento Basin (Foe *et al*., 2008). The study authors found this surprising because the Yolo Bypass is only 59,000-acres while the Sacramento Basin is 16,765,000-acres or 285 times larger. When there are no flood flows in the bypass, the wetlands and other lands in the bypass have little-to-no discharge to the Delta. The final results of this study and any additional studies conducted during the first phase of the Delta mercury control program implementation will be incorporated into TMDL calculations during the Delta mercury control program review at the end of the first phase of implementation.

The Sacramento River was the primary tributary source of methylmercury (2.0 kg/yr) during WY2000-2003 (Table 6.2). LWA (2002) calculated an annual average methylmercury load of 3.2 ±1.6 kg/yr for the Sacramento River at Freeport for 1980-1999 (a wetter period than the TMDL base period). Foe (2003) also concluded that the Sacramento River was the major methylmercury tributary source in all months between March 2000 and September 2001, except for March 2000 when the Yolo Bypass was flooded and it became the primary source of methylmercury. Water years 2000 through 2003 were considered normal to dry years in the Sacramento and San Joaquin watersheds. Therefore, tributary loads for the TMDL study period may underestimate long-term values. In particular, the Yolo Bypass may provide a more substantial methylmercury load to the Delta when flooded for prolonged periods, as in 1997 and 1998.

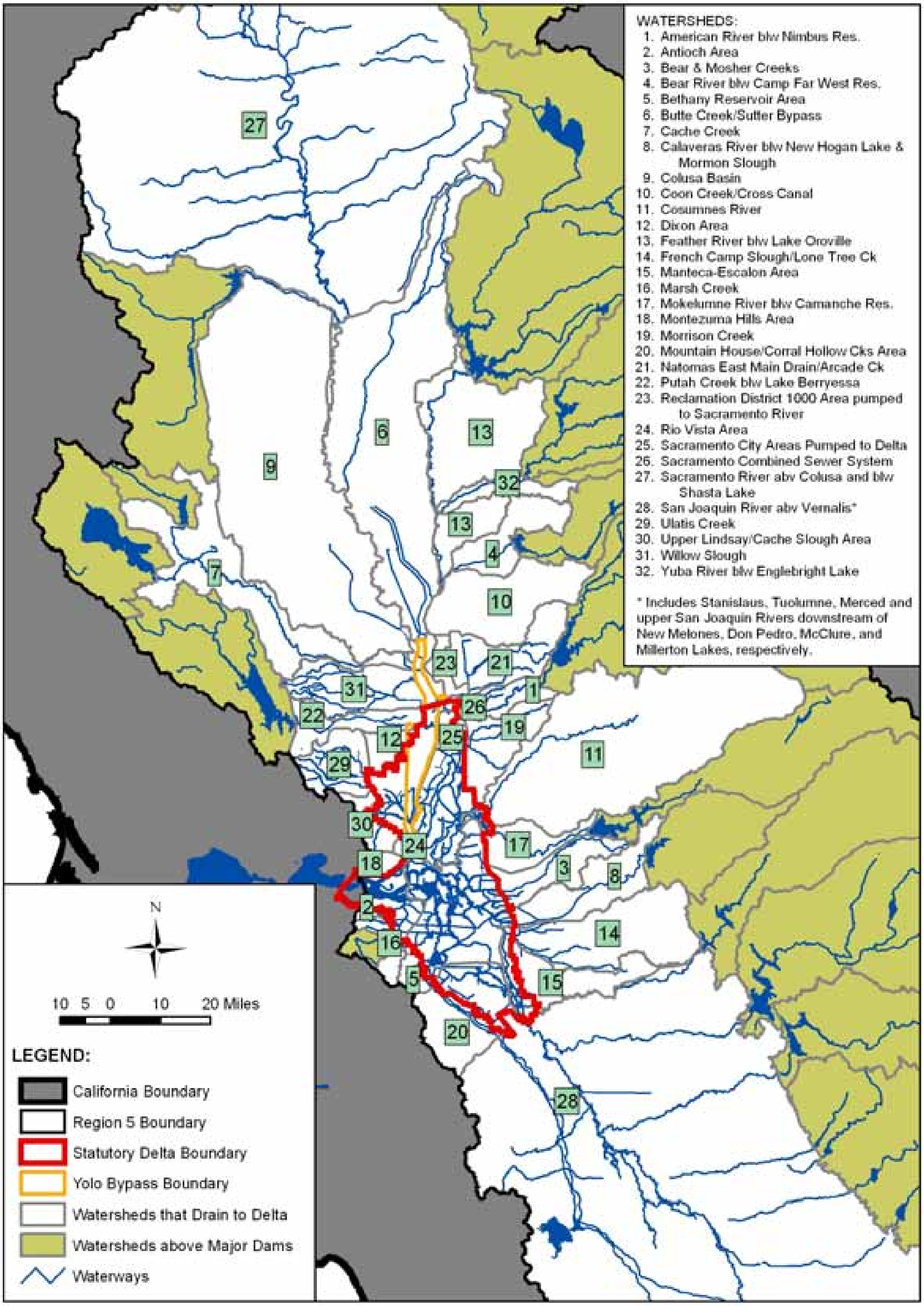

Figure 6.1: Watersheds that Drain to the Delta and Yolo Bypass.

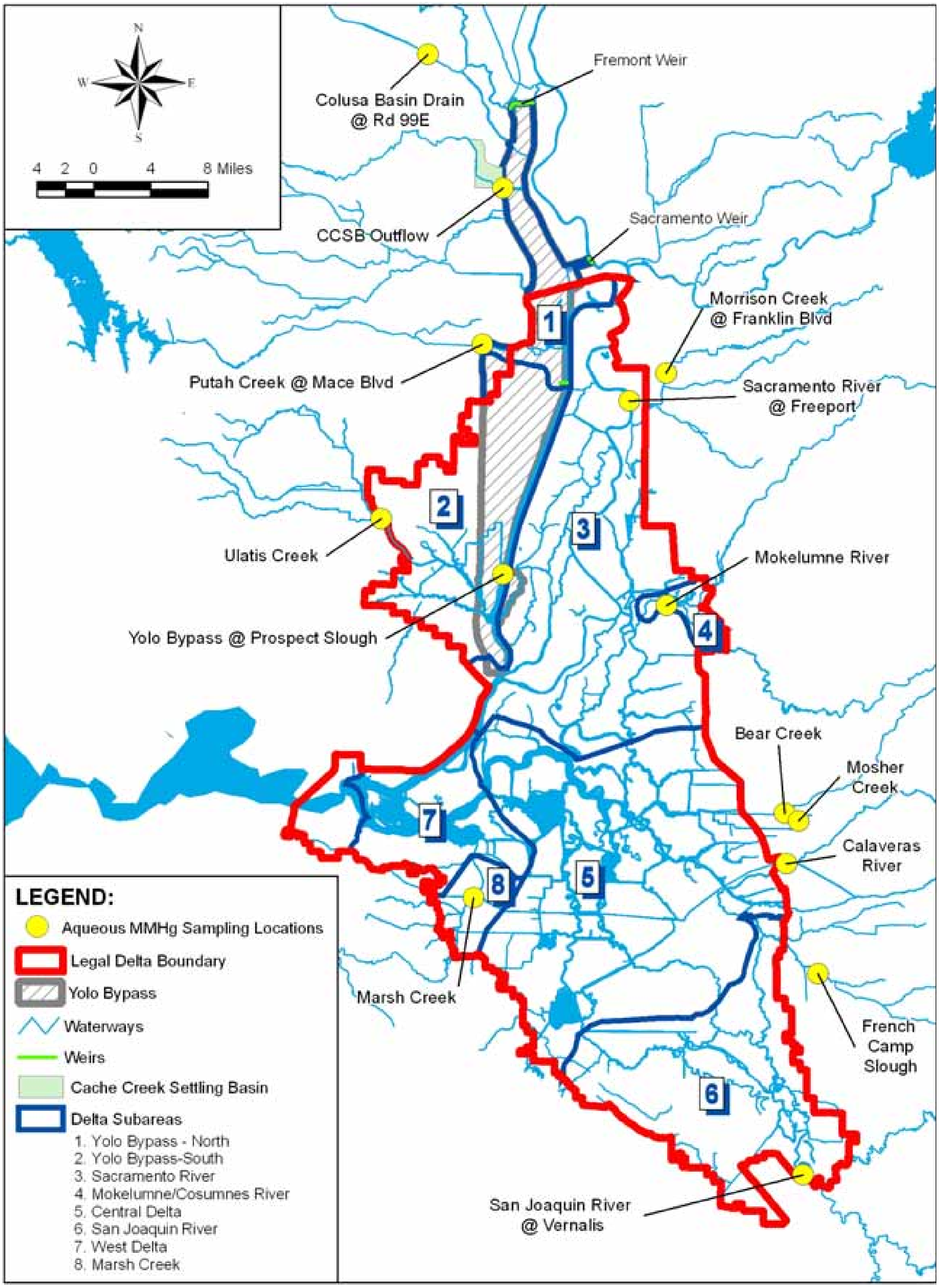

Figure 6.2: Tributary Aqueous Methylmercury Monitoring Locations

Table 6.3: Methylmercury Concentrations for Tributary Inputs.

Site (a)	# of Samples	Sampling Begin Date	Sampling End Date	Min. MeHg Conc. (ng/l)	Ave. MeHg Conc. (ng/l)	Annual Ave. MeHg (ng/l) (a)	Median MeHg Conc. (ng/l)	Max. MeHg Conc. (ng/l)
Large Tributaries to the Delta								
Cache Creek Settling Basin Outflow	8	3/1/2000	9/29/2003	0.155	0.504	0.504	0.432	0.991
Fremont Weir (Sacramento River @ Colusa)	30	7/20/2000	9/15/2003	0.041	0.105	0.097 (0.102) (b)	0.089	0.327
Knights Landing Ridge Cut (Colusa Basin Drain @ Road 99E)	21	7/21/2000	9/15/2003	0.080	0.214	0.191	0.125	0.552
Mokelumne River @ I-5	23	3/28/00	9/30/03	0.011	0.153	0.166	0.167	0.320
Putah Creek @ Mace Blvd	23	3/28/2000	9/29/2003	0.053	0.197	0.180	0.126	1.120
Prospect Slough (Yolo Bypass) (c)	22 (6)	3/28/00	9/30/03	0.114 (0.142)	0.256 (0.346)	0.273 (0.346)	0.209 (0.312)	0.701 (0.701)
Sacramento River @ Freeport	36	7/18/00	6/11/03	0.050	0.105	0.103	0.097	0.242
San Joaquin River @ Vernalis	31	3/28/00	4/12/04	0.093	0.156	0.160	0.147	0.256
Small Tributaries to the Delta								
Bear Creek @ West Lane	3	2/2/04	2/26/04	0.336	0.404	0.310	0.431	0.446
Calaveras River @ RR u/s West Lane	4	3/15/03	2/26/04	0.110	0.144	0.144	0.137	0.193
French Camp Slough d/s Airport Way	5	1/28/02	2/26/04	0.063	0.127	0.142	0.143	0.193
Marsh Creek @ Hwy 4	7	3/15/03	2/2/04	0.090	0.224	0.255	0.237	0.323
Morrison Creek @ Franklin	1	1/28/02	1/28/02	0.102	0.102	0.102	0.102	0.102
Mosher Creek @ Morada Lane (d)	1	3/15/03	3/15/03	0.028	0.028	(d)	0.028	0.028
Ulatis Creek near Main Prairie Rd	6	1/28/02	2/26/04	0.004	0.172	0.240	0.180	0.322

(a) For the large tributary inputs, methylmercury concentration data were pooled by month to estimate monthly average methylmercury concentrations and loads; the monthly average loads were summed to estimate annual average methylmercury loads for water years 2000-2003. The methylmercury concentration data are provided in Appendix L. The monthly average concentrations and flows are listed in Appendix F. The monthly average concentrations were averaged to estimate annual average concentrations, which were included in Table 6.2. Sampling on the small tributaries and Cache Creek Settling Basin did not take place monthly, and flow gages were unavailable for the small tributaries. All available methylmercury concentration data were averaged to estimate annual average methylmercury concentrations and loads for the Cache Creek Settling Basin, and wet weather methylmercury concentration data were averaged to estimate annual average methylmercury concentrations and loads for the small tributaries.

(b) The average of monthly average concentrations for Sacramento River at Colusa for months when Fremont Weir spilled during WY2000-2003 (January, February, March, May, and December) is shown in parentheses.

(c) Only six Prospect Slough MeHg sampling events took place when there was a net outflow. These sampling events are described in parentheses. Methylmercury concentrations during other times were strongly affected by tidal pumping of waters from the Sacramento River.

(d) The one Mosher Creek sample result was combined with the Bear Creek methylmercury data to estimate methylmercury loads for both creeks.

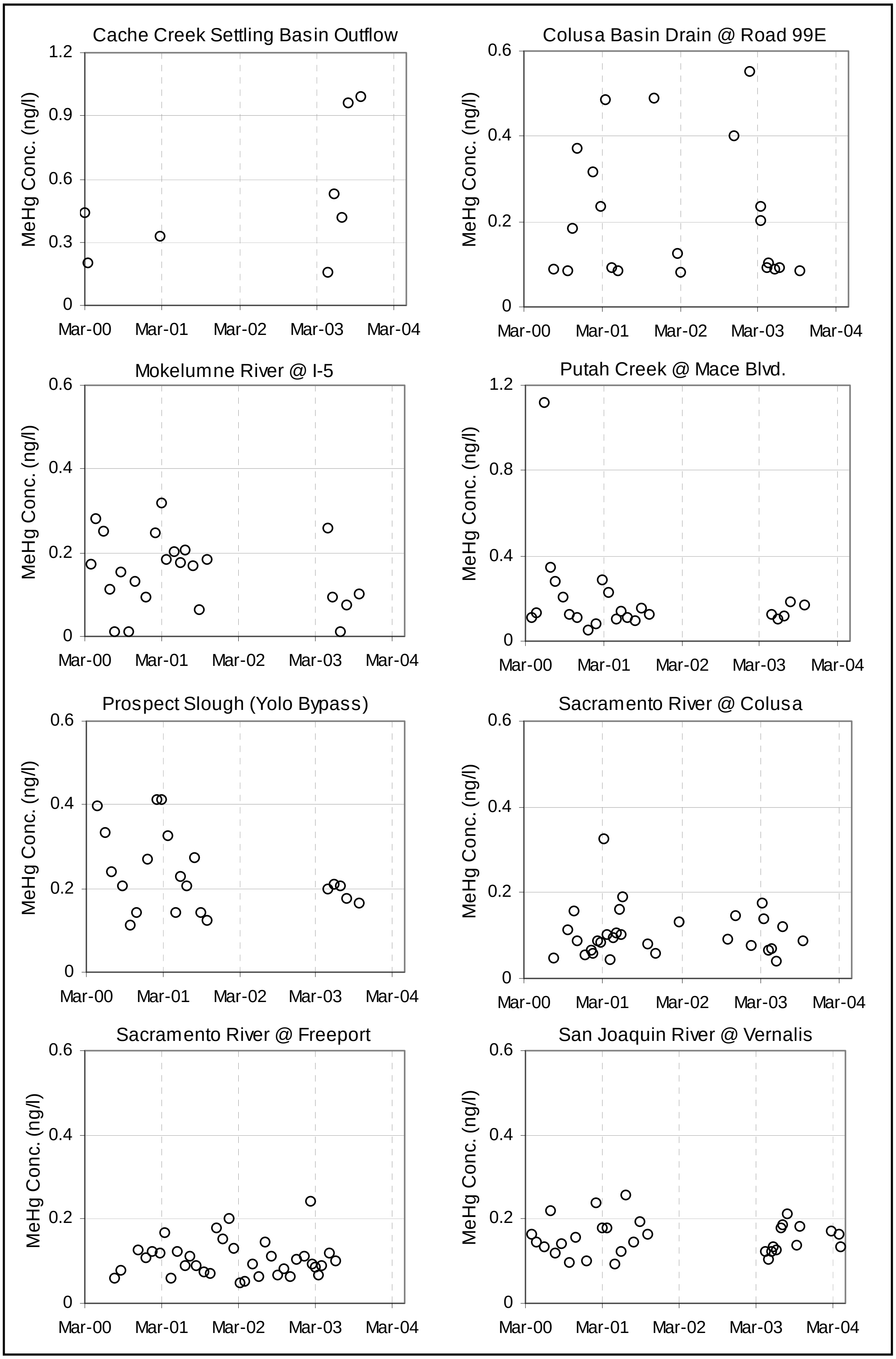

Figure 6.3a: Methylmercury Concentrations for Major Tributary Inputs

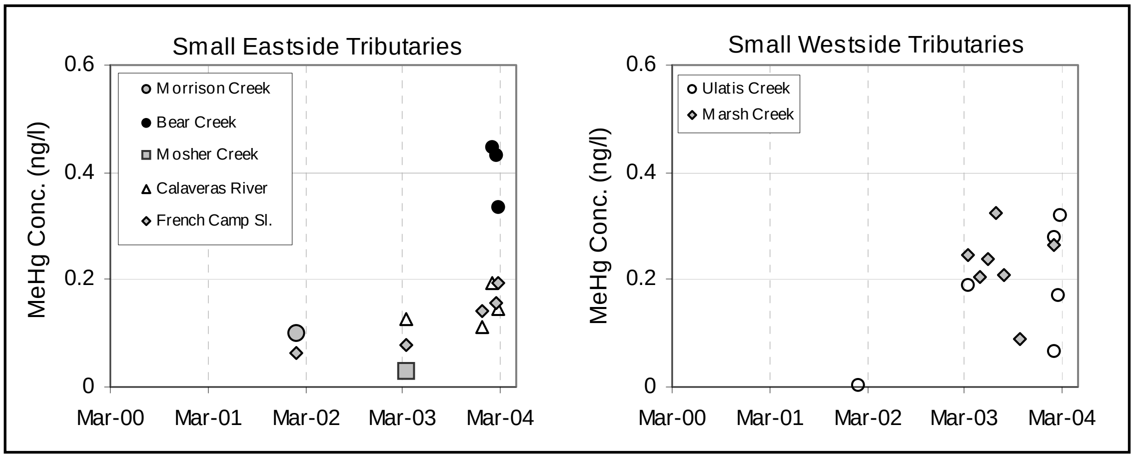

Figure 6.3b: Methylmercury Concentrations for Small Tributary Inputs

6.2.2 Within-Delta Sediment Flux

Methylmercury flux from within-Delta sediments is estimated to contribute about 36% of the overall methylmercury load (Table 6.2). Methylmercury loads from bottom sediment in open water were estimated from flux rates measured by Gill and others (2003). Wetland flux rates were from Heim, Sassone and others (Heim *et al.*, 2004; Sassone *et al.*, 2004) and a load calculation method outlined by Heim and others (Heim, 2004; Heim *et al.*, 2004). To measure methylmercury flux in open water habitats, Gill and others (2003) deployed benthic flux chambers at nine locations in the Bay-Delta region during five separate field-sampling efforts between May 2000 and October 2001. This study estimated a methylmercury flux rate of approximately 10 ng/m^2/day for open water habitat. An additional study of sediment-water MeHg flux within marsh and wetland habitat was conducted at two experimental ponds on Twitchell Island (Heim *et al.*, 2004; Sassone *et al.*, 2004). The west pond, which had more shallow water and greater coverage of emergent vegetation, had sediment-water flux rates of 41 ng/m^2/day during June 2003, while the flux from the east pond had a flux rate of 3 ng/m^2/day. In October 2003, the flux from both ponds decreased to 3 ng/m^2/day. Heim (2004) recommended that the flux rates for the west pond be used to estimate warm and cool season loads; the warm season was defined as March through September (214 days) and the cool season as October through February (151 days).

Wetland and open water acreages were estimated using the 2006 National Wetland Inventory coverage for the Delta region (USFWS, 2006; Figure 6.4). Types of wetland habitat in the Delta and Yolo Bypass are predominantly seasonal wetlands and tidal, salt, brackish and freshwater marshes. The open-water, warm season wetland and cool season wetland flux rates were multiplied by the open water and wetland areas, respectively, to estimate daily loading. The daily loads were multiplied by the number of days in the warm and cool seasons and then summed to estimate annual loading. The loads to each Delta subarea were calculated (Table 6.4) to develop subarea-specific allocations (Chapter 8). The Yolo Bypass subarea has the greatest methylmercury loading from sediment because it has the greatest acreage of wetlands; the Central Delta subarea is second because it has the greatest amount of open water habitat. Methylmercury loading from wetland and open water sediments in each subarea was summed so that the Delta-wide methylmercury loading from sediments could be compared with other sources in Table 6.2.

Using the Twitchell Island west pond summer flux rates, methylmercury loading from wetlands in the Delta/Yolo Bypass accounts for about 19% of all methylmercury to the Delta during the relatively dry period of WY2000-2003. However, if the east pond data had been used, methylmercury loading from wetlands would account for only about 3% of all methylmercury to the Delta. In addition, research completed since the February 2008 draft TMDL Report (Sassone *et al*, 2008; Stephenson *et al*., 2008) indicates that the Twitchell Island west pond flux rates are lower than initially estimated from the preliminary monitoring results, and that the Twitchell Island ponds are not characteristic of all wetlands in the Delta region, in part because they receive continual inputs of water (compared to seasonal wetlands). This illustrates the need for better characterization of wetlands throughout the Delta and Yolo Bypass, particularly of the seasonality of their discharges. Nonetheless, research elsewhere in California and the United States has found that wetlands are sites of efficient methylmercury production (Slotton *et al*., 2003; Heim *et al*., 2003; St. Louis *et al*., 1994, 1996; Gilmour *et al.*, 1998), so much so that one of the best predictors of methylmercury concentrations in water and in biota is the amount of wetland present in upstream watersheds (Krabbenhoft *et al.*, 1999; Wiener *et al.*, 2003b). Until additional research has been conducted in the Delta and Yolo Bypass, the Twitchell Island west pond summer flux rates will be used to estimate methylmercury loading from wetlands for the TMDL. As described in the draft Basin Plan Amendment staff report, staff recommends that a control program review take place after additional Delta-specific studies are completed, during which the TMDL source analysis can be updated.

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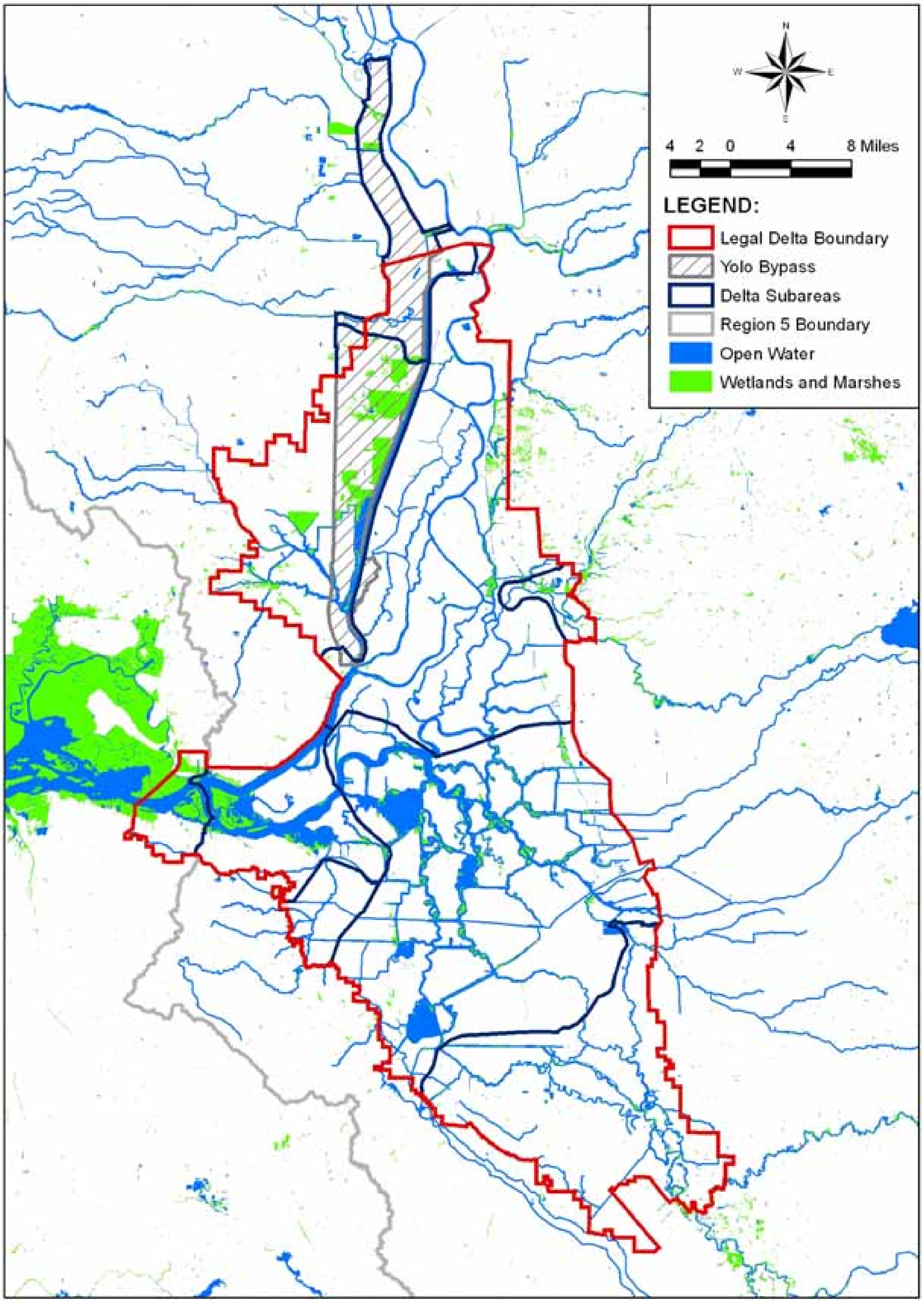

Figure 6.4: Delta and Yolo Bypass Wetlands and Open Water Habitat. Wetland areas include seasonal wetlands and brackish and freshwater marshes. (Wetland and open water acreage: USFWS, 2006.)

Table 6.4: Methylmercury Loading from Wetland and Open Water Habitats in Each Delta Subarea. (a)

	Central Delta	**Cosumnes / Mokelumne River**	**Marsh Creek**	**Sacramento River**	**San Joaquin River**	**West Delta**	**Yolo Bypass-North (d)**	**Yolo Bypass-South**	**Grand Total**
Open Water Habitats									
Open Water (acres):	25,141	271	12.0	9,483	3,246	13,118	1,281	5,709	58,261
% of Total Water Area:	43%	0.47%	0.02%	16%	5.6%	23%	2.2%	10%	100%
Open Water (m^2):	101,743,759	1,096,558	48,501	38,375,389	13,136,719	53,088,806	5,185,613	23,102,662	235,778,006
Daily Open Water MeHg Load (g/day) (b):	1.02	0.0110	0.0005	0.38	0.13	0.53	0.052	0.23	2.4
Annual Open Water MeHg Load (g/year):	371	4.0	0.18	140	48	194	19	84	861
Wetland Habitats (c)									
Wetland Area (acres):	5,594	803	9.2	2,538	1,170	3,609	1,577	11,276	26,576
% of Total Wetland Area:	21%	3.0%	0.03%	9.6%	4.4%	14%	5.9%	42%	100%
Wetland Area (m^2):	22,636,361	3,250,048	37,399	10,272,237	4,735,497	14,605,419	6,382,048	45,632,423	107,551,433
Warm Season MeHg Daily Load (g/day):	0.92	0.13	0.0015	0.42	0.19	0.59	0.26	1.9	4.4
Cool Season MeHg Daily Load (g/day):	0.068	0.010	0.00011	0.031	0.014	0.044	0.019	0.14	0.32
Annual Wetland MeHg Load (g/year):	207	29.7	0.34	94	43	134	58	417	983
Annual MeHg Load (grams/year):	**578**	**34**	**0.52**	**234**	**91**	**327**	**77**	**501**	**1,844**

(a) Wetland and open water habitat acreages were obtained from the National Wetland Inventory (USFWS, 2006).

(b) The daily open water MeHg load for each Delta subarea was estimated by multiplying its open water area by the open water sediment flux rate, 10 ng/m2/day. The open water MeHg flux rate was developed by Gill and others using benthic flux chambers (Gill *et al.*, 2003).

(c) The daily warm season and cool season wetland MeHg loads for each Delta subarea were estimated by multiplying the open water area by the warm and cool season wetland flux rates, 41 ng/m2/day and 3 ng/m2/day. The warm and cool season wetland flux rates were developed by Heim and others (2004) using direct measurement of MeHg concentrations in inflows and outflows from test wetlands on Twitchell Island in the west Delta. The warm season for the wetland flux rate is defined approximately as March through September (214 days) and the cool season is defined approximately as October through February (151 days) (Heim, 2004). The annual load was estimated by multiplying the number of days in the warm and cool seasons by the daily warm and cool season loads, respectively, and summing the resulting seasonal loads.

(d) The Yolo Bypass-North subarea includes wetland and open water areas in the Yolo Bypass north of the legal Delta boundary.

6.2.3 Municipal & Industrial Sources

Information about NPDES-permitted municipal and industrial dischargers in the Delta and Yolo Bypass was obtained from the State Water Resources Control Board's Surface Water Information (SWIM) database and from the Central Valley Water Board's discharger project files and permits. During the TMDL period, WY2000-2003, there were 23 NPDES-permitted municipal and industrial dischargers in the Delta and Yolo Bypass (Figure 6.5, Table 6.5). These facility discharges accounted for about 4% (205 g/yr) of the annual methylmercury loading to the Delta/Yolo Bypass during the WY2000-2003 period (Table 6.2). Since then, several facilities have ceased discharging to surface waters and others have begun discharging. The following paragraphs describe past and present (as of January 2010) discharges, available effluent methylmercury data, and load calculation methods.

As described in Sections 6.2.1 and 6.3.1, the WY2000-2003 period encompasses the methylmercury concentration data available for the major Delta tributary inputs and exports at the time TMDL development took place. However, only one NPDES-permitted discharger collected effluent methylmercury data during this period. Between December 2000 and June 2003, the Sacramento Regional County Sanitation District (SRCSD) collected 60 samples to characterize its effluent methylmercury levels. In February and March 2004, Central Valley Water Board staff conducted two sampling events at four municipal wastewater treatment plants (WWTPs) to determine whether the SRCSD data are representative of other municipal wastewater treatment plants' effluent methylmercury levels. The 2004 sampling results indicated that the methylmercury data from the SRCSD facility may not be representative of other facilities in the Delta region. Therefore, the Central Valley Water Board issued a California Water Code Section 13267 order in July 2004 requiring municipal WWTPs and other dischargers located in the Delta and in the Delta's tributary watersheds downstream of major dams to monitor and characterize their effluent.

Table 6.5 summarizes the results of available methylmercury data for facility discharges in the Delta and Yolo Bypass. Table G.3 in Appendix G provides a summary of the methylmercury data generated by NPDES facility sampling efforts throughout the Delta region. A detailed review of the data is provided in the Central Valley Water Board staff report, *"A Review of Methylmercury and Inorganic Mercury Discharges from NPDES Facilities in California's Central Valley"* (Bosworth *et al.*, 2010), along with a copy of the letter and a list of facilities that received the Section 13267 order and a summary of all available methylmercury data for facility discharges to the Delta and its tributary watersheds. Appendix L of this report provides the available data for facilities within the legal Delta boundary and Yolo Bypass.

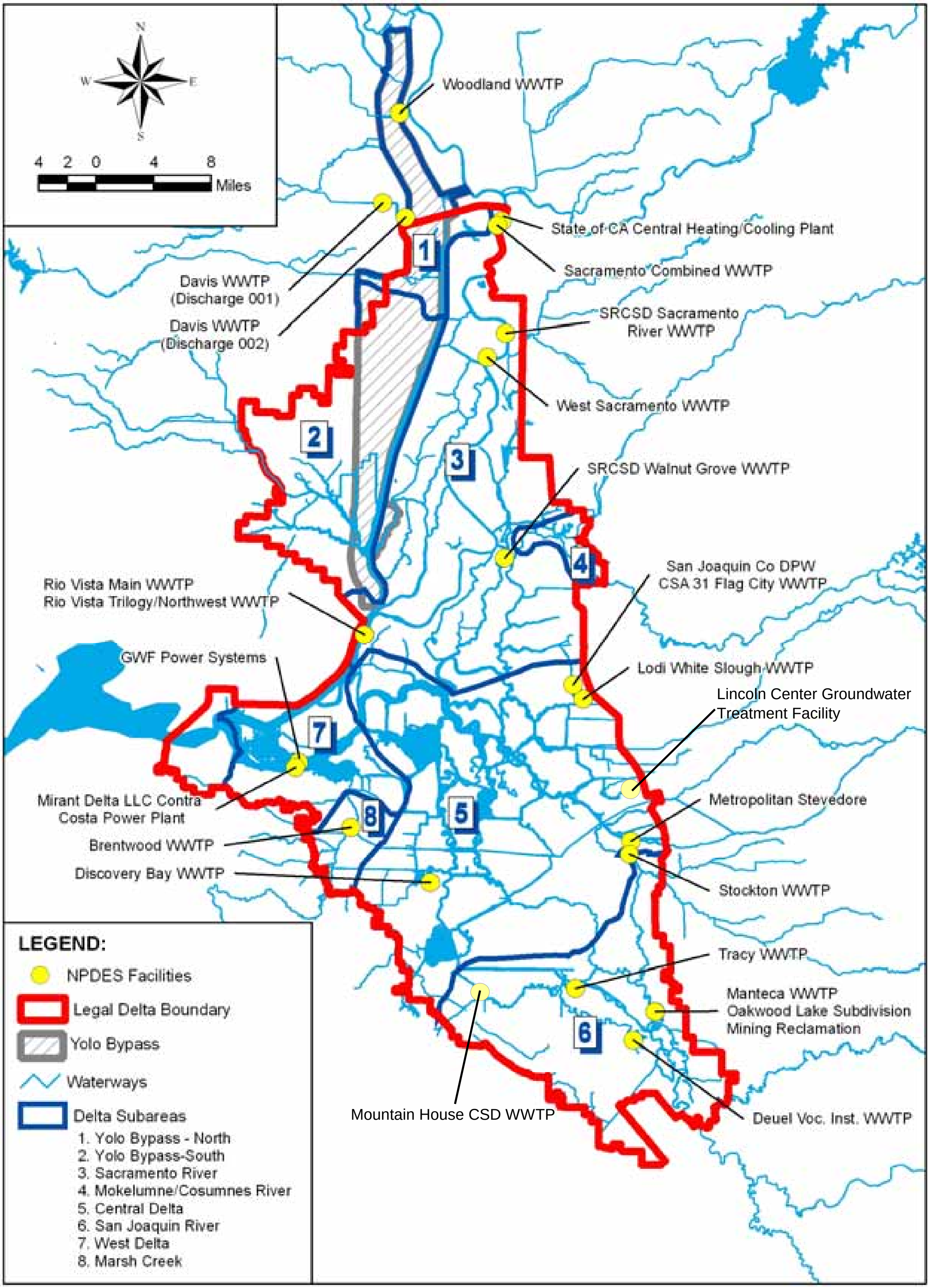

Figure 6.5: NPDES Facilities that Discharge to the Statutory Delta and Yolo Bypass.

Table 6.5: Summary of Unfiltered Methylmercury Concentration Data for Effluent from NPDES-permitted Facilities That Discharged to the Delta and Yolo Bypass North of the Delta during the WY2000-2003 Period and Later.

Facility Name (a)	Discharged during WY2000-2003	Discharged as of February 2010	NPDES #	Facility Type	Delta Subarea	# of MeHg Sampling Events	Average MeHg Conc. (ng/l) (b)	MeHg Conc. Range (ng/l)	# of Non-detect Results	MeHg Sampling Period	Average Daily Discharge Used for Load Calculation (mgd)	Annual MeHg Load (g/yr)
Brentwood WWTP	X	X	CA0082660	Mun. WWTP	Marsh Ck	13	0.02 (ND) (b)	All ND (b)	13	8/04-8/05	3.1	0.086
Davis WWTP (Discharge 001) (g)	X	X	CA0079049	Mun. WWTP	Yolo Bypass	7	0.55	0.305-1.04	0	8/04-1/05, 7/05	2.8	1.3
Davis WWTP (Discharge 002) (g)	X	X	CA0079049	Mun. WWTP	Yolo Bypass	5	0.61	0.247-1.44	0	2/05-6/05	2.4	0.78
Deuel Vocational Institute WWTP (e)	X	X	CA0078093	Mun. WWTP	San Joaquin	3	0.02 (ND)	All ND	3	1/05-6/05	0.47	0.013
Discovery Bay WWTP	X	X	CA0078590	Mun. WWTP	Central	12	0.19	ND-2.03	7	8/04-7/05	1.5	0.37
GWF Power Systems	X	X	CA0082309	Power	West	4	0.03 (ND)	All ND	4	8/04-5/05	0.05	0.0019
Lincoln Center Groundwater Treatment Facility	X	X	CA0084255	Groundwater Treatment	Central	(i)	(i)	(i)	(i)	(i)	0.25	0.010
Lodi White Slough WWTP (f)	X	X	CA0079243	Mun. WWTP	Central	10	0.15	ND-1.24	3	9/04-6/05	4.5	0.93
Manteca WWTP	X	X	CA0081558	Mun. WWTP	San Joaquin	11	0.22	0.037-0.356	0	9/04-7/05	4.6	1.4
Mirant Delta LLC Contra Costa Power Plant (Outfall 1)	X	X	CA0004863	Power	West	12	0.07	0.020-0.121	0	2/04-5/05	2.90	(c)
Mirant Delta LLC Contra Costa Power Plant (Outfall 2)	X	X	CA0004863	Power	West	10	0.09	0.042-0.15	0	2/04-3/05	121.03	(c)
Mountain House CSD WWTP		X	CA0084271	Mun. WWTP	San Joaquin	21	0.05 (ND)	ND (0.05) - 0.05	17	8/07-5/09	0.45	0.031
Oakwood Lake Subdivision Mining Reclamation (d)	X	X	CA0082783	Lake Dewatering	San Joaquin	2	0.03	ND-0.043	1	8/04-11/04	9.15	0.38
Rio Vista WWTP	X	X	CA0079588	Mun. WWTP	Sacramento	4	0.16	0.035-0.522	0	8/04-4/05	0.47	0.10

Table 6.5: Summary of Unfiltered Methylmercury Concentration Data for Effluent from NPDES-permitted Facilities That Discharged to the Delta and Yolo Bypass North of the Delta during the WY2000-2003 Period and Later.

Facility Name (a)	**Discharged during WY2000-2003**	**Discharged as of February 2010**	**NPDES #**	**Facility Type**	**Delta Subarea**	**# of MeHg Sampling Events**	**Average MeHg Conc.** (ng/l) (b)	**MeHg Conc. Range** (ng/l)	**# of Non-detect Results**	**MeHg Sampling Period**	**Average Daily Discharge Used for Load Calculation** (mgd)	**Annual MeHg Load** (g/yr)
Rio Vista Trilogy	X		CA0083771	Mun. WWTP	Sacramento	(i)	(i)	(i)	(i)	(i)	0.10 (seasonal)	0.0041 (i)
Rio Vista Northwest WWTP (i)		X	CA0083771	Mun. WWTP	Sacramento	(i)	(i)	(i)	(i)	(i)	1.0	0.069 (i)
Sacramento Combined WWTP	X	X	CA0079111	Mun. WWTP	Sacramento	10	0.536	0.299-0.820	0	12/04-3/06	1.3	0.95
San Joaquin County Service Area 31 Flag City WWTP	X		CA0082848	Mun. WWTP	Central	3	0.08	ND-0.152	1	1/05-10/05	0.06	0.0066
SRCSD Sacramento River WWTP	X	X	CA0077682	Mun. WWTP	Sacramento	60	0.72	0.118-1.64 (h)	0	12/00-6/03	162	161
SRCSD Walnut Grove WWTP (e)	X		CA0078794	Mun. WWTP	Sacramento	2	2.2	0.949-3.36	0	1/05-4/05	0.08	0.24
State of California Central Heating and Cooling Plant	X		CA0078581	Heating / Cooling	Sacramento	4	0.01	ND-0.029	3	8/04-6/05	5.26	(c)
Stockton WWTP	X	X	CA0079138	Mun. WWTP	San Joaquin	12	0.94	ND-2.09	1	8/04-7/05	28	36
Tracy WWTP	X	X	CA0079154	Mun. WWTP	San Joaquin	13	0.14	ND-0.422	1	8/04-8/05	9.5	1.8
West Sacramento WWTP	X		CA0079171	Mun. WWTP	Sacramento	12	0.05	ND-0.085	1	8/04-7/05	5.6	0.39
Woodland WWTP	X	X	CA0077950	Mun. WWTP	Yolo Bypass	12	0.03	ND-0.059	2	8/04-7/05	6.05	0.25

Table 6.5 Footnotes:

(a) No methylmercury or discharge volume data are available for Metropolitan Stevedore (CA0084174), a marine bulk commodity terminal in the Central Delta subarea.

(b) ND: nondetect (below method detection limit). Analytical method detection limits were 0.025 ng/l or less, except for the Mountain House CSD WWTP data, which had a detection limit of 0.05 ng/l. One half the detection limit was used for nondetect values to calculate the average methylmercury concentrations and loads, except when a facility reported all data as equal to or less than the nondetect limit, in which case the detection limit was used to calculate loads.

(c) Based on the comparison of the available intake and outfall methylmercury data (Table G.4 in Appendix G), power and heating/cooling facilities that use ambient water for cooling water do not appear to act as a source of new methylmercury to the Delta. This assumption will be re-evaluated as additional information becomes available.

(d) The Oakwood Lake Subdivision Mining Reclamation was formerly known as the Manteca Aggregate Sand Plant.

(e) Results for the following facilities and sample dates were not incorporated in the summary calculations due to sample preservation hold times exceeding USEPA recommendations: Deuel Vocational Institute WWTP (26 October 2004, <MDL) and SRCSD Walnut Grove WWTP (29 December 2004, 0.759 ng/l).

(f) Lodi White Slough WWTP sampled effluent when discharging to land and to surface water. Only samples collected when the WWTP discharged to surface water (September 2004 through June 2005) were used in the summary. Effluent that was reclaimed in August 2004 and July 2005 had methylmercury concentrations of 0.054 ng/l and <0.020, respectively.

(g) The City of Davis WWTP (CA0079049) has two seasonal discharge locations; wastewater is discharged from Discharge 001 to the Willow Slough Bypass upstream of the Yolo Bypass and from Discharge 002 to the Conaway Ranch Toe Drain in the Yolo Bypass. The Discharge 001 methylmercury load is based on effluent volumes for October 2004 through January 2005 plus July 2005 through September 2005. The Discharge 002 methylmercury load is based on effluent volumes for February 2005 through June 2005.

(h) The SRCSD Sacramento River WWTP (CA0077682) methylmercury concentration data was collected between December 2000 and June 2003. Two data points failed SRCSD's Quality Assurance review (7/13/2001: 2.93 ng/l, 6/18/2006: 0.08 ng/l); these data are not included in the TMDL calculations.

(i) No effluent methylmercury concentration data were available for the City of Rio Vista's Trilogy WWTP and Northwest WWTPs or the Lincoln Center Groundwater Treatment Facility. As explained in detail in the text, their effluent methylmercury loads were estimated by using effluent methylmercury concentration data available for other facilities with similar treatment processes.

6.2.3.1 Municipal WWTPs

Fifteen municipal wastewater treatment plants discharged the Delta/Yolo Bypass during WY2000-2003. The average annual methylmercury load for SRCSD's Sacramento River WWTP was calculated using the average effluent methylmercury concentrations observed between December 2000 and June 2003 and the average annual discharge volume for WY2001-2003 (October 2000 through September 2003). Average annual methylmercury loads were calculated for all other municipal WWTPs, except as noted in the following paragraphs, using the average effluent methylmercury concentrations based on available data collected between August 2004 and October 2005 and the annual discharge volume for WY2005 (October 2004 through September 2005). Facility-specific average effluent methylmercury concentrations ranged from less than 0.02 ng/l (Brentwood and Deuel Vocational Institute WWTPS) to 2.2 ng/l (SRCSD Walnut Grove WWTP).

Staff compiled and evaluated NPDES municipal WWTP effluent methylmercury data collected during the Section 13267 monitoring period, 2004-2005, as well as other available data for WWTPs in and upstream of the Delta, in a separate report: *A Review of Methylmercury and Inorganic Mercury Discharges from NPDES Facilities in California's Central Valley* (Bosworth *et al.*, 2010). The effluent data for 67 municipal WWTPs in the Central Valley indicate that:

- 14 facilities had average effluent methylmercury levels that approached or were less than analytical method detection limits (e.g., less than 0.03 ng/l) and 24 facilities had effluent methylmercury levels equal to or less than the proposed implementation goal (0.06 ng/l) for ambient water. This indicates that it is possible for WWTPs to have effluent methylmercury concentrations lower than the proposed implementation goal.

- 19 facilities had effluent exceeding 0.2 ng/l methylmercury and 7 facilities had effluent exceeding 1 ng/l methylmercury. This demonstrates that methylmercury in effluent is variable between WWTPs.
- Eleven of the 12 facilities with the highest effluent methylmercury made use of some type of pond system for treatment; none of the facilities with effluent methylmercury less than 0.2 ng/l made use of pond systems. This indicates that the type of treatment process may affect effluent methylmercury levels.
- One municipal WWTP in the Delta, SRCSD's Sacramento River WWTP, had effluent methylmercury data for 2001-2007; the data illustrate a marked decrease in effluent methylmercury and total mercury concentrations with time. The decline indicates that it is possible for a given WWTP's effluent methylmercury to decrease. During the April 2008 Board hearing meeting for the Delta mercury control program, the SRCSD District Engineer testified that implementation of the Be Mercury Free Program to reduce inorganic mercury sources to SRCSD's WWTP resulted in reductions in both inorganic mercury and methylmercury discharges from the WWTP.

The variability in the methylmercury concentrations observed in effluent from different municipal WWTPs in the Delta and its upstream watersheds is comparable to WWTP effluent concentrations observed elsewhere. Sampling at the San Jose/Santa Clara Water Pollution Control Plant in California indicated an average effluent methylmercury concentration of 0.04 ng/l (SJ/SC, 2007). A study that evaluated methylmercury concentrations in three domestic sewage treatment plants at the City of Winnipeg, Canada, found average effluent methylmercury concentrations to be very low at two facilities (0.13 to 0.56 ng/l, no seasonal trend) and higher at a third (greater than 2 ng/l, with highest concentrations in the summer) (Bodaly *et al*., 1998). A separate study that evaluated seasonal patterns in sewers and wastewater unit processes in the Onondaga County Metropolitan Wastewater Treatment Plant in Syracuse, New York, observed a mean methylmercury concentration (± standard deviation) of 1.63 ± 1.19 and 1.43 ± 0.67 ng/l in warm and cool months, respectively; a peak of 3.70 ng/l was measured in May (McAlear, 1996). Additional information about facilities elsewhere in California and the United States is provided in "*A Review of Methylmercury and Inorganic Mercury Discharges from NPDES Facilities in California's Central Valley*" (Bosworth *et al.*, 2010).

Some type of seasonal or other treatment-related variability was observed in effluent methylmercury concentrations at several of the municipal WWTPS in the Delta and its tributary watersheds (Bosworth *et al.*, 2010). Identifying the reasons why some facilities discharge effluent with higher methylmercury concentrations than others, and why some facilities have seasonal or other treatment-related variability in their methylmercury discharges, could be critical components to the development of methylmercury controls.[34]

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[34] In addition, seasonal increases in effluent methylmercury loading from some facilities could result in a greater influence on local water bodies, especially during the dry season. For example, SRCSD Sacramento River WWTP (the largest permitted facility discharge in the Central Valley) has an annual effluent methylmercury load (161 g/yr,

As noted earlier, several municipal WWTPs in the Delta/Yolo Bypass have ceased discharging to surface waters, others have begun discharging, and one has had substantial modifications to its treatment processes since WY2003. In summary:

- The San Joaquin County Service Area 31 Flag City WWTP, Walnut Grove WWTP, West Sacramento WWTP, and Rio Vista Trilogy WWTP have ceased discharging to surface water;
- The Mountain House WWTP and Northwest WWTP began discharging to surface water;
- The Stockton WWTP has had substantial treatment upgrades.

The San Joaquin County Service Area 31 Flag City WWTP was discharging to surface water during the WY2000-2003 period. As a result, its effluent methylmercury load is included in the Table 6.2 summary. However, the discharger recently completed the construction of a pump station and dual forcemain project that allows for discharge of the Flag City wastewater to the City of Lodi White Slough WWTP. As of 10 April 2008, all wastewater flows from the Flag City area are being directed to the Lodi WWTP, and the Flag City WWTP's discharge to surface waters has ceased. Chapter 8 addresses this change in the allocation calculation for the Lodi WWTP.

Because the West Sacramento and Walnut Grove WWTPs discharged to surface waters during the TMDL period, WY2000-2003, their effluent methylmercury loads shown in Table 6.5 are included in the Table 6.2 load summary. However, as part of regionalization efforts, SRCSD's Sacramento River WWTP now receives influent that had been treated by the West Sacramento and Walnut Grove WWTPs. Chapter 8 addresses this regionalization in the allocation calculation for the Sacramento River WWTP.

The Rio Vista Trilogy WWTP had an annual average dry weather flow of 0.10 mgd. Trilogy discharged treated wastewater to land during irrigation months (May through October) and to an unnamed ephemeral stream during non-irrigation months. The Trilogy WWTP was equipped with flow equalization, primary clarification, trickling filtration, secondary clarification, chemical addition, tertiary filtration, chlorine disinfection, and emergency storage. Discharge methylmercury data were not available for the Trilogy WWTP. Table 23 in "*A Review of Methylmercury and Inorganic Mercury Discharges from NPDES Facilities in California's Central Valley*" (Bosworth *et al.*, 2010) indicated that municipal WWTPs that employed filtration and chlorination/dechlorination had average and median effluent methylmercury concentrations of 0.105 and 0.056 ng/l, respectively, based on 134 samples from 17 facilities. Table 26 in Bosworth and others' 2010 report indicates that the one facility that also had a trickling filter had

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see Table 6.5) that averages about 8% of its receiving water load (2,026 g/yr, Sacramento River at Freeport, see Table 6.2). Between December 2000 and September 2003 (the TMDL Period), SRCSD daily effluent loads during the wet seasons (e.g., December to April) ranged between 1 and 7% of river loads, and daily effluent volumes averaged about 2% of river volume (Bosworth *et al.*, 2008). However, during the dry season, SRCSD daily effluent loads ranged between about 10 and 35% of river loads while effluent volume remained about 2% of river volume. Currently, little is known about the seasonal exposure regime controlling methylmercury concentrations in aquatic biota. Therefore, this TMDL is based on annual average source loads to weight all seasons equally. However, studies are planned to better determine the seasonal exposure regime when most of the methylmercury is sequestered in the aquatic food chain; results from these studies may lead to future revisions in the TMDL. Seasonal discharge information is not yet available for most methylmercury sources to the Delta, but would be required by the source control and characterization studies proposed by the draft implementation plan described in Chapter 4 of the Proposed Basin Plan Amendment draft staff report.

an average and median of 0.058 and 0.044 ng/l, respectively. To estimate Trilogy WWTP wet season effluent methylmercury loads discharged to the Sacramento River during WY2000-2003, 0.06 ng/l was multiplied by 0.1 mgd and 181 days to obtain an annual load estimate of 0.0041 g/year.

In 2007 the Trilogy WWTP was closed and the Northwest WWTP began to discharge in its place. The Central Valley Water Board Order No. R5-2004-0092 considers the closure of the Trilogy WWTP coinciding with the start-up of the Northwest WWTP as a change in treatment process and location rather than as a new treatment plant. The Northwest WWTP is equipped with extended aeration activated sludge biological treatment with nitrogen removal (nitrification and denitrification), ultrafiltration (i.e., membrane filtration), and ultraviolet (UV) disinfection. The new Northwest WWTP (1) makes use of UV disinfection in lieu of chlorination and dechlorination to prevent the formation of disinfection byproducts (trihalomethanes) and reduce the salt concentration of the effluent; (2) discharges directly to the Sacramento River in lieu of continued discharge to the unnamed tributary stream to prevent elevated salts from adversely affecting local agriculture, and (3) eliminates continued discharge to the golf course irrigation reservoir and irrigation of the golf course to prevent groundwater impacts.

The Northwest WWTP has an average dry weather flow start-up capacity of 1 mgd but no effluent methylmercury data have been collected yet. Table 23 in "*A Review of Methylmercury and Inorganic Mercury Discharges from NPDES Facilities in California's Central Valley*" (Bosworth *et al.*, 2010) indicated that WWTPs that employed nitrification/denitrification, filtration and UV disinfection had effluent methylmercury concentrations that ranged from nondetect to 0.078 ng/l and average and median effluent methylmercury concentrations of 0.029 and 0.020 ng/l, respectively, based on three facilities and 21 samples, 11 of which had methylmercury concentrations less than the method detection limit. In the absence of monitoring data, it may not be reasonable to estimate its effluent load or calculate an allocation for the Northwest WWTP based on a concentration that is less that the current calibration standard for methylmercury analysis (0.05 ng/l). As a result, the effluent methylmercury load was estimated using a concentration of 0.05 ng/l and discharge volume of 1 mgd to obtain an annual load of 0.069 g/year. Because the Northwest WWTP was not discharging in WY2000-2003, its load is not included in Table 6.2. However, because it will continue to discharge for the foreseeable future, it is included in the allocation calculations described in Chapter 8. Because it is likely that the estimated effluent load for the Northwest WWTP may be an overestimate, given effluent methylmercury concentrations observed at WWTPs that employ similar treatment processes, its corresponding allocation may include a margin of safety. As described in the draft Basin Plan Amendment staff report, staff recommends that a control program review take place after additional Delta-specific studies are completed, during which the Northwest WWTP discharge load estimate and allocation can be updated if needed.

The Mountain House Community Services District (CSD) WWTP was not discharging to surface water prior to March 2007 and therefore was not identified in the source analysis for the TMDL period, WY2000-2003. The Mountain House CSD WWTP now discharges to Old River within the San Joaquin River subarea. Because it is now discharging and has submitted effluent methylmercury concentration data for its discharge (see Appendix L), staff estimated its average annual effluent methylmercury load and calculated an allocation for its discharge. Between August 2007 and May 2009, 21 monthly effluent samples were analyzed for methylmercury.

Four results were reported as equal to the detection limit (0.05 ng/l) and 17 results were reported as “ND” (nondetect) with a method detection limit of 0.05 ng/l. Its annual average discharge load shown in Table 6.5 (0.031 g/yr) was calculated using a methylmercury concentration of 0.05 ng/l and its Phase 1 average dry weather design capacity of 0.45 mgd. Because the Mountain House CSD WWTP was not discharging in WY2000-2003, its load is not included in the Table 6.2 summary. However, because it will continue to discharge for the foreseeable future, it is included in the allocation calculations described in Chapter 8.

The City of Sacramento owns and operates a combined sewer system (CSS) that serves about eleven thousand acres. The CSS conveys up to 60 mgd of domestic and industrial wastewater and storm runoff to the SRCSD’s Sacramento River WWTP. The City of Sacramento operates its Combined Wastewater Treatment Plant (CA0079111) only when combined wastewater/storm flows exceed 60 mgd (Table G.2 in Appendix G). The Combined WWTP provides primary treatment with disinfection. If flows exceed total treatment and storage capacity, discharges may occur from Pioneer Reservoir; these discharges receive partial settleable solids and floatables removal, in a flow-through process, without disinfection. During extreme high flow conditions, discharges of untreated combined wastewater may occur at Sump 2. Discharges are predominantly urban storm runoff. At the time of the February 2008 draft report, no methylmercury data were available for the Combined WWTP or untreated CSS discharges. Hence, the average methylmercury concentration in wet weather urban runoff (0.241 ng/l, see Section 6.2.5) and average annual discharge volume (467 million gallons/year, see Table G.2b) were used to estimate a CSS methylmercury load of 0.43 g/yr. Since then, the City of Sacramento submitted methylmercury data for three samples collected from Combined WWTP discharges (0.295, 0.757 and 0.499 ng/l) and seven samples from Pioneer Reservoir discharges (0.299, 0.368, 0.457, 0.506, 0.666, 0.694 and 0.82 ng/l) between December 2004 and March 2006 (see Appendix L). Because the average methylmercury concentration of the Pioneer Reservoir and Combined WWTP discharges were not significantly different, the average concentration of all the samples (0.536 ng/l) was used with the average annual discharge volume (467 million gallons/year) to obtain an updated load estimate (0.95 g/yr).

Upgrades to the City of Stockton WWTP completed in September 2006 to meet new ammonia effluent limits and Title 22 (or equivalent) tertiary requirements appear to have led to reductions in total mercury and methylmercury as well as ammonia. Before the upgrades, the City of Stockton WWTP provided advanced secondary treatment including high-rate trickling filters and secondary clarifiers, followed by unlined facultative oxidation ponds, dissolved air flotation, mixed-media filters, and chlorination/dechlorination facilities. The September 2006 upgrade included the addition of two nitrifying biotowers and engineered wetlands to remove ammonia from the waste stream. The City of Stockton WWTP was also upgraded to meet Title 22 tertiary requirements, which included new tertiary filters and new facilities to provide coagulation, flocculation, and sedimentation prior to filtration. A comparison of WWTP effluent ammonia, inorganic mercury and methylmercury data collected before (August 2004-July 2005) and after (January-July 2009) the treatment plant upgrade indicates that since the WWTP was upgraded, average effluent ammonia concentrations decreased by 95%, and average inorganic mercury concentrations decreased 83% (Figure 6.6). Methylmercury effluent concentrations decreased by 91% (0.08 ng/l average, seven monthly samples) after the plant upgrade. Note, it is not known if the treatment plant upgrades are responsible for the mercury and methylmercury reductions, or if the reductions are a result of other operational or physical changes. Additional sampling may be needed to determine the cause of the decrease. In addition, methylmercury results for only seven monthly effluent samples have been submitted since the upgrades were completed. As more data are collected, Board staff will work with City of Stockton staff to evaluate whether the above trends are representative of current conditions.

Although more recent effluent data are available for the Stockton WWTP discharges, its average annual methylmercury load shown in Table 6.5 was calculated using the average effluent methylmercury concentrations observed between August 2004 and July 2005 (the Section 13267 monitoring period) because this data set is more representative of conditions during the TMDL period, WY2000-2003. This is consistent with the method used to calculate the SRCSD Sacramento River WWTP, described at the beginning of this section.

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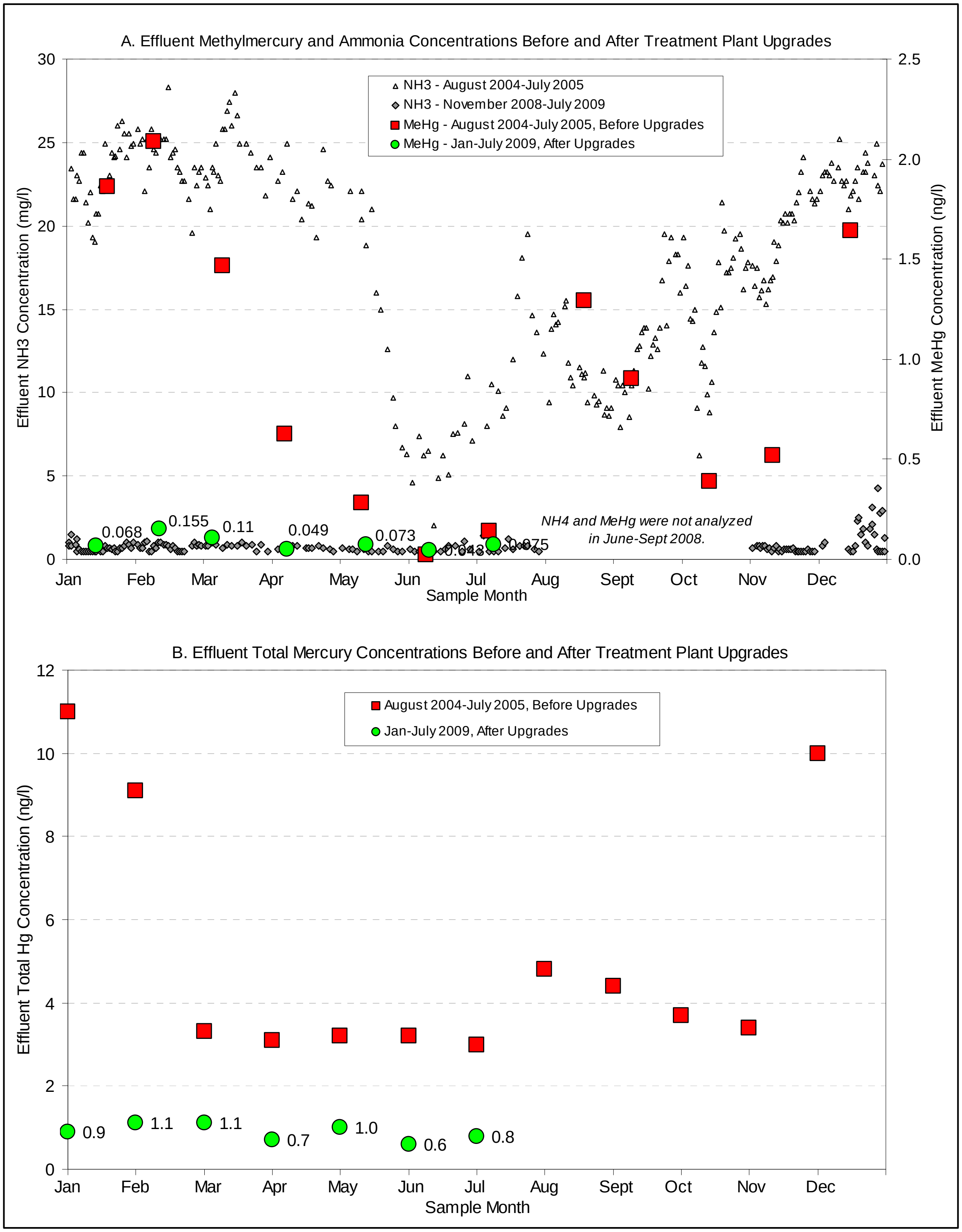

Figure 6.6: City of Stockton WWTP Effluent Ammonia, Methylmercury, and Total Mercury Concentration Data Collected Before and After WWTP Upgrades

6.2.3.2 Other Facilities

The Oakwood Lake Subdivision Mining Reclamation (formerly known as the Manteca Aggregate Sand Plant) allows flood-control pumping from Oakwood Lake, a former excavation pit filled primarily by groundwater, to the San Joaquin River. The results from discharge sampling in August and November 2004, nondetect (<0.02 ng/l) and 0.043 ng/l respectively, are comparable to groundwater treatment plant discharges in the Delta's tributary watersheds (refer to Table G.3 in Appendix G) and are substantially lower than the monthly average methylmercury concentrations observed in the San Joaquin River at Vernalis between August and December (0.102 to 0.167; refer to Table F.1 in Appendix F). Average annual methylmercury loading from Oakwood Lake was estimated using a methylmercury concentration of 0.03 ng/l and the average annual discharge volume.

The Lincoln Center Environmental Remediation Trust owns and operates a ground water extraction and treatment system in Stockton that discharges treated groundwater to Fourteenmile Slough in the Central Delta subarea. The Lincoln Center Groundwater Treatment Facility removes volatile organic compounds, petroleum products and lead from ground water, and to treat residual fluids generated during the continuing investigation, remediation, and monitoring activities at the site. Discharge methylmercury data are not available for the facility. The groundwater treatment facility discharges monitored elsewhere to date have average methylmercury concentrations below current method detection limits (< 0.03 ng/l; Bosworth *et al.*, 2010). Consequently, the discharge methylmercury load for the Lincoln Center Facility shown in Table 6.5 (0.010 g/yr) was estimated using a methylmercury concentration of 0.03 ng/l and the facility's average discharge volume of 0.25 mgd.

Three of the facilities in the Delta are power or heating/cooling facilities: GWF Power Systems, Mirant Delta LLC Contra Costa Power Plant, and the State of California Central Heating/Cooling Plant. Two of these facilities use ambient water for cooling water. Based on the comparison of the available intake and outfall methylmercury data (Table G.4 in Appendix G and Bosworth *et al.*, 2010), such facilities do not appear to act as a source of new methylmercury to the Delta. This assumption will be re-evaluated as additional information becomes available (see Section 7.1.2). GWF Power Systems (CA0082309) acquires its intake water from sources other than ambient surface water; adequate data were available to estimate the methylmercury load in its discharge.

The State of California Central Heating/Cooling Plant no longer requires a NPDES permit for the discharge of cooling water to the Sacramento River because the California Department of General Services (DGS) recently constructed cooling towers and a thermal energy storage tank. Consequently, DGS ceased the discharge to the Sacramento River in August 2009. Although the plant is listed in Table 6.5 because it discharged during the WY2000-2003 period, it is not given an allocation in Chapter 8 because the plant no longer discharges.

The Metropolitan Stevedore Company operates a marine bulk commodity terminal on leased land at the Port of Stockton. Storm water runoff, dust suppression water, and wash down water from bulk materials handling operations collect in a primary retention basin and some other low areas onsite, and evaporate or percolate into groundwater. Discharges may occur during intense storm events or when annual accumulated rainfall far exceeds the average for a given year. Methylmercury concentrations and loads in non-storm water discharges will be evaluated once the Metropolitan Stevedore Company completes methylmercury monitoring.

6.2.4 Agricultural Return Flows

More than half a million acres of the Delta islands are under agricultural production (Figure 6.7). Water seeps and is diverted onto the islands for irrigation from the surrounding river channels. The unused water is returned to Delta waterways via a series of main drains. Many of the islands are predominately peat, a substance that Gill and others (2003) and Heim and others (2003) have shown to be a good substrate for methylmercury production. Water samples collected from five Delta Island main drains in June and July 2000 suggest that the agricultural islands are net exporters of unfiltered methylmercury (Foe, 2003). Methylmercury concentrations were variable but high compared to concentrations in the river channels surrounding the islands from which the irrigation supply water was diverted and unused tail-water returned. Agricultural return flow concentrations averaged 0.35 ng/l in June and July 2000 while concentration in the supply water was 0.07 ng/l; this translates to a net production rate of approximately 17 to 35 grams per month (~0.5 to 1.1 g/day) if occurring over the entire Delta or 10 to 25% of all river loading in the two-month period (Foe, 2003).

The annual methylmercury load from agricultural lands located in the Delta was estimated to be 123 g/yr (Table 6.2). Delta agricultural diversion and return flow estimates were obtained from the Delta Island Consumptive Use Model for water year 1999, the year during which the majority of agricultural drain methylmercury data were collected (Table 6.8); these flow estimates do not include the Yolo Bypass area north of the legal Delta. The annual diversion and return flow water volumes were multiplied by their respective methylmercury concentrations to estimate annual loads. For this preliminary evaluation, the average of available agricultural drain methylmercury data (Tables 6.6 and 6.7) was used to estimate methylmercury concentrations in all Delta agricultural return flows. The methylmercury concentration of river diversions was estimated by averaging monthly Sacramento River and State Water Project MeHg concentrations between May and December (Appendix D, Table D.3). To estimate the methylmercury loading from agricultural lands, the estimated methylmercury load in the river waters diverted onto the islands was subtracted from the agricultural return loads (Table 6.6), resulting in a net input of 123 grams per year. This load was multiplied by the percentage of total agricultural acreage located in each Delta subarea to estimate a subarea specific loading rate (Table 6.9). The Central Delta and Sacramento River subareas have the greatest estimated methylmercury loading from agricultural lands because they have the largest acreage of agricultural land.

This evaluation indicates that agricultural runoff within the Delta and Yolo Bypass may contributes about 2.4% of the methylmercury load to the Delta/Yolo Bypass.

A recent study evaluated methylmercury production on and discharges from eight farmed Delta islands (Farmed Islands). In exchange for access to the properties, the study authors did not include Farmed Island names or sampling locations in the report. The study results indicated that Farmed Islands in the northern/central Delta dominated by mineral soils had lower net methylmercury loads than Farmed Islands dominated by organic soils (Heim *et al.*, October 2009), with an overall annual loading rate (0.1 g/day x 365 = 36.5 g/yr) lower than that estimated by the above method for the WY2000-2003 period (123 g/yr). Even though there is a three-fold difference in the two methods' resulting annual loads, their similarity is encouraging given very different method approaches and concentration data sets were used. In addition, both methods indicate that agricultural runoff contributes a relatively small portion of all methylmercury loading to the Delta/Yolo Bypass (2.4% versus about 1%).

The Heim and others' October 2009 study report evaluated runoff throughout the year, not just during the irrigation season. The study authors found that on an annual basis Farmed Islands throughout the Delta appear to be net sources of methylmercury to the Delta and that on a seasonal basis Farmed Islands appear to be net sources of MeHg during high flow periods (December to May) but net sinks during low flow periods (June to November). On two of the Farmed Islands that were studied, water was purposely siphoned onto the islands for winter flooding; these two islands showed a strong seasonal trend of elevated methylmercury concentrations during winter months, significantly higher than other islands studies. In contrast, a comparison of Tables 7 and 10 in Heim and others' October 2009 study report indicates that several islands may act as net sink for methylmercury throughout the year, not just during the low flow months. During Phase 1 of the proposed implementation program outlined in Chapter 4 of the draft Basin Plan Amendment staff report, staff would need to work with the study authors and Farmed Island landowners to determine which specific areas in the Delta and Yolo Bypass are acting as a net source and which areas are acting as a net sink in order to update the TMDL methylmercury source analysis.

Heim and others' October 2009 study focused exclusively on farmed islands and did not evaluate upland areas in the periphery of the Delta. A review of the upland areas mapped in DWR's Delta Atlas (DWR, 1995) indicates that upland areas may comprise about 20% or more of the Delta and Yolo Bypass. Staff recommends that a follow-up study be undertaken to characterize loads from the upland areas within and upstream of the legal Delta and, if elevated, determine the primary land uses responsible for methylmercury production. The study should be done in cooperation with agricultural interests in the Delta region.

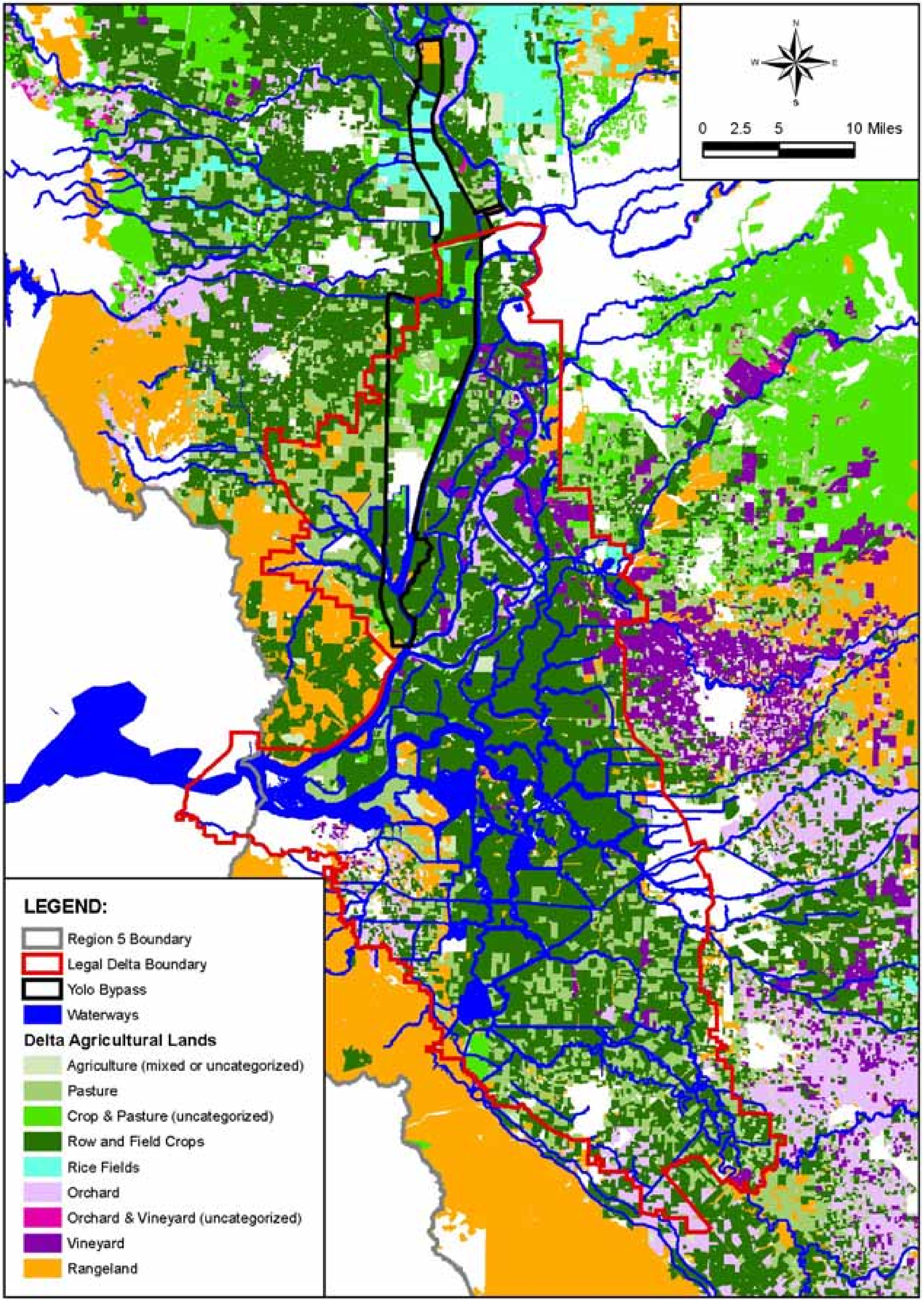

Figure 6.7: Agricultural Lands within the Statutory Delta Boundary and Yolo Bypass.

Table 6.6: Values Used to Estimate MeHg Loads from Agricultural Lands within the Legal Delta Boundary

	Average MeHg Conc. (ng/l) (a)	**Flow** (acre-feet/ yr) (b)	**MeHg Load** (g/yr)
Diversions:	0.071	1,597,880	139
Ag Drain Returns:	0.352	603,546	262
Net Ag Drain Input (g/yr):			**123**

(a) Average agricultural drain methylmercury concentration obtained from Table 6.7. Average methylmercury concentration for diversion flows was estimated by averaging monthly Sacramento River and State Water Project MeHg concentrations during May through December (Appendix D).

(b) Estimated annual average agricultural diversion and return flows were obtained from Table 6.8.

Table 6.7: Delta Agricultural Main Drain Methylmercury Concentration Data (a)

Site	**Sample Date**	**MeHg Conc.** (ng/l)
Empire Tract Main Drain	6/26/00	0.093
Empire Tract Main Drain	7/19/00	0.117
Lower Jones Main Drain	6/26/00	0.302
Staten Island Main drain	6/26/00	0.198
Staten Island Main drain	7/19/00	0.094
Twitchell Island Main Drain	6/26/00	0.387
Twitchell Island Main Drain	7/19/00	1.500
Twitchell Island Main Drain	6/30/03	0.292 (b)
Twitchell Island Main Drain	7/28/03	0.341
Twitchell Island Main Drain	8/27/03	0.609
Twitchell Island Main Drain	9/25/03	0.157 (b)
Upper Jones Main Drain	7/19/00	0.131

(a) Source: Foe, 2003; Central Valley Water Board sampling, 2003.

(b) Average of laboratory replicates (0.289 and 0.294 ng/l on 6/30/03 and 0.147 and 0.167 ng/l on 9/25/03).

Table 6.8: Delta-wide Island Consumptive Use Estimates – Water Year 1999 (acre-feet)

Period (a)	**Diversions + Seepage**	**Return Flow**	**Net Channel Depletion**
Oct-98	92,969	36,155	56,815
Nov-98	74,202	34,988	39,213
Dec-98	81,348	31,359	49,989
Jan-99 (b)	*42,180*	*111,661*	*-69,481*
Feb-99 (b)	*34,044*	*120,960*	*-86,916*
Mar-99	57,306	43,410	13,896
Apr-99	108,000	46,532	61,468
May-99	193,317	67,944	125,373
Jun-99	273,838	92,648	181,190
Jul-99	353,800	120,147	233,653
Aug-99	221,540	77,167	144,373
Sep-99	141,560	53,197	88,364
Annual Totals (b)	**1,597,880**	**603,546**	**994,334**

(a) Diversion and return flow volumes were obtained from the Delta Island Consumptive Use Model (Suits, 2000).

(b) Only months with positive depletion were used in the annual methylmercury load estimates because no methylmercury concentration data were available for the agricultural return drains during the coolest/wettest months.

Table 6.9: Agricultural Acreage and Methylmercury Load Estimates by Delta Subarea

	Central Delta	Cosumnes / Mokelumne River	Marsh Creek	Sacramento River	San Joaquin River	West Delta	Yolo Bypass-North [(c)]	Yolo Bypass-South	**TOTAL**
Acreage [(a)]	157,035	6,790	9,362	155,532	96,874	17,313	11,046	70,523	**524,474**
% of Total Acreage	30%	1.3%	1.8%	30%	18%	3.3%	2.1%	13%	**100%**
Estimated Annual MeHg Load (g/year) [(b)]	36.8	1.6	2.2	36.4	22.7	4.1	2.6	16.5	**123**

(a) Land cover source: DWR land use GIS coverages (1993-2003).

(b) A Delta-wide agricultural land methylmercury loading of 123 g/yr was estimated using the information presented in Tables 6.6 through 6.8. The Delta-wide load was multiplied by the percentage of total agricultural acreage located in each Delta subarea to estimate the amount of loading from agricultural lands in each subarea.

(c) The Yolo Bypass-North subarea does not include agricultural areas in the Yolo Bypass north of the legal Delta boundary.

6.2.5 Urban Runoff

Approximately 60,000 acres of the land in the Delta and Yolo Bypass north of the legal Delta boundary is classified as urban (DWR, 1993-2003). Most of the urban area is regulated by waste discharge requirements under the National Pollutant Discharge Elimination System (NPDES), which permits discharge of storm water from municipal separate storm sewer systems (MS4s).[35] Table 6.10 lists the permits that regulate urban runoff in the Delta and the amount of urban acreage in each Delta subarea. Figure 6.8 shows their locations. Urban acreages corresponding to each Permittee were estimated from the DWR Land Use coverage (DWR, 1993-2003) using available MS4 service area delineations. MS4 service area delineations for Sacramento, Stockton and Tracy are based on paper or electronic maps provided by the MS4 Permittees; all other MS4 service areas were delineated using 1990 city and county boundaries. Urban areas not encompassed by a MS4 service area were grouped into a “nonpoint source” category within each Delta subarea, consistent with USEPA’s requirements and guidance for establishing waste load allocations for storm water sources (USEPA, 2002).

Methylmercury concentration data have been collected by Central Valley Water Board staff and the City and County of Sacramento from several urban waterways in or adjacent to the Delta. Figure 6.9 shows the sampling locations, Figure H.1 in Appendix H illustrates the wet and dry

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[35] A municipal separate storm sewer system (MS4) is a conveyance or system of conveyances that include roads with drainage systems, municipal streets, alleys, catch basins, curbs, gutters, ditches, manmade channels, or storm drains, owned by a State, city, county, town or other public body. MS4s are designed and used for collecting or conveying storm water and do not include combined sewer systems or parts of a publicly owned treatment works. MS4s discharge to Waters of the United States. The Municipal Storm Water Permitting Program regulates storm water discharges from MS4s. MS4 permits were issued in two phases. Under Phase I, which started in 1990, the RWQCBs have adopted NPDES storm water permits for medium (serving between 100,000 and 250,000 people) and large (serving greater than 250,000 people) municipalities. Most of these permits are issued to a group of co-permittees encompassing an entire metropolitan area. These permits are reissued as the permits expire. As part of Phase II, the State Board adopted a General Permit for the discharge of storm water from small MS4s (WQ Order No. 2003-0005-DWQ, NPDES No. CAS000004) to provide permit coverage for smaller municipalities, including non-traditional small MS4s, which are governmental facilities such as military bases, public campuses, and prison and hospital complexes.

weather concentrations by location, and Appendix L provides the concentration data used in Figure H.1. Methylmercury concentrations ranged from a wet weather low of 0.035 ng/l (City of Sacramento Sump 111) to a dry weather high of 2.04 ng/l (Strong Ranch Slough). A visual inspection of the methylmercury data suggests that the differences between urban watersheds are not related to land use. Therefore, the data were averaged by wet and dry weather for each location (Table 6.11). The averages of these location-based wet and dry weather averages are assumed to represent runoff from all urban areas in or adjacent to the Delta and were used to estimate loads. These values are similar to methylmercury levels observed during high flow conditions in two urbanized tributaries in the Washington, D.C. region. The urbanized Northeast and Northwest Branches of the Anacostia River had average methylmercury concentrations of 0.12 ± 0.06 ng/l and 0.07 ± 0.07 ng/l, respectively, during base flows, and 0.39 ± 0.21 ng/l and 0.77 ± 0.46 ng/l, during high flows (Mason and Sullivan, 1998).

Average annual urban runoff loading was estimated for WY2000-2003 so that urban runoff loading could be compared to tributary loading (Table 6.2). To estimate wet weather methylmercury loads, the wet weather concentration (0.241 ng/l) was multiplied by the runoff volumes estimated for WY2000-2003 for each MS4 area within each Delta subarea. To estimate dry weather methylmercury loads, the dry weather concentration (0.363 ng/l) was multiplied by the estimated dry weather urban runoff volume. Section E.2.3 in Appendix E describes the methods used to estimate wet and dry weather runoff volumes from urban areas within the Delta. Wet and dry weather methylmercury loads were summed to estimate the average annual loading of 20 grams to Delta waterways. The loading to each Delta subarea (Table 6.12) was used to develop MS4 Permittee and subarea-specific allocations (Chapter 8).

Urban land use comprises a small portion of the surface area in the Delta and contributes only about 0.4% of the Delta methylmercury load (Table 6.2). In contrast, approximately 320,000 acres of urban land – about 42% of all urban area within the Delta source region – occur within 20 miles of the statutory Delta boundary, about one day water travel time upstream. In addition, some of the urban watersheds outside the Delta discharge via sumps into Delta waterways. These discharges were not included in the Delta load estimate. As a result, the urban contribution to the Delta methylmercury load may be underestimated.

To evaluate the potential contributions from upstream urban lands, the methylmercury loadings from the two MS4 service areas with the greatest urban acreage immediately upstream of the Delta were estimated. The sum of methylmercury loads from the Sacramento and Stockton MS4 areas may contribute about 1% of methylmercury loading to the Delta (Table 6.13). These loads are expected to increase as urbanization continues around the Delta.

Table 6.10: Urban Acreage and MS4 Permits that Regulate Urban Runoff within the Delta/Yolo Bypass.

Permittee	**NPDES #** [(a)]	**Urban Acreage within Delta Subareas** [(b)]							**Total Acreage**
		Central Delta	Marsh Creek	Mokelumne / Cosumnes Rivers	Sacra-mento River	San Joaquin River	West Delta	Yolo Bypass [(c)]	
Contra Costa County	CAS083313	2,181	3,427				9,518		15,126
Lathrop (City of)	CAS000004					738			738
Lodi (City of)	CAS000004	134							134
Port of Stockton	CAS084077	1,067				28			1,095
Rio Vista (City of)	CAS000004				37				37
Sacramento Area MS4 [(d)]	CAS082597				4,766				4,766
San Joaquin County	CAS000004	1,494		121	521	6,040			8,176
Solano County	CAS000004				181			220	401
Stockton MS4 Permit Area	CAS083470	10,574				1,481			12,055
Tracy (City of)	CAS000004					5,268			5,268
West Sacramento (City of)	CAS000004				1,824			2,756	4,580
Yolo County	CAS000004				200			796	966
Urban Nonpoint Source [(e)]		337		44	1,615	7	231		2,234
Total Acreage		**15,787**	**3,427**	**165**	**9,144**	**13,562**	**9,749**	**3,772**	**55,606**

(a) Permittees with NPDES No. CAS000004 are covered under the General Permit for the discharge of storm water from small MS4s (WQ Order No. 2003-0005-DWQ) adopted by the State Water Board to provide permit coverage for smaller municipalities (serving less than 100,000 people).

(b) Urban land uses and acreages corresponding to each Permittee were estimated from the DWR Land Use coverage (DWR, 1993-2003) using available service area delineations. MS4 service area delineations for Sacramento, Stockton and Tracy are based on paper or electronic maps provided by the MS4 Permittees; all other MS4 service areas were delineated using 1990 city boundaries.

(c) The Yolo Bypass subarea includes urban areas in the Yolo Bypass north of the legal Delta boundary.

(d) The Sacramento MS4 Area does not include the Sacramento Combined Sewer System (CSS) service area illustrated in Figure 6.8. The CSS service area is permitted by a separate NPDES permit, which is described in Section 6.2.3 and Table G.2 in Appendix G.

(e) Urban areas not encompassed by a MS4 service area were grouped into the “nonpoint source” category.

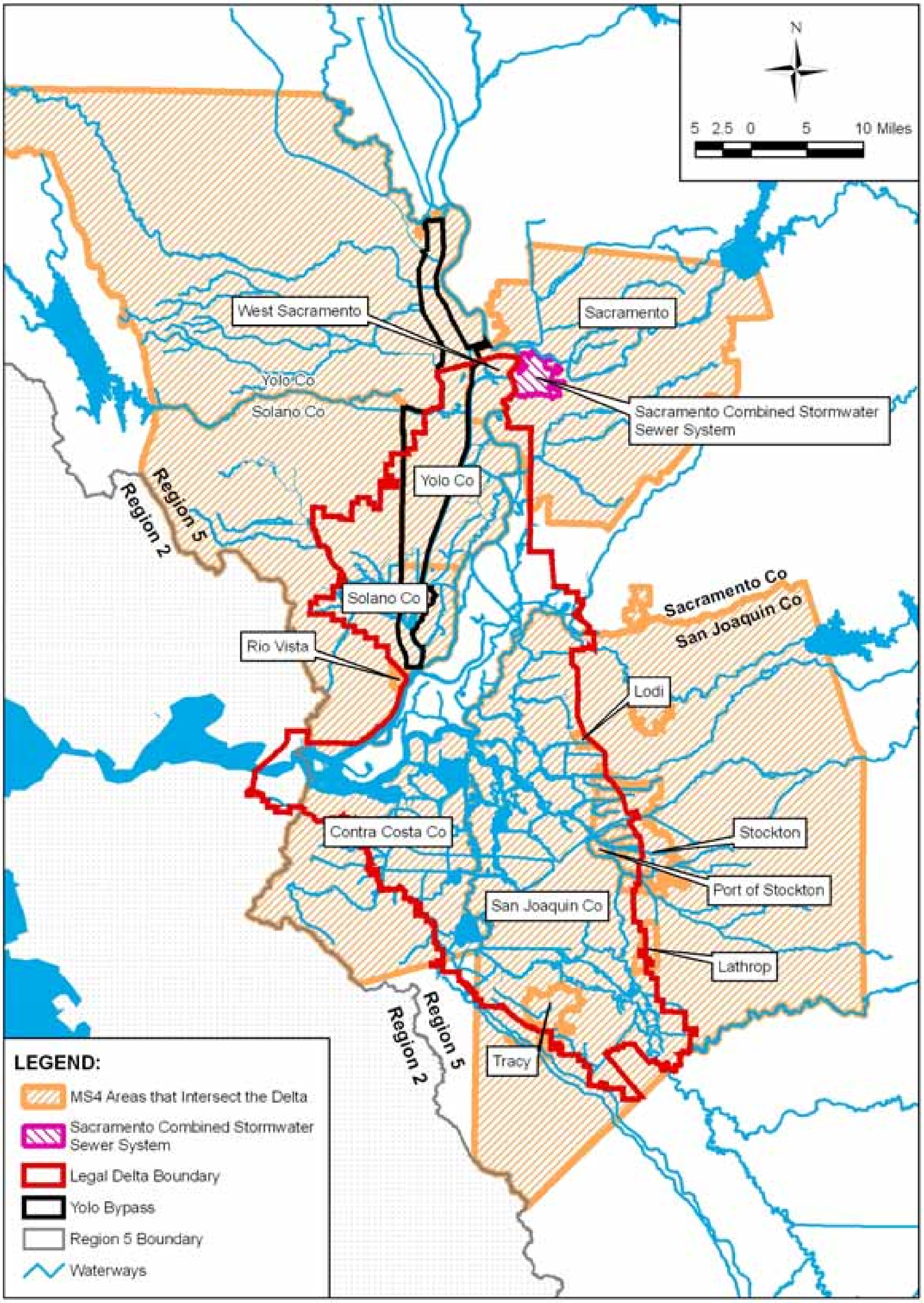

Figure 6.8: NPDES Permitted Municipal Separate Storm Sewer System (MS4) Areas in the Delta Region. (Only those MS4 areas that intersect the statutory Delta boundary and Yolo Bypass are labeled. MS4 service area delineations for Sacramento, Stockton and Tracy are based on paper or electronic maps provided by the MS4 Permittees; all other MS4 service areas were delineated using 1990 city or county boundaries.)

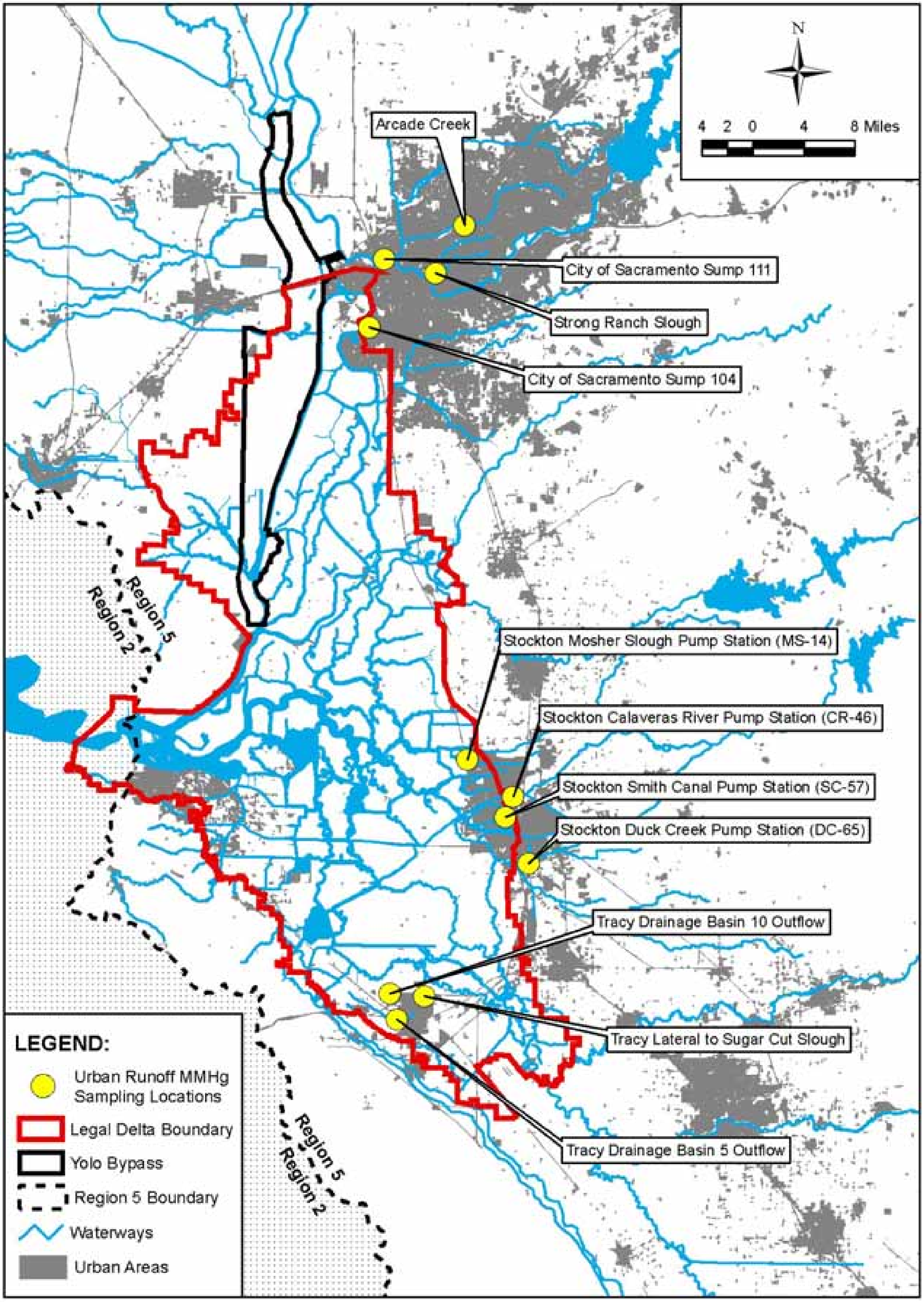

Figure 6.9: Urban Areas and Aqueous MeHg Sampling Locations in the Delta Region.

Table 6.11: Summary of Urban Runoff Methylmercury Concentrations

Location	**# of Samples**	**Minimum Conc.** (ng/l)	**Average Conc.** (ng/l)	**Maximum Conc.** (ng/l)
DRY WEATHER				
Arcade Creek	9	0.099	0.358	1.213
Sacramento Strong Ranch Slough	2	0.158	1.099	2.040
Sacramento Sump 104	2	0.088	0.093	0.097
Sacramento Sump 111	2	0.135	0.176	0.217
Tracy Lateral to Sugar Cut Slough	1	0.091	0.091	0.091
Average of Location Averages:	**0.363 ng/l**			
WET WEATHER				
Arcade Creek	7	0.099	0.240	0.339
Sacramento Strong Ranch Slough	4	0.237	0.522	0.878
Sump 104	4	0.153	0.290	0.610
Sump 111	4	0.035	0.212	0.420
Stockton Calaveras River Pump Station	5	0.105	0.167	0.301
Stockton Duck Creek Pump Station	1	0.103	0.103	0.103
Stockton Mosher Slough Pump Station	4	0.084	0.125	0.189
Stockton Smith Canal Pump Station	4	0.099	0.263	0.533
Tracy Drainage Basin 10 Outflow	3	0.103	0.192	0.257
Tracy Drainage Basin 5 Outflow	3	0.110	0.138	0.191
Tracy Lateral to Sugar Cut Slough	3	0.040	0.400	0.918
Average of Location Averages:	**0.241 ng/l**			

Table 6.12: Average Annual Methylmercury Loading from Urban Areas within Each Delta Subarea for WY2000-2003

MS4 PERMITEE	**DELTA SUBAREA** (g/yr)							**Grand Total** (g/yr)
	Central Delta	Marsh Creek	Mokelumne / Cosumnes Rivers	Sacramento River	San Joaquin River	West Delta	Yolo Bypass	
Contra Costa County	0.75	1.2				3.2		**5.2**
Lathrop (City of)					0.27			**0.27**
Lodi (City of)	0.053							**0.053**
Port of Stockton	0.39				0.010			**0.40**
Rio Vista (City of)				0.014				**0.014**
Sacramento Area MS4				1.8				**1.8**
San Joaquin County	0.57		0.045	0.19	2.2			**3.0**
Solano County				0.073			0.085	**0.16**
Stockton MS4 Permit Area	3.6				0.50			**4.1**
Tracy (City of)					1.8			**1.8**
West Sacramento (City of)				0.65			1.1	**1.8**
Yolo County				0.073			0.33	**0.40**
Urban Nonpoint Source	0.14		0.018	0.63	0.0022	0.066		**0.85**
Grand Total	**5.5**	**1.2**	**0.063**	**3.4**	**4.8**	**3.3**	**1.5**	**20**

Table 6.13: Comparison of Sacramento and Stockton Area MS4 Methylmercury Loading to Delta Methylmercury Loading for WY2000-2003.

MS4 Service Area [(a)]	**Water Volume** (M acre-feet) [(b)]	**MeHg Load** (grams/year)
Sacramento MS4 Urban Total	0.18	59
Stockton MS4 Urban Total	0.026	8.6
Total Delta Inputs [(c)]	20	5,219
Stockton & Sacramento Runoff as % of Total Delta Inputs	**1.0%**	**1.3%**

(a) The Sacramento and Stockton Area MS4s are the two MS4 service areas with the greatest urban acreage in the greater Delta region, with urban land use areas of about 161,000 and 25,000 acres, respectively.

(b) Refer to Section E.2.3 in Appendix E for urban runoff volume estimates for wet and dry weather, which were summed to estimate the annual average water volumes shown above.

(c) These values represent the sum of all tributary inputs and within-Delta methylmercury sources shown in Table 6.2.

6.2.6 Atmospheric Deposition

At the time the TMDL was developed, atmospheric deposition of methylmercury had not yet been measured within the Delta. However, several published papers provided reviews of methylmercury levels in wet deposition in a variety of locations around the world (e.g., Nguyen *et al.*, 2005; Lawson and Mason, 2001; Mason *et al.*, 1997 and 2000). These reviews indicate that the ratios of methyl to total mercury concentrations in wet deposition range from 0.25 to 6%, and that typically less than 1% of total mercury in wet deposition is methylmercury. As described in Section 7.1.4 and Table 7.1, total mercury loading from wet deposition to Delta water surfaces and land surfaces not including urban areas was estimated to be 2,318 g/yr for WY2000-2003. A methyl to total mercury ratio of 1% was used to estimate the mass of methylmercury deposited by wet deposition:

Equation 6.2:

$$\begin{aligned}\text{MeHg Mass} &= \text{Total mercury mass} * \text{MeHg:TotHg}\\ 23\ \text{g/yr} &= 2.3\ \text{kg/year} * 0.01\end{aligned}$$

Table 6.14 provides the methylmercury load estimates for atmospheric deposition to each Delta subarea. Wet deposition in the Delta and Yolo Bypass likely contributes less than 1% of all methylmercury entering the Delta (Table 6.2). Therefore, it is assumed that atmospheric input to waterways and land surfaces within the Delta and Yolo Bypass is not a significant source of methylmercury. A recently completed CalFed study similarly found that atmospheric inputs within the Delta contribute less than 1% of all methylmercury entering the Delta (Foe *et al.*, 2008). Methylmercury in wet deposition to urban land surfaces was not evaluated because it is incorporated in the estimates for loading from urbanized lands described in Section 6.2.5.

Table 6.14: Estimate of Average Annual Methylmercury Loading from Wet Deposition

Delta Subarea	**WY2000-2003 Average Annual TotHg Load** (g/yr) [(a)]	**Estimated MeHg Load** (g/yr) [(b)]
Central Delta	729	7.3
Marsh Creek	23	0.23
Mokelumne / Cosumnes River	29	0.29
Sacramento River	560	5.6
San Joaquin River	272	2.7
West Delta	237	2.4
Yolo Bypass-North [(c)]	100	1.0
Yolo Bypass-South	315	3.2
TOTAL	**2,265 (2.3 kg/yr)**	**23**

(a) Total mercury loading from precipitation on surface water and non-urbanized land surfaces in the Delta and Yolo Bypass was estimated by multiplying the average mercury concentration in North Bay/Martinez rainwater by the average rainfall runoff volume during WY2000-2003 (see Section 7.1.4 in Chapter 7 and Section E.2.3 in Appendix E).

(b) The published literature indicates that ratios of methyl to total mercury concentrations in wet deposition typically range from 0.25% to 6%, and that typically less than 1% of total mercury in wet deposition is methylmercury. A methyl to total mercury ratio of 1% was used to estimate the mass of methylmercury deposited to waterways in each subarea.

(c) The Yolo Bypass-North subarea includes areas in the Yolo Bypass north of the legal Delta boundary.

6.2.7 Other Potential Sources

Potential methylmercury sources in the Delta/Yolo Bypass not evaluated by this TMDL may include the following:

- Methylmercury flux from floodplain sediments when floodplains are inundated;
- Agricultural areas in the Yolo Bypass north of the legal Delta boundary;
- Rainwater runoff from agricultural areas throughout the Delta and Yolo Bypass; and
- Runoff from rangeland and other open-space areas not encompassed by urban, wetland, or agricultural areas.
- Return water from dredge material disposal ponds.

The methylmercury load estimates for methylmercury flux from open water sediments described in Section 6.2.2 do not address floodplain acreage that is not permanently inundated. As illustrated in the Sacramento-San Joaquin Delta Atlas (DWR, 1995), the Delta encompasses a maze of over 1,100 miles of river channels that are almost entirely constrained by local and federal flood control project levees. Throughout the Delta, there is very little acreage between channel levees not already included in the wetland and open water acreages, with the exception of the Yolo Bypass. The Yolo Bypass is a massive floodplain (about 73,000 acres) on the west side of the lower Sacramento River that receives floodwaters routed from the Sacramento and Feather Rivers by the Fremont and Sacramento Weirs (see Section E.2.2 and Figure E.2 in Appendix E). The Yolo Bypass typically floods in more than half of water years, for an average of two months every other year; complete inundation of the floodplain approximately doubles the wetted area of the Delta and is equivalent to about one-third the area of San Francisco and San Pablo bays (Sommer *et al*., 2001; Foe *et al.*, 2008). The WY2000-2003 period that encompasses the available methylmercury concentration data for the major Delta inputs and exports was a relatively dry period. However, bypass floodplain inundation may contribute substantial methylmercury loading to the Delta. Results from a recent CalFed study indicate that inundated areas in the Yolo Bypass are potentially large sources of methylmercury to the bypass and Delta (Foe *et al*., 2008). Board staff will include results from this and other floodplain habitat studies completed during the first phase of TMDL implementation when the source analysis is re-evaluated during the Delta mercury control program review.

As noted in Section 6.2.4, the agricultural return flows upon which the return flow methylmercury load estimates are based do not include the Yolo Bypass area north of the legal Delta or other upland areas in the Delta periphery. In addition, the load estimates address only runoff during the active irrigation season because no methylmercury concentration data were available for stormwater runoff from agricultural areas at the time the TMDL was developed. Staff recommends that the following activities take place during the first phase of the proposed implementation program outlined in Chapter 4 of the draft Basin Plan Amendment staff report in order to improve the source analysis:

- Work with the study authors of the recent Farmed Islands study (Heim *et al.*, 2009) and Farmed Island landowners to determine which specific areas in the Delta and Yolo Bypass are acting as a net source and which areas are acting as a net sink on an annual basis.
- Undertake a follow-up study to characterize loads from farmed land in upland areas in the Delta region and, if elevated, determine the primary land uses responsible for methylmercury production, in cooperation with agricultural interests in the Delta region.

Similarly, methylmercury concentration data were not available for stormwater runoff from rangeland and other upland areas not encompassed by urban, wetland, water, or agricultural load estimates. Because such upland areas comprise only about 8% of land cover within the Delta and Yolo Bypass, they are not expected to contribute substantially more methylmercury loading than that already present in rainfall, which was estimated for this TMDL. However, such upland areas could account for more of the methylmercury loading to tributary watersheds. Staff recommends that upstream TMDL program studies incorporate analyses of methylmercury in runoff from upland areas.

As discussed in the following section, sediment is dredged at various locations in the Delta to maintain ship channels and marinas. Dredge material typically is pumped to either disposal ponds on Delta islands or upland areas. At the time that the TMDL was developed, no methylmercury data were available for return flows to the Delta/Yolo Bypass from dredge material disposal (DMD) ponds. Since the February 2008 draft report was released, methylmercury monitoring took place at five DMD ponds in the Delta to determine whether DMD ponds produce methylmercury that could be discharged to Delta waterways (AMS, 2010). Samples of pond water, representing water that would leave the DMD ponds if discharge occurred, were collected approximately every 10 days for 40 days after dredge disposal. Monitoring indicated the following:

- Average and median methylmercury concentrations in samples representing DMD pond outflows were about 10x to >100x higher than what is observed in receiving waters. Sacramento River and San Joaquin Rivers average 0.11 and 0.18 ng/l, respectively, per a recent CalFed study (Foe *et al*., 2008). Average DMD pond outflow methylmercury concentrations were 1.1, 1.5, 5.9, 9.6 and 20.8 ng/l for the five ponds.
- The methylmercury concentration in all sampled DMP site ponds increased above inflow levels during the monitoring effort, which likely indicates that methylmercury was produced at the sites.

During the first phase of TMDL implementation, Board staff will need to work with U.S. Army Corps of Engineer staff and contractors to determine how to estimate the volume of DMD pond return flows to the Delta/Yolo Bypass during a range of dredging project years (e.g., during some years there may be little-to-no discharge from the DMD ponds) in order to estimate the amount of methylmercury produced by the DMD ponds and methylmercury loads discharged to the Delta/Yolo Bypass. New information will be incorporated in the TMDL when the source analysis is re-evaluated during the Delta mercury control program review.

6.3 Methylmercury Losses

The following were identified as contributing to methylmercury losses from the Delta: water exports to southern California, outflow to San Francisco Bay, removal of dredged sediments, photodegradation, biotic uptake and other loss terms. Table 6.15 lists the average methylmercury concentrations and estimated average annual loads associated with the losses for the WY2000-2003 period, a relatively dry period that encompasses the available concentration data for the major Delta inputs and exports. Figure 6.10 shows the aqueous monitoring locations for major methylmercury exports and the approximate locations of recent dredging projects.

Figures and tables cited in Sections 6.3.1 through 6.3.4 are arranged after Section 6.3.4 in the order in which they were mentioned.

Table 6.15: Methylmercury Concentrations and Loads Lost from the Delta for WY2000-2003.

	Average Annual Load (g/yr)	**% All MeHg**	**Average Aqueous Concentration** (ng/l)
Outflow to San Francisco Bay (X2)	1,717	69.7%	0.08
Dredging	341	13.9%	- - -
State Water Project	203	8.2%	0.05
Delta Mendota Canal	201	8.2%	0.06
Photodegradation	*To Be Determined*		
Accumulation in Biota	*Unknown*		
TOTAL EXPORTS:	**2,462 g/yr (2.5 kg/yr)**		

6.3.1 Outflow to San Francisco Bay

Outflow to San Francisco Bay is the primary way that methylmercury is lost from the Delta. Methylmercury in Delta outflow to San Francisco was evaluated by collecting samples at X2. X2 is the location in the Bay-Delta Estuary with 2 parts per thousand (o/oo) bottom salinity. The location of X2 moves as a function of both tidal cycle and freshwater inflow, typically between the Cities of Martinez and Pittsburg, west of the legal Delta boundary. This salinity was chosen because 2 to 3 o/oo salinity is the normal osmotic tolerance of freshwater organisms, and a goal of the CALFED studies was to estimate the methylmercury exposure of these organisms.

Staff from the Central Valley and San Francisco Bay Central Valley Water Boards has agreed to consider Mallard Island as the boundary between the two regions for control of mercury. The site was selected as it is near the legal boundary and has a U.S. Geological Survey flow gauge.

Central Valley Water Board staff conducted monthly aqueous methylmercury sampling at X2 from March 2000 to September 2001 (Foe, 2003) and from April to September 2003. Figure 6.11 and Table 6.16 summarize the export data. Methylmercury concentrations at X2 averaged 0.075 ng/l and ranged from below detection limits to 0.241 ng/l. Net daily Delta outflow water volumes were obtained from the Dayflow model (Section E.2.4 in Appendix E). Methylmercury concentrations for X2 and net daily Delta outflows were regressed against each other to determine whether flow could be used to predict methylmercury concentration (Appendix F). The regression was significant at $P<0.05$ and accounted for about 20% of the variation in methylmercury concentrations. The regression-based export load was 2,086 g/yr.

An alternate approach is to use average monthly methylmercury concentrations to estimate Delta exports. Concentration data were pooled by month to calculate monthly average concentrations for WY2000-2003 (Table F.1 in Appendix F). Monthly average concentrations were multiplied by monthly average flows for WY2000-2003 to estimate monthly loads and summed to calculate an annual average methylmercury load for WY2000-2003 of 1,717 g/yr. The latter estimate appears similar to the regression-based estimate (2,086 g/yr). Table 6.15 uses an advective export rate of 1,717 g/yr to San Francisco Bay. This accounts for approximately 70% of identified Delta methylmercury losses from exports to San Francisco Bay and south of the Delta (*via* State Water Project and Delta Mendota Canal) and sediment removal by dredging activities. No attempt was made to estimate dispersive loads. It is not known whether dispersive or tidal flows would increase or decrease the net methylmercury load exported to the Bay area. The results from a recently completed CalFed study (Foe *et al*., 2008) indicate that the methylmercury load exported to San Francisco Bay may be much greater (3,577 g/yr; see Figure 9 in Foe *et al*., 2008), when data for wet years are incorporated in the load calculations.

6.3.2 South of Delta Exports

Water diversions to southern California account for approximately 16% of identified Delta methylmercury losses from exports to San Francisco Bay and south of the Delta (*via* State Water Project and Delta Mendota Canal) and sediment removal by dredging activities (Table 6.15). Methylmercury in Delta Mendota Canal (DMC) and State Water Project (SWP) exports to southern California were evaluated by collecting water samples from the DMC canal off Byron Highway (County Road J4) and from the input canal to Bethany Reservoir, respectively. Bethany is the first lift station on the State Water Project canal system and is about one mile south of Clifton Court Forebay in the Delta. Figure 6.10 illustrates the sampling locations.

Central Valley Water Board staff conducted monthly methylmercury sampling at the DMC and SWP from March 2000 to September 2001 (Foe, 2003) and from April 2003 to April 2004. Appendix L provides the methylmercury concentration data collected at the DMC and SWP and Figure 6.11 and Table 6.16 summarize methylmercury concentrations. The volume of water exported by the DMC and SWP was obtained from the Dayflow model (Section E.2.4 in Appendix E). Like at X2, methylmercury concentrations were regressed against daily flow to determine whether the concentrations could be predicted from the flow (Appendix F). Neither regression was significant ($P<0.05$). Therefore, average methylmercury concentrations of 0.05 and 0.06 ng/l (Table 6.16) were used to estimate SWP and DMC export loads of 203 and 201 g/yr, respectively (Table 6.15). A recently completed CalFed study (Foe *et al*., 2008) found average methylmercury concentrations of 0.07 and 0.10 ng/l for the SWP and DMC, respectively, and slightly higher annual methylmercury loads (548 g/yr for the sum of SWP and DMC exports; see Figure 9 in Foe *et al*., 2008), when data for wet years were incorporated.

6.3.3 Export via Dredging

Sediment is dredged at various locations in the Delta to maintain ship channels and marinas. No data have been gathered on methylmercury levels in dredge material removed from the Delta. To determine whether dredging activities could result in notable methylmercury loss from the Delta, a preliminary load estimate was developed using available dredge volume and total mercury information and surficial sediment methylmercury concentration data. Methylmercury removed by dredge activities could account for almost 14% of the identified methylmercury losses from exports to San Francisco Bay and south of the Delta (*via* State Water Project and Delta Mendota Canal) and sediment removal by dredging activities (Table 6.15).

Dredge material is typically pumped to either disposal ponds on Delta islands or upland areas. Table 6.17 provides information for recent dredge projects within the Delta and Figure 6.10 shows their approximate locations. The Sacramento and Stockton deep water channels have annual dredging programs; the locations dredged each year vary. Dredging occurs at other Delta locations when needed, when funds are available, or when special projects take place. Approximately 533,400 cubic yards of sediment are dredged annually on average, with 199,000 cubic yards from the Sacramento Deep Water Ship Channel and 270,000 cubic yards from the Stockton Deep Water Channel. Other minor dredging projects at marinas remove sediment at various frequencies for a combined total of about 64,400 cubic yards per year. Average mercury concentrations in the sediment for the project sites range from 0.04 to 0.41 mg/kg (dry weight). The annual mass of mercury removed from the Delta through dredging projects is approximately 57 kg/year. Section 7.2.3 provides a description of the methods used to estimate the annual mass of total mercury removed by dredging and the uncertainty in the estimate. None of the dredging projects analyzed sediment samples for methylmercury. Heim and others (2003) evaluated surficial sediment MeHg:TotHg at several locations in the Sacramento and Stockton Deep Water Channels (Table 6.18), where nearly 90% of all dredged materials from the Delta are removed. The average MeHg:TotHg of 0.006 was used to estimate the mass of methylmercury removed by dredging projects:

Equation 6.3:

$$\begin{aligned} \text{MeHg Mass} &= \text{Total mercury mass} \;*\; \text{MeHg:TotHg} \\ 341\text{ g/yr} &= 57\text{ kg/year} \;*\; 1000\text{ (g/kg)} \;*\; 0.006 \end{aligned}$$

Use of surficial sediment MeHg:TotHg to estimate methylmercury mass removed by dredging assumes that MeHg:TotHg is consistent throughout all depths of sediment in the dredged areas, which may overestimate the mass removed if methylmercury levels actually decrease with depth. In addition, methylmercury production may increase after dredging activities if the newly exposed sediment has higher total mercury concentrations. Central Valley Water Board staff recommends that dredgers quantify the amount of methylmercury removed, determine the mercury concentration of fine grain material in newly exposed sediment, and monitor methylmercury production at dredge material disposal and reuse areas (see previous discussion in Section 6.2.7 in this chapter and Chapter 4 in the draft Basin Plan Amendment staff report).

6.3.4 Other Potential Loss Pathways

Possible methylmercury loss processes within the Delta include degradation by sunlight (photodegradation), particle settling, and accumulation by biota. Data collected after the TMDL source analysis was completed show that photodegradation and particle settling are important processes that can account for the within-Delta losses (Stephenson and Bonnema, 2008; Gill, 2008a). Photodegradation rates vary with depth of light penetration into water and hours of sunlight. On average at four locations in the Delta, loss by photodegradation was 2.5 g methylmercury/day, or 13% of the average daily input of methylmercury (Gill, 2008a). In the Sacramento River near Rio Vista, the photodegradation rate was about 4 g/day or 30% of the dissolved methylmercury per day at the top half meter of water (Byington *et al.*, 2005). Results in the Delta are similar to photodegradation rates observed in Florida and Canada. Methylmercury photodegradation rates in a boreal forest lake in northwestern Ontario, Canada, ranged between -3 and 27% per day, with the highest rates at the lake surface (Sellers and Kelly, 2001). In the Everglades, Krabbenhoft and others (1999) observed methylmercury degradation rates ranging from 2 to 15% per day. Krabbenhoft and others (1999 and 2002) also found that the majority of photodegradation occurred in the top half meter of water; however, they also found that the rate of degradation was largely dependent on the concentration of dissolved organic carbon. The large surface to depth ratio of the Delta, coupled with its relatively long residence time, may result in significant loss of methylmercury by photodegradation.

Settling of particles in the Delta creates significant methylmercury loss because the Delta is a sink for incoming sediment and more than half of the methylmercury is bound to particulates (Foe et al., 2008). In CalFed studies completed after the TMDL source analysis, particle settling removed methylmercury at an average rate of 25% of incoming loads (Stephenson and Bonnema, 2008). Methylmercury loss due to sedimentation is flow-dependent, meaning more methylmercury is lost during winter (usually higher flows) than in summer.

The amount of methylmercury accumulating in aquatic biota is not known. However, studies could be undertaken to ascertain the rate of transfer from the abiotic to the biotic component of the food web.

Table 6.16: Methylmercury Concentrations for the Delta's Major Exports

Site	**# of Samples**	**Min. MeHg Conc.** (ng/l) [(a)]	**Ave. MeHg Conc.** (ng/l)	**Annual Ave. Conc.** (ng/l) [(b)]	**Median MeHg Conc.** (ng/l)	**Max. MeHg Conc.** (ng/l)
Delta Mendota Canal	21	ND	0.062	0.064	0.061	0.171
State Water Project	20	ND	0.051	0.054	0.049	0.144
Outflow to San Francisco Bay (X2)	22	ND	0.075	0.083	0.070	0.241

(a) ND: below method detection limit.

(b) Sampling of these exports took place between March 2000 and September 2003. Methylmercury concentration data were pooled by month to estimate monthly average methylmercury concentrations and loads (Table F.1 in Appendix F); the monthly average loads were summed to estimate annual average methylmercury loads for water years 2000-2003. The monthly average concentrations were averaged to estimate annual average concentrations, which were included in Table 6.15.

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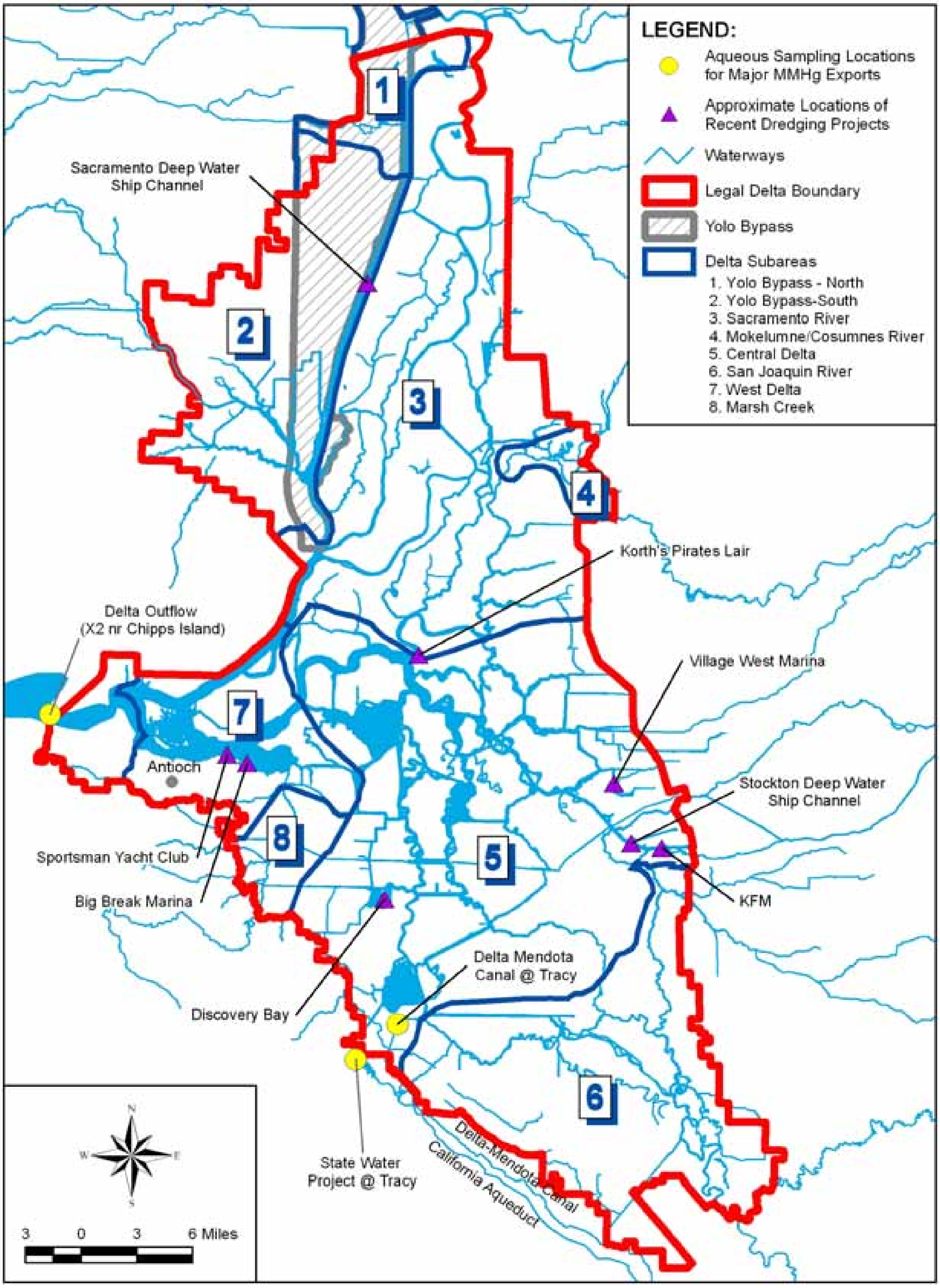

Figure 6.10: Aqueous Monitoring Locations for Major Methylmercury Exports and Approximate Locations of Recent Dredging Projects.

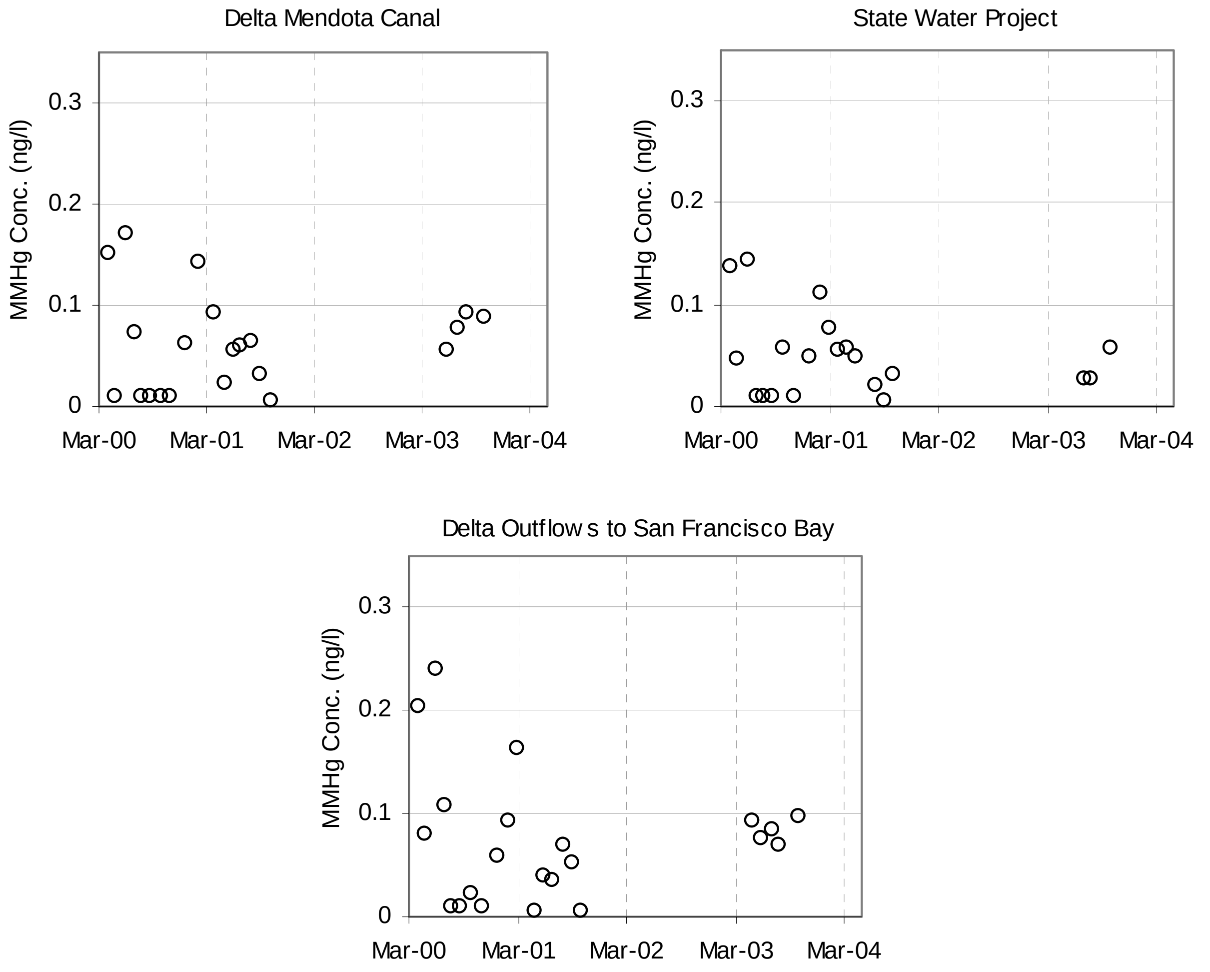

Figure 6.11: Available Methylmercury Concentration Data for the Delta's Major Exports

Table 6.17: Recent Dredge Projects within the Delta.

Delta Dredging Project	Project Location	Volume of Dredge Material (cubic yards)	Dredge Frequency	Disposal Location (upland, Delta island, wetland areas, etc.)	Mean Sediment Mercury Conc. (mg/kg, dry wt) [a]	# of Samples	Standard Dev.	T Value (p=0.975, conf 95%, df =n-1)	Total Weight of Mercury Removed (kg)	Annual Weight of Mercury Removed [a] (kg)	Annual Weight of Sediment Removed (Mkg, dry wt)	Annual Volume of Water Removed (acre-feet)	Does Effluent Return to a Receiving Water?	Average Effluent Hg Conc. (µg/l)
Sac. River Deep Water Ship Channel [b]	Sacramento River	199,000	Annually	Delta Island/ upland	0.37 ±3.93	2	0.4377	12.71	42	42 ±446 (n)	110.5	89.6	No	0.05 to 0.1
Stockton Deep Water Channel [c]	San Joaquin River	270,000	Annually	Delta Islands	0.083 ±0.023	28	0.0594	2.052	13	13 ±3.5	150.0	121.5	No	0.05 to 0.13
Village West Marina [d]	14-Mile Slough	70,000	Every 10 years	Delta Islands	0.043 ±0.014	3	0.0058	4.303	1.7	0.2 ±0.057	3.9	3.2	Yes [l]	0.05
KFM [e]	San Joaquin River	3,000	One time	Upland	*Unknown*						1.7	1.4	No	0.05
Korths Pirates Lair [f]	Mokelumne River	15,000	Every 5 years	Upland	0.15 ±0.11	2	0.0120	12.71	1.3	0.25 ±0.18	1.7	1.4	No	0.05
Big Break Marina [g]	San Joaquin River	12,000	Every 5 years	Upland	0.41 ±0.24	6	0.2318	2.571	2.8	0.55 ±0.33	1.3	1.1	No	0.25
Sportsman Yacht Club [h]	San Joaquin River	10,000	Every 5 years	Upland	0.12 ±0.014	3	0.0058	4.303	0.70	0.14 ±0.016	1.1	0.9	No	0.05
Discovery Bay [i]	Delta	50,000 [j]	Annually	Upland	0.027 ±0.018	7	0.0195	2.447	0.78	0.78 ±0.51	27.8	22.5	Yes [k, l]	0.05
Annual Averages [m]		**533,400 cubic yards**								**57 ±451 kg** [n]	**349 Mkg**	**241 a-ft**		

(a) The uncertainty of the mercury load values was estimated by calculating the 95% confidence interval for the mean of the concentration data for each project.
(b) U.S. Army Corps of Engineers, 2002 NOI (Notice of Intent) Sacramento DWSC.
(c) U.S. Army Corps of Engineers, 2000-2003 NOI Stockton DWSC.
(d) DCC Engineering Co, Inc., Village West Dredge Material Test, September 5, 2000.
(e) KFM, 401 Water Quality Certification.
(f) Anderson Engineers, 2003 Sediment Sampling and Analysis Plan for Korths Pirates Lair.
(g) Subsurface Consultants, Inc., Environmental Site Assessment 2001 & Aquifer Sciences, Inc., Pre-Dredge Sampling and Analysis Plan July 29, 2003.
(h) Padre Associates, Inc., Laboratory Analytical Results of Proposed Dredge Material and Associated Waste Classification May 23, 2003.
(i) Kennetic Laboratories/ToxScan, Inc., Sediment Properties and Chemistry April 2002, Discovery Bay, 2003 Final Water Quality Monitoring Report, WDR Order No. R5-2003-0027.
(j) Discovery Bay assumptions: The initial dredge project was 153,000 cubic yards, and 50,000 cubic yards/year thereafter. Therefore, assume 50,000 cy/year.
(k) WDR Order N. R5-2003-0027 indicates effluent returned to Discovery Bay averaged 3 mgd for several days to several weeks; staff assumed discharge period is 14 days/year.
(l) Two dredging projects, Village West Marina and Discovery Bay, had effluent that returned to Delta waters. The volume of effluent returned to receiving waters by the Discovery Bay project was approximately 42 million gal/year. The volume of effluent returned by the Village West Marina project is unknown. Staff estimated that the annual weight of mercury returned by the Discovery Bay dredge effluent was 0.008 kg, assuming that all water was returned.
(m) Annual averages do not include KFM, a one-time project.
(n) The uncertainty associated with the amount of mercury removed by dredging in the Sacramento Deep Water Ship Channel is particularly substantial (±446 kg), as a consequence of its calculation being based on only two sample results (0.68 and 0.061 mg/kg mercury) that have a tenfold range.

Table 6.18: MeHg:TotHg in Deep Water Ship Channel Surficial Sediments

	MeHg Conc. (ng/g)	**TotHg Conc.** (ng/g)	**MeHg:TotHg Ratio**
Sacramento Deep Water Ship Channel (a)			
Sacramento River DWSC	0.49	194.70	0.0025
Stockton Deep Water Channel (a)			
Little Connection Slough	0.20	82.51	0.0024
Headreach Cutoff	1.86	89.46	0.0208
Port of Stockton Turnabout #1	0.32	193.78	0.0017
Port of Stockton Turnabout #2	0.32	130.30	0.0025
		AVERAGE RATIO:	**0.006**

(a) Source: Heim *et al.*, 2003. Latitude/longitude coordinates provided with the above samples indicated that these were collected within the dredged deep water ship channels.

6.4 Delta Methylmercury Mass Budget & East-West Concentration Gradient

Figure 6.12 illustrates the Delta's average daily methylmercury imports and exports based on the annual loads presented in Tables 6.2 and 6.15. *In situ* sediment production and tributary water bodies account for about 35 and 58%, respectively, of methylmercury inputs to the Delta during the relatively dry WY2000-2003 period. Agricultural return flow and NPDES-permitted wastewater treatment plants contribute about 6% of the load while runoff from urban areas within the Delta/Yolo Bypass contributes about 0.4%.

The difference between the sum of known inputs and exports is a measure of the uncertainty of the loading estimates and of the importance of other unknown processes at work in the Delta. As noted in Section 6.2, the sum of WY2000-2003 water imports and exports balances within approximately 5%, indicating that all the major water inputs and exports have been identified. In contrast, the methylmercury budget does not balance. Average annual methylmercury inputs and exports were approximately 14.3 g/day (5.2 kg/yr) and 6.7 g/day (2.5 kg/yr), respectively (Tables 6.2 and 6.15 and Figure 6.12). Exports are only about 50% of inputs, suggesting that the Delta acts as a net sink for methylmercury.

A special study was conducted in the summer of 2001 to ascertain the location where much of the decrease in methylmercury occurred (Foe, 2003). Three transects were run down the Sacramento River and out toward San Francisco Bay, the water path from the main tributary source (Sacramento River) to the main export of methylmercury (Suisun Bay). The largest decrease in concentration consistently occurred in the vicinity or immediately downstream of Rio Vista (Figure 6.13). The drop in concentration was between 30 and 60%. Later studies funded by CalFed showed that losses from photodegradation and settling of methylmercury bound to particulates are of sufficient magnitude to explain the methylmercury decrease across the Delta (Gill, 2008a; Stephenson and Bonnema, 2008). For example, as described in the previous section, preliminary photodegradation study results for the Sacramento River near Rio Vista indicate relative surface water photodegradation rates of about 30% of the dissolved methylmercury per day at the top half meter of water (Byington *et al.*, 2005). Extrapolating the methylmercury photodegradation rate of 2.5 g/day from the 2008 CALFED studies, photodegradation could account for about 30% of the 7.6 g/day loss rate illustrated in Figure 6.12. As described in the draft Basin Plan Amendment staff report, staff recommends that a control program review take place after additional Delta-specific studies are completed, during which the TMDL source analysis can be updated.

The methylmercury budget in Figure 6.12 was created using data collected in a relatively dry period. After development and scientific peer review of the TMDL source analysis were completed, additional CalFed-funded studies of methylmercury in the Delta were completed. These studies added to our knowledge of methylmercury loads from various sources during a wetter period, quantified losses through photodegradation and particle deposition, and estimated methylmercury loads in several tidal and non-tidal wetlands (Stephenson *et al*., 2008). Staff will use data from the recent CALFED studies and other studies to revise the methylmercury source analyses for each Delta subarea as part of the program review at the end of the first phase of Delta TMDL implementation. Although some methylmercury load estimates may change with incorporation of data from the 2008 CALFED reports, the first implementation activities (methylmercury control studies and total mercury reductions) proposed for the control program (see Chapter 4 in the draft Basin Plan Amendment staff report) would not change. Stakeholders participating in Stakeholder Group meetings in 2009 accepted this approach to using data that became available after the TMDL was developed.

Stephenson, Foe, and colleagues developed a revised methylmercury budget for the Delta, based on Figure 6.12 (Foe *et al*., 2008). In their revised budget, tributaries provided a greater percentage of the methylmercury loads and wetlands and open water provided lower percentages than shown in Figure 6.12. The recent CALFED data were collected in a period of greater runoff and flows, so it is not surprising that tributary loads are larger and provide a greater proportion of total loading to the Delta. Other important differences between the TMDL budget in Figure 6.12 and the 2008 CALFED study budget include:[36]

- In the TMDL, the Yolo Bypass is part of the TMDL area, so its methylmercury loads are part of the within Delta/Yolo Bypass calculations. In the 2008 CALFED study budget, the Yolo Bypass is treated as a tributary to the Delta (that is, the tributary area is defined to be upstream of Prospect Slough), which has a substantial effect on the CalFed mass budget for a couple reasons:
    - The 2008 CalFed study found that *in situ* methylmercury production within the Yolo Bypass averaged 40% of the methylmercury loading to the Delta from the entire Sacramento Basin when the bypass was inundated (Stephenson *et al*., 2008). As a result, considering this area to be "tributary" versus "within Delta/Yolo Bypass" causes a substantial increase in the tributary input load.
    - Nearly half of all wetlands in the Delta/Yolo Bypass are in the Yolo Bypass (see Figure 6.4 and Table 6.4). Classifying the Yolo Bypass (and its wetlands) as a tributary area causes a substantial reduction in loading attributed to within-Delta wetlands.

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[36] Differences were identified by review of the 2008 study reports and through personal communications in 2008 between Michelle Wood (Environmental Scientist, Central Valley Water Board) and several of the study authors: Chris Foe (Environmental Scientist, Central Valley Water Board), Wes Heim (Research Associate, Moss Landing Marine Laboratories), and Mark Stephenson (Director, Marine Pollution Studies, California Department of Fish and Game, Moss Landing Marine Laboratories).

- The 2008 CALFED studies produced separate methylmercury flux rates for tidal, non-tidal seasonal, and non-tidal permanent wetlands. All of the newer flux rates estimated by the recent CalFed studies are lower than the flux rate determined from the initial Twitchell Island study data used in the TMDL wetland load calculations.
- The 2008 CALFED budget authors did not include non-tidal seasonal wetland acreage in their calculations. More than 30% of wetlands in the Delta downstream of Prospect Slough are non-tidal seasonal wetlands (USFWS, 2006). As a result, not including non-tidal seasonal wetland acreage reduced the load attributed to within-Delta wetlands.
- The methylmercury flux rate from open water in the 2008 CALFED budget is about half of the rate used in the TMDL budget. The TMDL budget is based on measurements taken in test chambers placed on Delta sediment (see section 6.2.2). The 2008 CALFED budget applies the flux rate from tidal wetlands to open water.
- Both budgets use the same total acreage of open water. However, to estimate methylmercury flux from open water sediment, the 2008 CALFED budget authors divided the open water acreage in half to account for sandy substrate. They assumed that sandy substrate would produce little methylmercury.

Key points for the methylmercury source analysis are listed after Figures 6.12 and 6.13.

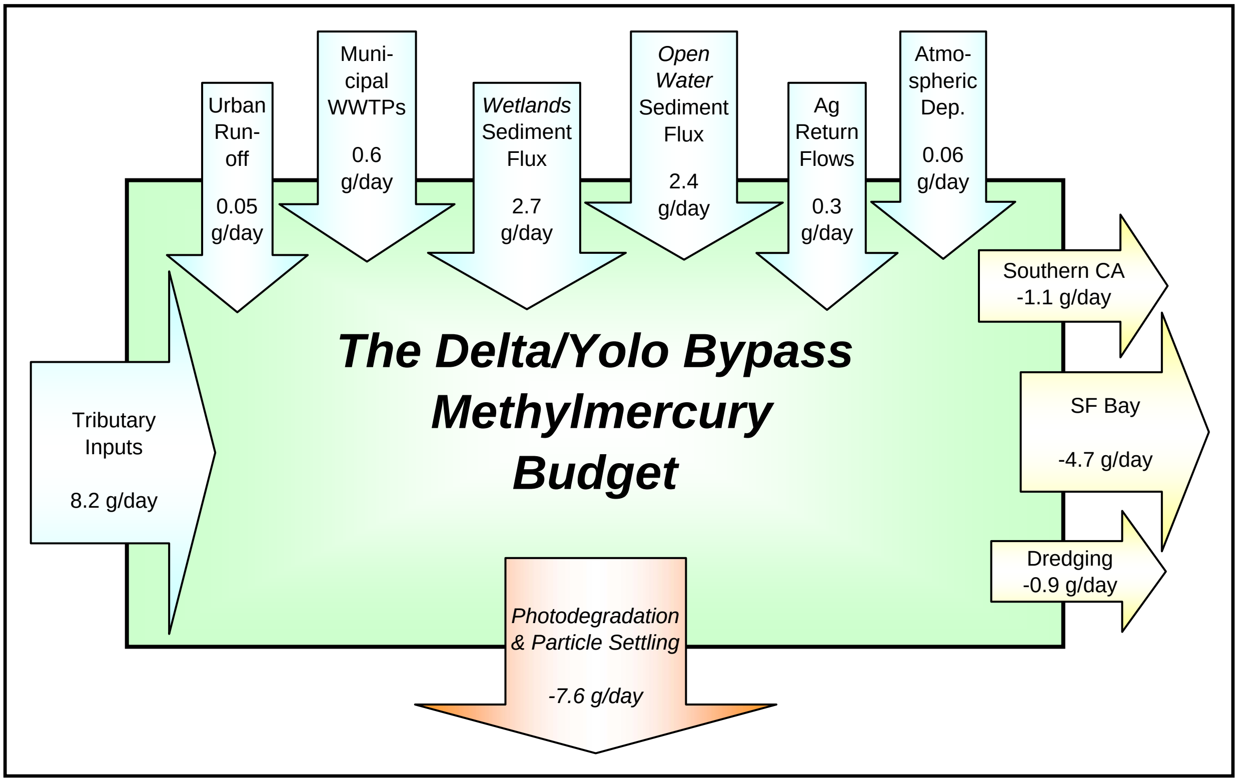

Figure 6.12: Average Daily Delta/Yolo Bypass Methylmercury Inputs and Exports. The rate of unidentified loss processes was determined by subtracting the sum of the inputs from the sum of the exports.

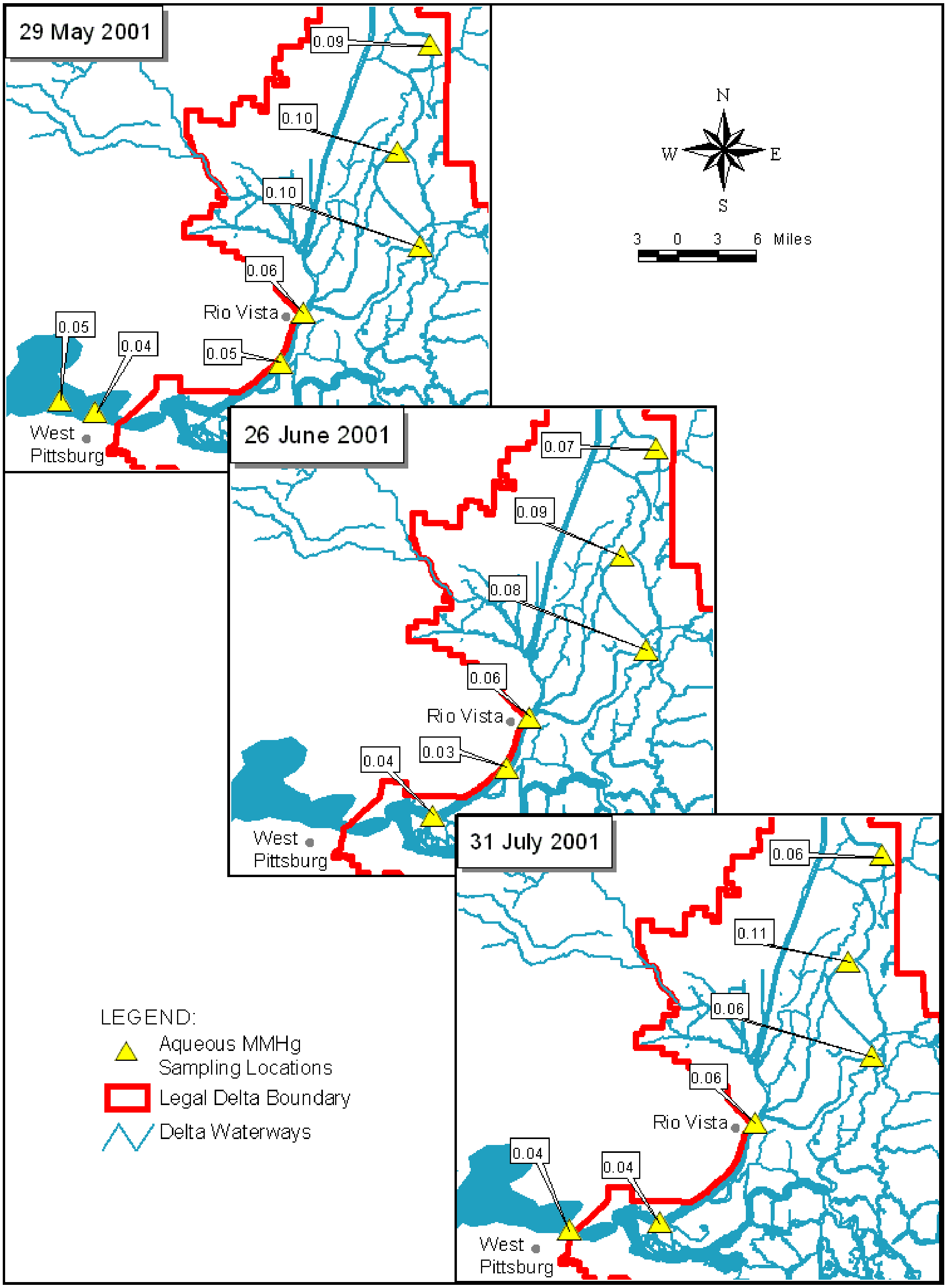

Figure 6.13: Water Sampling Transects down the Sacramento River to Ascertain Location of Methylmercury Concentration Decrease. Westernmost sampling stations changed with each transect depending on the locations of 1 o/oo through 5 o/oo bottom salinities, which move as a function of tidal cycle and freshwater inflow. (Data source: Foe, 2003.)

Key Points

- Sources of methylmercury in the Delta/Yolo Bypass include tributary inflows from upstream watersheds and within-Delta/Yolo Bypass sources such as methylmercury flux from sediment in wetland and open water habitats, municipal and industrial wastewater, agricultural drainage, and urban runoff. During the relatively dry WY2000-2003 period, approximately 58% of identified methylmercury loading to the Delta comes from tributary inputs while within-Delta sources account for approximately 42% of the load.
- Losses include water exports to southern California, outflow to San Francisco Bay, removal of dredged sediments, photodegradation, sedimentation, and uptake by biota. .
- The sum of WY2000-2003 water imports and exports balances within approximately 5%, and the sum of WY2000-2003 water imports and exports balances within approximately 1%, indicating that all the major water inputs and exports have been identified. In contrast, the methylmercury budget does not balance. A comparison of the sum of identified inputs (5.2 kg/yr) and exports (2.5 kg/yr) indicates that there is an additional loss term of approximately 50%. Data collected after the TMDL source analysis was completed indicate that methylmercury degradation by sunlight and settling of particle-bound methylmercury could account for the loss.

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7 SOURCE ASSESSMENT – TOTAL MERCURY & SUSPENDED SEDIMENT

Sources and losses of total mercury and suspended sediment are described in this chapter. The Delta mercury TMDL program addresses total mercury in addition to methylmercury because:

- Methylmercury production has been found to be a function of the total mercury content of the sediment (Chapter 3), and decreasing total mercury loads may be an option for controlling methylmercury;
- The mercury control program for the Delta must maintain compliance with the USEPA's CTR criterion of 50 ng/l for total recoverable mercury for freshwater sources of drinking water developed for human protection; and
- The mercury TMDL for San Francisco Bay assigns a total mercury load reduction to the Central Valley watershed to protect human and wildlife health in the San Francisco Bay (Johnson and Looker, 2004; SFBRWQCB, 2006). The San Francisco Bay mercury control program approved by the State Water Board requires a reduction of 110 kg/yr of mercury from all sources entering the Delta or in water moving past Mallard Island. Meeting the San Francisco Bay goal will require a quantitative understanding of mercury and sediment loads entering and leaving the Delta.

Sections 7.1 and 7.2 describe mercury and suspended sediment concentrations (measured as total suspended solids, or TSS) for Delta sources and sinks and identify major data gaps and uncertainties. Input and loss loads were calculated for WY2000-2003, a relatively dry period corresponding to the available methylmercury data. In addition, the WY1984-2003 period was evaluated to determine mass balances for a more typical hydrologic period. This 20-year period includes a mix of wet and dry years that is statistically similar to what has occurred in the Sacramento Basin since accurate water records began to be collected (about 100 years). An assessment of mass balances during a typical distribution of wet and dry water years is critical because transport of sediment and mercury is a function of water velocity and volume.

Section 7.3 presents the total mercury and suspended sediment mass budgets based on the input and export loads described in Sections 7.1 and 7.2. Section 7.4.1 reviews the mercury-to-TSS ratio (TotHg:TSS) for each input and export site to identify areas that may be the focus of future remediation efforts to reduce total mercury loading. Finally, Section 7.4.2 evaluates compliance with the CTR.

7.1 Total Mercury and Suspended Sediment Sources

The following were identified as sources of total mercury and suspended sediment to the Delta: tributary inflows from upstream watersheds, municipal wastewater, atmospheric deposition, and urban runoff. Table 7.1 lists the estimated loads associated with each source for WY2000-2003 and WY1984-2003.

Table 7.1: Average Annual Total Mercury and TSS Source Loads for WY2000-2003 and WY1984-2003.

	WY2000-2003				**WY1984-2003**			
	TotHg		**TSS**		**TotHg**		**TSS**	
	kg/yr ± 95% CI	% of All Inputs	Mkg/yr ± 95% CI	% of All Inputs	kg/yr ± 95% CI	% of All Inputs	Mkg/yr ± 95% CI	% of All Inputs
Tributary Inputs (a, b)								
Sacramento River	146 ±1	66%	689 ±7	64%	183 ±1	45%	865 ±7	40%
Prospect Slough	37 ±1	17%	197 ±5	18%	169 ±5	42%	1,014 ±31	47%
San Joaquin River	18 ±2	8.2%	138 ±23	13%	29 ±4	7.2%	223 ±37	10%
Calaveras River	3.8 ±2	1.7%	15 ±21	1.4%	4.1 ±2	1.0%	16 ±23	0.7%
Mokelumne-Cosumnes Rivers	2.8 ±0.6	1.3%	7.7 ±2	0.7%	4.6 ±1	1.1%	12 ±3	0.6%
Ulatis Creek	2.1 ±2	1.0%	16 ±19	1.5%	2.2 ±2	0.5%	17 ±19	0.8%
French Camp Slough	1.6 ±3	0.7%	2.3 ±2	0.2%	1.7 ±3	0.4%	2.4 ±2	0.1%
Morrison Creek	0.79 ±0.2	0.4%	4.3 ±2	0.4%	0.83 ±0.2	0.2%	4.5 ±2	0.2%
Marsh Creek	0.54 ±0.01	0.3%	1.1 ±11	0.1%	0.54 ±0.01	0.1%	1.1 ±11	0.1%
Bear/Mosher Creeks	0.29 ±0.2	0.1%	2.4 ±5	0.2%	0.30 ±0.2	0.1%	2.4 ±5	0.1%
Sum of Tributary Sources:	**213 ±4**	**97%**	**1,073 ±28**	**99%**	**395 ±7**	**98%**	**2,157 ±51**	**>99%**
Inputs within the Delta/Yolo Bypass								
Wastewater	2.5	1.1%			2.5	0.6%		
Urban	2.3	1.1%	7.5	0.7%	2.4	0.6%	7.8	0.4%
Atmospheric (Indirect)	1.5	0.7%			1.5	0.4%		
Atmospheric (Direct)	0.81	0.4%			0.84	0.2%		
Sum of Within-Delta Sources:	**7.1**	**3%**	**7.5**	**1%**	**7.2**	**2%**	**7.8**	**<1%**
TOTAL INPUTS:	**220 ±4**		**1,080 ±28**		**402 ±7**		**2,165 ±51**	

(a) Confidence intervals (CI) were calculated for the average annual loads for inputs with daily flow data. See Appendix I for the calculation methods.

(b) Total mercury and TSS concentrations are not available for several small drainages to the Delta, including the following areas shown on Figure 6.1: Dixon, Upper Lindsay/Cache Slough, Manteca-Escalon, Bethany Reservoir, Antioch, and Montezuma Hills areas.

7.1.1 Tributary Inputs

During WY2000-2003, tributaries to the Delta contributed approximately 97% of the mercury and 99% of the suspended sediment (Table 7.1). The Sacramento Basin alone (Sacramento River at Freeport + Yolo Bypass) contributed more than 80% of all mercury and TSS loads. The load estimates in Table 7.1 are based on the water volumes described in Section 6.1 and Appendix E and concentration data collected by several agencies provided in Appendix L.

Central Valley Water Board staff began evaluating mercury loads from the Sacramento River watershed and Yolo Bypass in 1994 (Foe and Croyle, 1998). From March 2000 to September 2001, staff conducted monthly sampling at the Delta's four major tributary input sites (Foe, 2003): Sacramento River; San Joaquin River; Mokelumne River (downstream of the Mokelumne/Cosumnes Rivers confluence); and Prospect Slough at Toe Drain in the Yolo Bypass. In addition, other programs conducted periodic aqueous sampling between 1993 and 2003 on the Sacramento River (SRWP, 2004; CMP, 2004; Stephenson *et al.*, 2002). Central Valley Water Board staff resumed sampling in April 2003. Figure 6.2 shows the tributary monitoring locations. Table 7.2 and Figures I.1 through I.6 in Appendix I summarize the mercury and TSS data available at the time the TMDL was developed.

Sections 7.1.1.1 through 7.1.1.3 describe the methods used to estimate the loads for the Delta's tributary watersheds and identify uncertainties. Because the Sacramento Basin is the primary source of mercury to the Delta, Section 7.1.1.3 provides an analysis of loading from major upstream Sacramento River tributaries. This information may be valuable for designing follow-up studies to determine where to implement mercury control programs.

7.1.1.1 Sacramento Basin Inputs to the Delta

Sacramento Basin mercury and TSS discharges to the Delta were determined for the Sacramento River at Freeport and the Yolo Bypass at Prospect Slough. Mercury and TSS concentrations for the Sacramento River at Freeport were regressed against Freeport flow to determine if a relationship might exist. Both regressions were statistically significant ($P< 0.01$) indicating that it is possible to predict Sacramento River mercury and TSS concentrations from flow. The mercury/flow and TSS/flow equations were used to predict average annual loads. [37,38] The methods used to calculate the 95% confidence intervals are described in Appendix I. The average annual load for the Sacramento River was 146 kg mercury and 689 Mkg TSS for WY2000-2003, and 183 kg mercury and 865 Mkg TSS for WY1984-2003 (Table 7.1).

Prospect Slough is a major channel draining the Yolo Bypass. Total mercury and TSS samples were collected in Prospect Slough during outgoing tides. Mercury and TSS concentrations observed on dates with net outflow were regressed against daily outflows at Lisbon Weir lagged by one day[39] to determine if statistically significant correlations might exist (Section E.2.2 in Appendix E and Figure I.1 in Appendix I). Extremely high mercury and TSS concentrations were measured on 10 and 11 January 1995 (Figure I.1). These values were not included in the regressions because, as described in Section E.2.2, the hydrologic conditions that caused them appear to have occurred only once during the WY1984-2003 study period. The TotHg/flow and TSS/flow regressions for Prospect Slough were significant ($P< 0.01$, Figure I.7a and I.7b), indicating that the concentrations of both constituents could be predicted from flow. The

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[37] For all tributaries with statistically significant TotHg/flow or TSS/flow relationships, the predicted concentrations were multiplied by daily flow volumes to estimate daily loads. The estimated daily loads were summed and then divided by the number of years in the study period to estimate the average annual loads for WY2000-2003. If a flow record had dates with missing values, the data were normalized to estimate annual loads. For example, a 20-year record would be normalized by dividing 7305 (the number of days in the 20-year period) by the number of days with a recorded value in the flow record and then multiplying the resulting quotient by the calculated sum of loads; the result was then divided by 20 to obtain the average annual load.

[38] The Delta area that drains to the 13-mile reach of the Sacramento River between Freeport (near river mile 46) and the I Street Bridge (the northernmost legal Delta boundary, near river mile 59) is predominantly urban and is encompassed by the urban load estimate described in Section 5.2.5. No attempt was made to subtract this area from the Sacramento River watershed load estimate. Therefore, the Sacramento River load noted in Table 7.1 incorporates a small portion of the within-Delta urban runoff loading.

[39] The estimated daily flows from Lisbon Weir on Toe Drain were lagged one day to address the approximate residence time of water along the ~15 miles between Lisbon Weir and Prospect Slough. During drier years, there may be little-to-no net outflow from the Yolo Bypass's Toe Drain downstream of Lisbon Weir between April and November. (See Appendix E for a description of Yolo Bypass hydrology.) Therefore, although sampling of Prospect Slough took place during outgoing tides with the intent of sampling outflows from the Yolo Bypass, during the summer months this sampling most likely represents waters tidally-pumped northward from Cache Slough, rather than outflows from the Yolo Bypass north of Lisbon Weir.

regressions were used to estimate annual average loads of 37 kg mercury and 197 Mkg TSS for WY2000-2003 and 169 kg mercury and 1,014 Mkg TSS for WY1984-2003 (Table 7.1). The five-fold increase in loads during the wetter WY1984-2003 years illustrates the importance of basing load calculations on the long-term average hydrology of the basin.

Other studies that have evaluated mercury and sediment loads from the Sacramento Basin are summarized in Table 7.3. The Sacramento watershed is the major source of water, mercury, and sediment to the Delta. The results confirm that export from the watershed is strongly a function of water year type. The lowest mercury export rate occurred during the driest study period (94.8 kg/yr; Foe 2003), while the highest (801 kg/yr; Foe and Croyle, 1998) was during a very wet period. Most annual loading rates fall between 200 and 500 kg of mercury per year.

The WY1984-2003 mercury-loading rate of 349±7 kg/yr is midway between these values. The most comparable study is likely that of LWA (2002), which estimated an export rate of 306 kg/yr of mercury for another relatively similar 20-year hydrologic period. The difference between the two 20-year periods, while statistically significant, is only about 10%. Interestingly, the Sacramento River is the primary source of mercury to the Delta during dry years, but exports from the Yolo Bypass increase and become comparable to Sacramento River loads during wet periods.

Sediment transport is also strongly a function of water year type (Table 7.3). The smallest export rate occurred during the driest period studied (568 Mkg/yr, Foe, 2003), while the highest rate happened during a wet year (3,900 Mkg/yr, Foe and Croyle, 1998). The WY1984-2003 sediment export rate of 1,894 ±32 Mkg/yr is among the higher reported. The importance of the Yolo Bypass, like for mercury, is strongly a function of flow. The Bypass only exports a small amount of sediment during dry periods, but loads increase and equal or exceed those of the Sacramento River during wet periods.

The sediment yield of the Sacramento Basin is reported to have declined by about 50% since 1957 (Wright and Schoellhamer, 2004). Primary causes are believed to be the reduced supply of erodible material since cessation of hydraulic mining and increased trapping of sediment in reservoirs. Therefore, future Sacramento Basin mercury and sediment export rates may be different than those computed with the present rating curves.

Table 7.2: Total Mercury and TSS Concentrations for Tributary Inputs

Site (a)	# of Samples	Sampling Begin Date	Sampling End Date	Min. Conc.	Ave. Conc.	Median Conc.	Max. Conc.
TOTAL MERCURY CONCENTRATIONS (ng/l)							
Bear/Mosher Creeks (b)	4	3/15/03	2/26/04	3.55	8.08	8.70	11.36
Calaveras River @ RR u/s West Lane (b)	4	3/15/03	2/26/04	13.23	20.53	21.34	26.22
French Camp Slough near Airport Way	5 [4]	7/11/00	2/26/04	1.73 [3.32]	16.75 [20.5]	4.71 [11.63]	55.42 [55.42]
Marsh Creek @ Hwy 4	19 [3]	11/05/01	2/02/04	0.93	7.34	4.36	30.18
Mokelumne River @ I-5	21	3/28/00	9/30/03	0.26	5.34	5.19	12.28
Morrison Creek (c)	47 [15]	4/09/97	1/28/02	1.62 [3.9]	7.96 [10.46]	7.23 [9.12]	19.75 [19.75]
Prospect Slough (Yolo Bypass) (d)	28 [26]	1/10/95	9/30/03	10.58	73.22 [30.80]	26.70 [25.73]	695.6 [92.2]
Sacramento River @ Freeport	155	2/15/94	11/06/02	1.20	8.28	6.31	36.19
San Joaquin River @ Vernalis	34	10/29/93	2/26/04	3.12	7.99	7.33	21.73
Ulatis Creek near Main Prairie Rd	6 [4]	1/28/02	2/26/04	1.34 [24.21]	36.06 [53.24]	28.68 [52.51]	83.74 [83.74]
TSS CONCENTRATIONS (mg/l)							
Bear/Mosher Creeks (b)	4	3/15/03	2/26/04	15.8	65.8	24.1	199.1
Calaveras River @ RR u/s West Lane (b)	4	3/15/03	2/26/04	32.4	82.7	55.4	187.5
French Camp Slough near Airport Way	5 [4]	1/28/02	2/26/04	12.0 [16.7]	26.0 [29.5]	26.4 [27.5]	46.5 [46.5]
Marsh Creek @ Hwy 4	7 [2]	3/15/03	2/02/04	17.9 [36.9]	69.1 [155.0]	36.9 [155.0]	273.2 [273.2]
Mokelumne River @ I-5	23	3/28/00	9/30/03	5.8	14.5	12.0	31.0
Morrison Creek (c)	44 [15]	4/09/97	1/28/02	6.0 [7.0]	39.9 [57.0]	27.0 [40.5]	140 [140]
Prospect Slough (Yolo Bypass) (d)	26 [24]	1/10/95	9/30/03	36.6	298.4 [166.8]	143.2 [139.9]	2300.7 [512.7]
Sacramento River @ Freeport	187	12/15/92	1/20/04	<0.5	38.0	26.0	368.0
San Joaquin River @ Vernalis	29	3/28/00	2/26/04	20.0	61.1	56.0	170.8
Ulatis Creek near Main Prairie Rd.	6 [4]	1/28/02	2/26/04	2.5 [140.2]	276.5 [411.6]	217.8 [338.4]	829.6 [829.6]

(a) Flow gage data were not available for most of the small tributary outflows to the Delta. Therefore, wet weather concentration data (noted in brackets) and estimated wet weather runoff (Section E.2.3 in Appendix E) were used to develop load estimates.

(b) Only wet weather events were sampled on the Calaveras River and Bear and Mosher Creeks in Stockton. The one wet weather Mosher Creek sample result was combined with the Bear Creek data to estimate loads for both creeks (Appendix I).

(c) Concentration data collected at multiple sites on lower Morrison Creek were compiled to develop load estimates (Appendix I).

(d) Sampling took place at Prospect Slough (export location of the Yolo Bypass) both when there were net outflows from tributaries to the Yolo Bypass and when there was no net outflow (i.e., the slough's water was dominated by tidal waters from the south). The regression analysis focuses only on the conditions when there was net outflow from the Yolo Bypass. The above values do not include data collected when there was no net outflow. The values in parentheses are from calculations without the two very high values shown in Figure I.1. The regression is between total mercury concentrations observed at Prospect Slough (not including the two very high values shown in Figure I.1) and total export flows for the previous day estimated for Lisbon Weir, approximately 15 miles north of the Prospect Slough sampling station. The previous day's flow values were used to address the approximate residence time of the water as it travels through the Yolo Bypass to the export location where samples were collected.

Table 7.3: Comparison of Load Estimates for Sacramento Basin Discharges to the Delta

Study	Sampling Location	Period	Average Sacramento Valley Water Year Hydrologic Index (a)	Average Annual TotHg Load [± 95 CI] (kg)	Average Annual TSS Load [95% CI] (Mkg)
Sacramento River					
Delta Mercury TMDL (b)	Freeport	WY2000-2003	7.3	146 ± 1	689 ± 7
		WY1984-2003	7.8	183 ± 1	865 ± 7
Foe and Croyle (1998)	Greene's Landing	May 1994- April 1995	12.9	426	1,400
Foe (2003)	Greene's Landing	WY2001 (c)	5.8	91	526
LWA (2002)	Freeport	WY1980-1999	8.5	189 ± 2	na
Wright & Schoellhamer (2005)	Freeport	WY1999-2002	7.7	na	1,100 ± 170
Louie and others (2008)	Freeport	WY1984-2003	7.8	183 ± 2	959 ± 6
Yolo Bypass					
Delta Mercury TMDL	Prospect Slough	WY2000-2003	7.3	37 ± 1	197 ± 5
		WY1984-2003	7.8	169 ± 5	1,014 ± 31
Foe and Croyle (1998)	Prospect Slough	May 1994- April 1995	12.9	375	2,500
Foe (2003)	Prospect Slough	WY2001 (c)	5.8	3.8	42
LWA (2002)	Woodland	WY1980-1999	8.5	118 ± 17	na
Wright & Schoellhamer (2005)	Woodland	WY1999-2002	7.7	na	310 ± 130
Louie and others (2008)	Prospect Slough	WY1984-2003	7.8	168 ± 4	1,107 ± 25
Sacramento Basin Total (Sacramento River + Yolo Bypass)					
Delta Mercury TMDL		WY2000-2003	7.3	183 ± 1	886 ± 9
		WY1984-2003	7.8	352 ± 5	1879 ±31
Foe and Croyle (1998)		May 1994- April 1995	12.9	801	3,900
Foe (2003)		WY2001 (c)	5.8	94.8	568
LWA (2002)		WY1980-1999	8.5	306	na
Wright & Schoellhamer (2005)		WY1999-2002	7.7	na	1,410 ± 300
Louie and others (2008)		WY1984-2003	7.8	351	2,066
Domagalski (2001) (d) 3 winter seasons, 20 December to 20 March		WY1997	10.8	487	na
		WY1998	13.3	506	na
		WY1999	9.8	169	na

(a) Source: DWR, 2006 (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST). DWR calculated a hydrologic index for the Sacramento Valley (Section E.1 in Appendix E). "Normal" hydrologic conditions for the Sacramento Valley are represented by an index value of 7.8, "wet" ≥9.2, "dry" 5.4 to 6.5, and "critical dry" ≤5.4. Figure E.1 in Appendix E illustrates the indices for each water year for the period of record.

(b) See Appendix I for the methods used to estimate the 95% confidence intervals (CI) for the TMDL load estimates.

(c) Foe's 2003 CALFED study estimated monthly total mercury and TSS loads for March 2000 through September 2001, but did not include load estimates for November 2000. November total mercury and TSS loads for WY2001 were estimated by averaging the loads for October and December 2000.

(d) Domagalski (2001) reported winter mercury loads from the Sacramento Basin for WY1997 through 1999 based on data collected at Sacramento River at Freeport and Yolo Bypass at Interstate 80 (upstream of Putah Creek inputs), but did not report individual loads for the Sacramento River and Yolo Bypass.

7.1.1.2 Other Tributary Inputs to the Delta

The TotHg/flow and TSS/flow regressions for the Mokelumne-Cosumnes and San Joaquin Rivers were not significant ($P > 0.05$). Therefore, average mercury and TSS concentrations (Table 7.2) were multiplied by average annual water volumes for WY2000-2003 and WY1984-2003 (Table 6.1) to estimate an average annual load. The Mokelumne River has an estimated average annual load of 3 kg mercury and 8 Mkg TSS for WY2000-2003 and 5 kg mercury and 12 Mkg TSS for WY1984-2003 (Table 7.1). Similarly, the San Joaquin River has an average annual load of 18 kg mercury and 138 Mkg TSS and 29 kg mercury and 223 Mkg TSS, for WY2000-2003 and WY1984-2003, respectively.

Several other studies have estimated mercury and sediment loads from the San Joaquin and Mokelumne-Cosumnes watersheds (Table 7.4). The studies confirm that mercury loads from both basins are much smaller than from the Sacramento Basin (Table 7.3). Annual mercury loads for the San Joaquin reported at the time the TMDL was developed ranged from 16 to 29 kg/yr. The WY1984-2003 mercury load is 29 ±4 kg/yr. This value is statistically similar to 20-year loads calculated by LWA (2002) and Louie and others (2008) of 26 kg/yr and 28.3 ±3.0 kg/yr, respectively. Louie and others 2008 CalFed study completed since the TMDL was developed incorporated additional data collected during wet periods; inclusion of more data did not substantially change the load estimate for the San Joaquin River.

The TMDL's WY1984-2003 load estimate for the Mokelumne River downstream of its confluence with the Cosumnes River is based on data available at the time the TMDL was developed and is 5 ±1 kg/yr. The WY1980-1999 LWA (2002) estimate is 3 kg/yr for the Mokelumne River downstream of the Cosumnes River confluence. The recent CalFed study that incorporated additional data collected during wet periods (Louie *et al*., 2008) estimated 20-year average annual loads of 1.8 ±0.08 kg/yr for the Mokelumne River and 12.4 ±0.8 kg/yr for the Cosumnes River, upstream of their confluence.

Sediment export rates (Table 7.4) are also much smaller for both the San Joaquin and Mokelumne-Cosumnes systems than for the Sacramento Basin (Table 7.3). The TMDL's export rates for the San Joaquin varied between 110 and 240 Mkg/yr. The Mokelumne-Cosumnes sediment yield is lower. The 20-year TMDL value is 12±3 Mkg/yr. The recent CalFed study that incorporated additional data collected during wet periods (Foe *et al*., 2008) estimated 20-year average annual loads of 8.4 ±0.2 kg/yr for the Mokelumne River and 48.0 ±3.2 kg/yr for the Cosumnes River, upstream of their confluence.

Louie and others (2008) noted that, although the Cosumnes and Mokelumne Rivers have adjacent watersheds with similar average annual water budgets and both watersheds have histories of hydraulic gold mining, there are several watershed characteristics that could explain why the Cosumnes River discharges six times more mercury and sediment to the Delta than does the Mokelumne River. Louie and others (2008) identified the following:

- The Mokelumne River has two major upstream impoundments (Camanche and Pardee Reservoirs), whereas the Cosumnes River has none. It is likely that some of the material being transported by the Mokelumne is deposited in upstream reservoirs and does not make it downstream to the Delta. Louie and others' study did not include sampling for the reservoirs on the Mokelumne River.

- The Cosumnes River is the largest river on the west-slope Sierra Nevada mountains without a major dam (Booth *et al*., 2006), allowing unimpaired downstream movement of storm runoff. For example, the maximum daily average flow for the Cosumnes River at Michigan Bar was 61,600 cfs during WY1984-2003, while the maximum daily average flow for the Mokelumne River at Woodbridge (below Camanche and Pardee Reservoirs) was only 5,240 cfs. Additionally, the return frequency of greater than 5,000 cfs for this 20-year period is 1 in 4 years for the Mokelumne River and 1 in 86 days for the Cosumnes River.
- The higher mercury and sediment yields from the Cosumnes are likely, at least in part, because the transport of both constituents is a function of water velocity (Foe and Croyle, 1998; Foe, 2003). Higher periodic flows on the Cosumnes may result in more mercury and suspended sediment transport.

Mercury and TSS loads for Marsh Creek were estimated using flow at the Marsh Creek Brentwood gage. The Brentwood gage was not operational during WY2000. Therefore, the mercury and TSS loads in Table 7.1 were based on flow data for WY2001-2003. A statistically significant relationship was found for mercury/flow but not for TSS/flow. Mercury concentrations and loads were estimated using the regression, while TSS loads were computed by multiplying the 3-year average annual water volume by the average TSS concentration. The WY2001-2003 annual average mercury and TSS loads were 1 kg/yr and 1 Mkg/yr, respectively.

There are no flow gages on several small east and westside Delta tributaries: Morrison Creek, Bear Creek, Mosher Creek, French Camp Slough, and Ulatis Creek. Average wet season mercury and TSS concentrations (Table 7.2) were multiplied by estimated average annual rainfall runoff volumes (Table 6.1 and Section E.2.2 in Appendix E) to calculate an average annual load. The WY1984-2003 estimate of mercury and suspended sediment yield from the combination of all these small tributaries is 5 ±2 kg/yr and 26 ±13 Mkg/yr, respectively (Table 7.1).

Table 7.4: Comparison of Loading Estimates for Other Major Delta Tributaries

Study	Period	Average San Joaquin Valley Water Year Hydrologic Index (a)	Average Annual TotHg Load [± 95% CI] (kg)	Average Annual TSS Load [± 95% CI] (Mkg)
San Joaquin River @ Vernalis				
Delta TMDL (b)	WY2000-2003	2.7	18 ± 2	138 ± 23
	WY1984-2003	3.1	29 ± 4	223 ± 37
Foe (2003)	WY2001 (c)	2.2	16	110
LWA (2002)	WY1980-1999	3.5	26	na
Wright & Schoellhamer (2005)	WY1999-2002	2.9	na	210 ± 21
Louie and others (2008)	WY1984-2003	3.1	28.3 ±3	236.9 ±29
Mokelumne River downstream of Cosumnes River Confluence				
Delta TMDL	WY2000-2003	2.7	3 ± 1	8 ± 2
	WY1984-2003	3.1	5 ± 1	12 ± 3
Foe (2003)	WY2001 (c)	2.2	2	5
LWA (2002)	WY1980-1999	3.5	3	na
Eastside Tributaries (Cosumnes, Mokelumne & Calaveras Rivers & French Camp Slough)				
Delta TMDL	WY2000-2003	2.7	8 ± 2	25 ± 13
	WY1984-2003	3.1	10 ± 2	30 ± 14
Wright & Schoellhamer (2005)	WY1999-2002	2.9	na	36 ± 8

(a) Source: DWR, 2006 (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST). DWR calculated a hydrologic index for the San Joaquin Valley (Section E.1 in Appendix E). "Normal" hydrologic conditions for the San Joaquin Valley are represented by an index value of 3.1, "wet" is ≥3.8, "dry" is 2.1 to 2.5, and "critical dry" is ≤2.1.

(b) See Appendix I for the methods used to estimate the 95% confidence intervals (CI) for the TMDL load estimates.

(c) Foe's 2003 CALFED study estimated monthly total mercury and TSS loads for March 2000 through September 2001, but did not include load estimates for November 2000. November total mercury and TSS loads for WY2001 were estimated by averaging the loads for October and December 2000.

7.1.1.3 Sacramento Basin Tributary Watersheds Loads

The Sacramento Basin accounts for about 80% of all mercury and TSS loading to the Delta (Table 7.1). Therefore, an evaluation was undertaken to determine the contribution of each of the major tributaries. The information may prove useful to help focus follow-up studies and implementation actions on key watersheds that contribute a disproportionate amount of mercury. During low flow, water in the Sacramento River at Freeport primarily originates from Shasta and Oroville Dams in the upper Sacramento and Feather River basins, respectively (Figure 7.1). In contrast, during large storms the Sacramento River at Freeport may be dominated by flows from the American and Feather Rivers. Storm overflow from the upper Sacramento River, Feather River, and Colusa Basin are routed down the Yolo Bypass. The Yolo Bypass also receives flows from Putah Creek and Cache Creek *via* the Cache Creek Settling Basin. The Cache Creek Settling Basin is located at the base of the Cache Creek watershed and currently captures about half of the sediment and mercury transported by Cache Creek (Foe and Croyle, 1998; CDM, 2004; Cooke *et al.*, 2004); untrapped sediment is flushed into the Yolo Bypass.

Four-year (WY2000-2003) and 20-year (WY1984-2003) average annual loading values were calculated for major tributaries to the Sacramento River. Table 7.5 summarizes the mercury and TSS concentration data. Table 7.6a, b, and c present watershed acreages, annual average export rates for water, mercury and TSS. The data were collected by the SRWP, DWR, USGS, CMP, and Central Valley Water Board staff (Appendix L). The water volume calculations are described in Appendix E. Appendix I provides time series plots of the available mercury and TSS data and TotHg/flow and TSS/flow regressions described in the following pages.

Total mercury and TSS concentrations for each tributary were regressed against flow to determine if correlations existed (Appendix I). The TotHg/flow and TSS/flow regressions for the American River, Cache Creek, Colusa Basin Drain, Feather River, Putah Creek and Sacramento River at Colusa were all significant ($P<0.05$) and were used to predict 4- and 20-year average annual loads (Table 7.6).

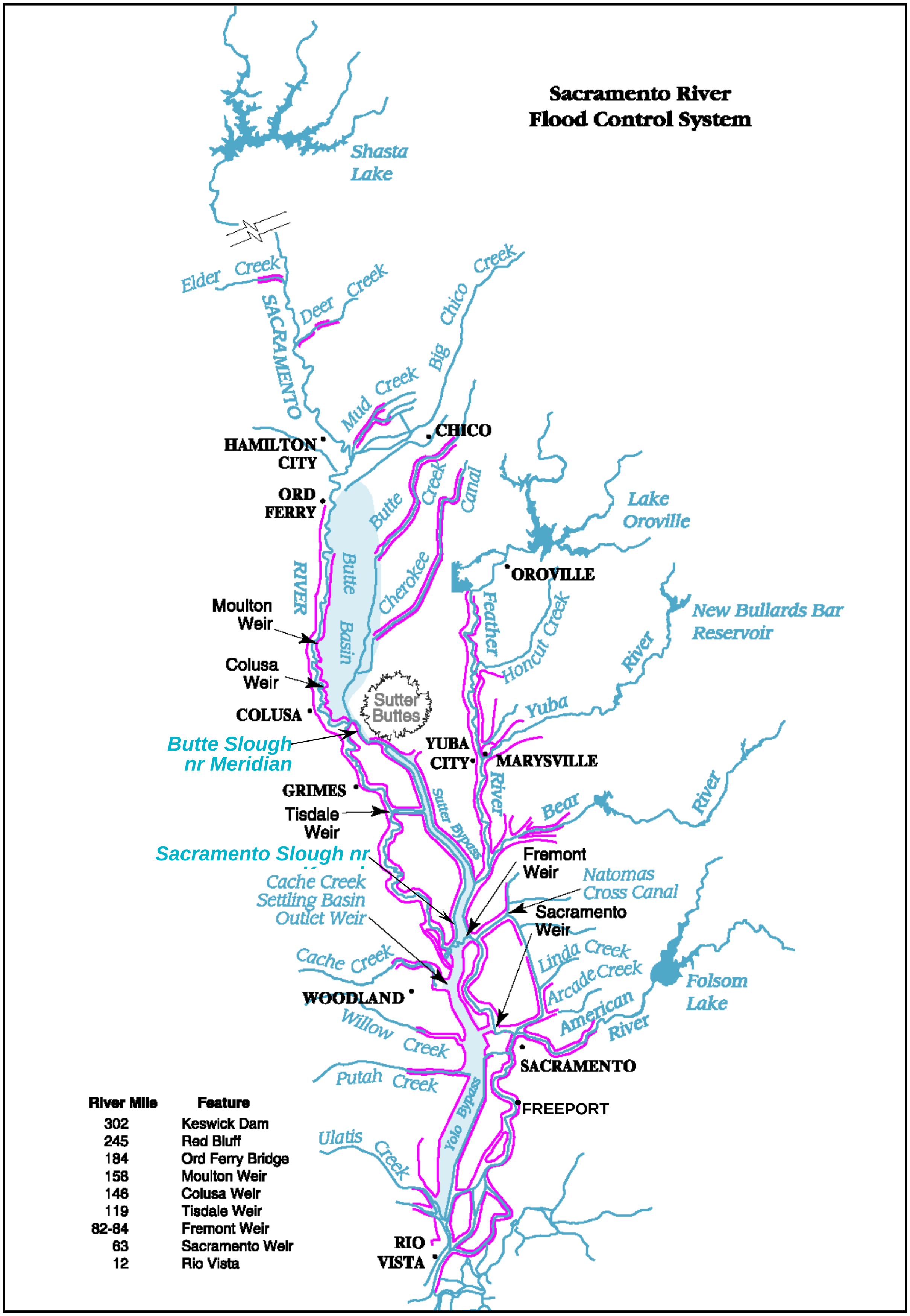
No daily flow or concentration data were available for Natomas East Main Drain (NEMD). Concentration data collected by the SRWP, USGS, and City of Roseville were available for Arcade Creek near Norwood, Del Paso Heights, and Dry Creek, all within the NEMD watershed. Wet weather concentration data for Arcade and Dry Creeks (noted in parentheses in Table 7.5) and estimated wet weather runoff for the entire Natomas East Main Drain watershed (Appendix E) were used to develop preliminary load estimates. The Sutter Bypass watershed includes the areas that drain into Butte Creek south of Chico and areas that drain into the Sutter Bypass between the Sacramento and Feather Rivers and south of the Sutter Buttes (Figure 7.1). In addition, flood flows from the Sacramento River upstream of Colusa are diverted into Sutter Bypass through the Moulton and Colusa bypasses; flood flows from the Sacramento River downstream of Colusa are diverted into the Sutter Bypass through the Tisdale bypass; and flood flows from the Feather River flow into the Sutter Bypass.

Floodwaters from the Sacramento River also spill at several locations into the Butte Creek basin and Butte Sink, which drain to Sutter Bypass. During low flow conditions, the Sutter Bypass drains through Sacramento Slough near Karnak into the Sacramento River less than a mile upstream of the Feather River confluence. During high flow, the Sacramento Slough channel is submerged and the Sutter Bypass has unchannelized flow directly into the Sacramento River. Sutter Bypass average annual water volumes and loads (Table 7.6) were estimated using flows from the DWR gage on Butte Slough near Meridian. The bypass at this location includes flows from Butte Creek and diversions from the Sacramento River made by Moulton and Colusa Weirs (which are upstream of the “Sacramento River above Colusa” sampling station), but not Tisdale Weir or other sources that discharge to the bypass downstream of Meridian. The WY1998-2003 flows were used to estimate long-term average mercury and TSS loads from Sutter Bypass, as only flows for these years are available for the Meridian gage. WY1998-2003 represents a relatively wetter period than the WY1984-2003, hence these load estimates may overestimate the Sutter Bypass contribution to the Delta.

Total mercury and TSS concentration data were available for the Sutter Bypass at Sacramento Slough near Karnak, about 30 miles downstream of the Meridian flow gage. The data were collected between February 1996 and September 2003 during a range of flow conditions, including when Sacramento Slough was submerged. There is a flow gage located nearby; however, it was operational only during the WY1996-1998 period. In addition, it was not rated for flows above 5,200 cfs (Figure 7.2); flows exceeded the 5,200 cfs rating curve happened for extended periods during each year. Therefore, the TotHg/flow and TSS/flow regressions for Sacramento Slough are based only on the samples collected when the Karnak gage recorded flows within its rating curve, most of which are low flow events. Not surprisingly, the TotHg/flow and TSS/flow regressions for Sacramento Slough were not statistically significant. Therefore, this report's preliminary estimates of Sutter Bypass loading (25 ±4 kg/yr for the WY1984-2003; 19 ±3 kg/yr for the WY2000-2003 period) were developed by multiplying water volumes recorded by the Meridian gage by the average total mercury and TSS concentrations observed at Karnak. This calculation does not address any uncertainty associated with using concentration data collected 30 miles downstream of the flow gage. The recent CalFed study that incorporated additional data collected during wet periods (Louie *et al*., 2008) estimated a 20-year average annual load of 31.0 ±4.2 kg/yr for the Sutter Bypass, which is statistically similar to the 20-year average load calculated for this report.

Four watersheds provided more than 90% of the annual average water volume of the Sacramento Basin during WY2000-2003 and WY1984-2003 (Table 7.6a). The watersheds are the Sacramento River above Colusa, Feather River, Sutter Bypass and American River. The 4- and 20-year water budgets balance within 4 to 5% indicating that all the major water sources have been identified. A different grouping of four watersheds contributed about 90% of the annual mercury load (Table 7.6b). The watersheds are the Sacramento River above Colusa, Cache Creek Settling Basin, Feather River and Sutter Bypass. The sum of tributary mercury inputs for both the 4 and 20-year periods is greater than the load exported to the Delta (Table 7.6b). Mercury exports average 79 to 87% of inputs. This suggests that either tributary loads are overestimated or that deposition is occurring in the river channel upstream of Freeport and/or in the Yolo Bypass.

The same four watersheds that contribute the majority of the mercury also export more than 90% of the sediment (Table 7.6c). The sum of tributary inputs of sediment is greater than the exports to the Delta. Exports range from 55% of inputs during WY2000-2003 to 89% during WY1984-2003. The results suggest, like for mercury, that incoming loads are either being overestimated or that deposition is occurring in the Central Valley. Wright and Schoellhamer (2005) and Louie and other (2008) also found that the Sacramento Basin landward of Rio Vista was depositional. However, unlike this report, Wright and Schoellhamer (2005) concluded that deposition was greater in wet than in dry periods.



River Mile	Feature
302	Keswick Dam
245	Red Bluff
184	Ord Ferry Bridge
158	Moulton Weir
146	Colusa Weir
119	Tisdale Weir
82-84	Fremont Weir
63	Sacramento Weir
12	Rio Vista

Figure 7.1: Sacramento River Flood Control System.
Pink lines represent levees. (Tetra Tech, Inc., 2005b; DWR, 2003)

Table 7.5: Total Mercury and TSS Concentrations for Sacramento Basin Tributaries.

Site	# of Samples	Sampling Begin Date	Sampling End Date	Min. Conc.	Average	Median Conc.	Max. Conc.
Total Mercury Concentrations (ng/l)							
American River @ Discovery Park	155	1/18/94	2/19/04	0.46	2.97	2.14	18.51
Cache Creek Settling Basin	26	12/23/96	2/17/04	4.07	171.89	58.24	984.60
Colusa Basin Drain	63	1/31/95	2/18/04	1.59	11.58	6.90	75.10
Feather River near Nicolaus	67	1/31/95	2/18/04	1.49	6.90	4.43	46.19
Natomas East Main Drain (a)	56 (12)	3/5/96	12/12/02	1.06 (9.52)	10.87 (27.78)	6.88 (20.84)	82.99 (82.99)
Putah Creek @ Mace Blvd.	36	1/31/95	3/09/04	1.25	33.02	9.14	485.00
Sacramento River above Colusa	64	3/10/95	2/17/04	0.60	12.30	4.27	105.16
Sacramento Slough near Karnak (b)	55	2/12/96	9/15/03	0.69	8.77	7.57	30.8
TSS Concentrations (mg/l)							
American River @ Discovery Park	191	12/15/92	2/19/04	0.5	6.23	3.0	116.0
Cache Creek d/s Settling Basin	23	12/23/96	2/17/04	41.0	425.1	140.0	1,900
Colusa Basin Drain	59	2/07/96	2/18/04	21.0	128.1	101.0	487.7
Feather River near Nicolaus	70	3/11/95	2/18/04	2.0	23.1	14.5	123.0
Natomas East Main Drain (a)	30 (8)	3/5/96	3/8/02	5.0 (16.6)	31.3 (43.0)	26.0 (34.5)	122.0 (96.0)
Putah Creek @ Mace Blvd.	29	3/28/00	2/29/04	1.6	59.01	30.0	417.8
Sacramento River above Colusa	48	3/10/95	2/17/04	10.0	98.6	36.0	662.2
Sacramento Slough near Karnak (b)	54	2/12/96	9/15/03	14.8	62.6	53.0	182.0

(a) No concentration or flow data gage data were available for Natomas East Main Drain outflows. The SRWP, USGS and City of Roseville collected total mercury and TSS concentration data on Arcade Creek near Norwood and Del Paso Heights and Dry Creek. Wet weather concentration data for Arcade Creek and Dry Creek (noted in parentheses), and estimated wet weather runoff for the entire Natomas East Main Drain watershed (Table 6.1 in Chapter 6 and Section E.2.2 in Appendix E), were used to develop preliminary load estimates. Natomas East Main Drain was recently renamed "Steelhead Creek".

(b) Sacramento Slough near Karnak is the low flow channel for Sutter Bypass.

Table 7.6a: Sacramento Basin Tributaries – Acreage and Water Volumes.

Tributary	**Acreage**	**% All Acreage**	**Water Volume** (M acre-feet/yr)		**% All Water**	
			WY2000-2003	WY1984-2003	WY2000-2003	WY1984-2003
Upstream Tributary Inputs						
American River	1,253,740	7.5%	1.9	2.5	11%	13%
Cache Creek	724,526	4.3%	0.22	0.38	1.3%	1.9%
Colusa Basin Drain	1,577,307	9.4%	0.67	0.66	4.0%	3.4%
Coon Creek/Cross Canal	287,914	1.7%	0.089	0.094	0.5%	0.5%
Feather River	3,793,179	23%	3.9	5.3	23%	27%
Natomas East Main Drain	231,598	1.4%	0.084	0.088	0.5%	0.5%
Putah Creek	652,762	3.9%	0.041	0.11	0.2%	0.6%
Sacramento River @ Colusa	7,562,525	45%	8.2	8.1	49%	41%
Sutter Bypass	682,071	4.1%	1.8	2.3	11%	12%
Sum of Upstream Inputs:	**16,765,622**	**100%**	**16.9**	**19.5**	**100%**	**100%**
Exports to Delta						
Yolo Bypass (Prospect Slough)	- - -		1.0	2.7	6%	14%
Sacramento River (Freeport)	- - -		15.1	16.1	94%	86%
Sum of Exports to Delta:	- - -		**16.1**	**18.8**	**100%**	**100%**
Tributary Inputs – Exports to Delta:			**0.8**	**0.7**		
Exports to Delta / Tributary Inputs:			**95%**	**96%**		

Table 7.6b: Sacramento Basin Tributaries – Total Mercury Loads.

Tributary	**Average Annual TotHg Load** ± 95 CI [(a)] (kg/yr)		**% of TotHg Inputs**	
	WY2000-2003	WY1984-2003	WY2000-2003	WY1984-2003
Upstream Tributary Inputs				
American River	6.4 ±0.1	14 ±0.1	2.8%	3.4%
Cache Creek Settling Basin	26 ±3	118 ±5	11%	30%
Colusa Basin Drain	10	13	4.3%	3.3%
Feather River	28 ±1	67 ±2	12%	17%
Natomas East Main Drain	2.9 ±1	3.0 ±1	1.2%	0.8%
Putah Creek	1.0 ±0	8.8 ±1	0.4%	2.2%
Sacramento River @ Colusa	139 ±4	151 ±4	60%	38%
Sutter Bypass	19 ±3	25 ±4	8.2%	6.3%
Sum of Upstream Inputs:	**232 ±6**	**400 ±8**	**100%**	**100%**
Exports to Delta				
Prospect Slough	37 ±1	169 ±5	20%	48%
Sacramento River @ Freeport	146 ±1	183 ±1	80%	52%
Sum of Exports to Delta:	**183 ±1**	**352 ±5**	**100%**	**100%**
Trib Inputs - Exports to Delta	**49**	**48**		
Exports to Delta / Trib Inputs	**79%**	**88%**		

(a) Confidence intervals (CI) were calculated for the average annual total mercury loads for the tributary stations with daily flow gages. See Appendix I for the methods used to estimate the confidence intervals.

Table 7.6c: Sacramento Basin Tributaries – TSS Loads.

Tributary	Average Annual TSS Load ± 95% CI [(a)] (MKg/yr)		% of TSS Inputs	
	WY2000-2003	WY1984-2003	WY2000-2003	WY1984-2003
Upstream Tributary Inputs				
American River	13 ±0.2	52 ±0.5	0.8%	2.4%
Cache Creek Settling Basin	68 ±6	259 ±10	4.2%	12%
Colusa Basin Drain	117	148	7.2%	7.0%
Feather River	98 ±3	216 ±6	6.0%	10%
Natomas East Main Drain	4.5 ±2	4.7 ±2	0.3%	0.2%
Putah Creek	2.2 ±0.2	16 ±1	0.1%	0.8%
Sacramento River above Colusa	1,180 ±41	1,256 ±41	73%	59%
Sutter Bypass	138 ±21	177 ±27	8.5%	8.3%
Sum of Upstream Inputs:	**1,621 ±48**	**2,129 ±49**	**100%**	**100%**
Exports to Delta				
Prospect Slough	197 ±5	1,014 ±31	22%	54%
Sacramento River @ Freeport	689 ±7	865 ±7	78%	46%
Sum of Exports to Delta:	**886 ±9**	**1,879 ±31**	**100%**	**100%**
Trib Inputs - Exports to Delta	**735**	**250**		
Exports to Delta / Trib Inputs	**55%**	**88%**		

(a) Confidence intervals (CI) were calculated for the average annual TSS loads for the tributary stations with daily flow gages. See Appendix I for the methods used to estimate the confidence intervals.

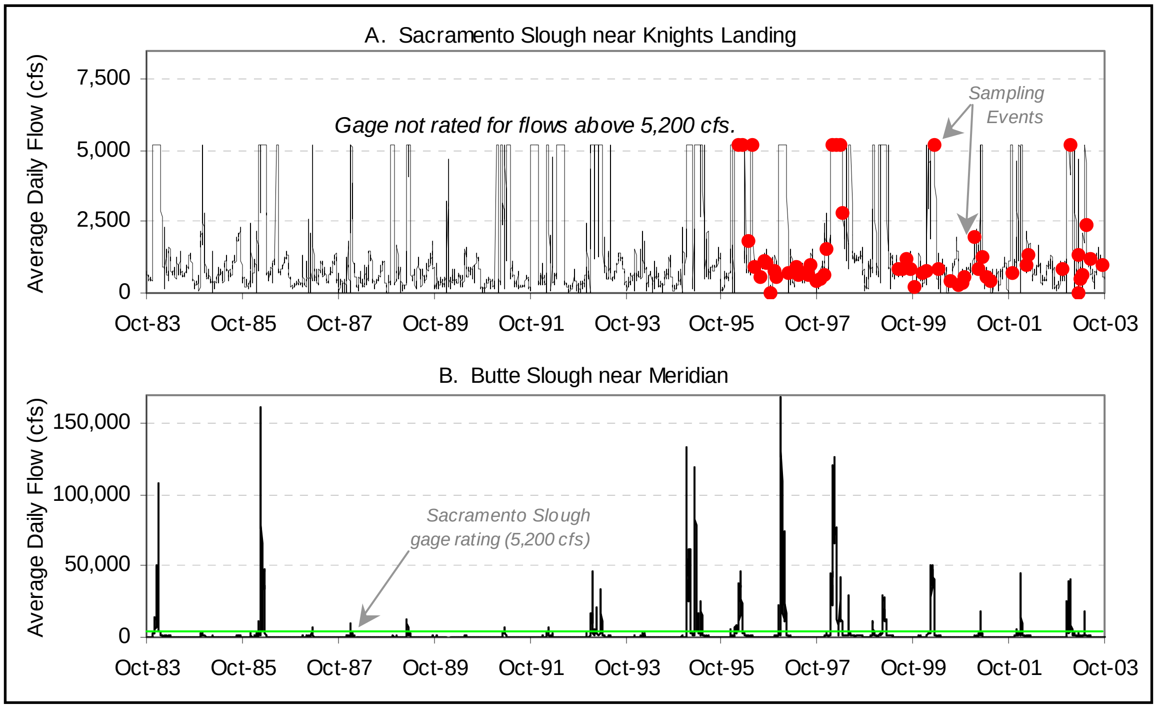


Figure 7.2: Flow Data Evaluated for Sutter Bypass.
(Note the 20-fold difference in the Y-axis flow values for these two graphs.)

7.1.2 Municipal & Industrial Sources

During the TMDL period, WY2000-2003, there were 23 NPDES-permitted municipal and industrial discharges to surface water in the Delta/Yolo Bypass[40] (Figure 6.5). The sum of total mercury loads from the discharges is approximately 2.4 kg/yr, about 1% of all Delta sources (Table 7.1).

Information on average flow rates for each facility was obtained from the Central Valley Water Board's discharger project files, permits and the State Water Resources Control Board's Surface Water Information (SWIM) database. Effluent total mercury concentration data were obtained from project files and dischargers' SIP monitoring efforts.[41] Table 6.5 in Chapter 6 and Table G.1 in Appendix G provide additional information about the facilities. Table G.1 lists the estimated annual mercury loads from each facility, which were obtained from the facility-specific average effluent concentration and average daily discharge volume multiplied by 365. Appendix L provides the effluent total mercury concentration data used to calculate the average effluent total mercury loads. It was assumed that total mercury loading from the facilities does not vary substantially between wet and dry years. This consideration will be re-evaluated as additional information becomes available.

Of the 23 facilities in the Delta, two are power and heating/cooling facilities that use ambient water for cooling water: Mirant Delta LLC Contra Costa Power Plant (CA0004863) and the State of California Central Heating/Cooling Plant (CA0078581). Based on the comparison of the available intake and outfall mercury data for the Mirant Delta facility and other similar facilities that discharged to the Delta in years past (Table G.5 in Appendix G), such facilities may not act as measurable sources of mercury to the Delta. According to its NPDES permit, the Central Heating/Cooling Plant adds no chemicals to its supply water; however, the permits for Mirant Delta and other similar facilities in the tributary watersheds indicate that mercury-containing chemicals may be added to their cooling water and other low-volume waste streams may be included in their discharges (see Tables G.6 and G.7 in Appendix G). Staff recommends that the assumption that power and heating/cooling plants do not contribute mercury to Delta and upstream surface waters be re-evaluated as additional information becomes available.

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[40] It is assumed that facility discharges contain negligible amounts of suspended solids.

[41] In September 2002, the Central Valley Water Board issued a California Water Code Section 13267 order to all NPDES dischargers (except municipal stormwater dischargers) requiring the dischargers to collect effluent and receiving water samples and to have the samples analyzed for priority pollutants contained in the U.S. Environmental Protection Agency's California Toxics Rule and portions of the USEPA's National Toxics Rule. This action was directed by Section 1.2 of the Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California, also known as the State Implementation Policy (SIP), which was adopted by the State Water Resources Control Board on 2 March 2000. The SIP monitoring requires that the dischargers' mercury monitoring utilize "ultra-clean" sampling and analytical methods including Method 1669 (Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels, US EPA) and Method 1631 (Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence, US EPA). The SIP monitoring requires major industrial and municipal NPDES dischargers to collect monthly samples for metals/mercury analysis, and minor industrial and municipal NPDES dischargers to collect quarterly samples.

7.1.3 Urban Runoff

Approximately 60,000 acres in the Delta are urban, most of which are regulated by NPDES waste discharge requirements. Table 6.10 in Chapter 6 lists the permits that regulate urban runoff and their corresponding acreage. Figure 6.7 shows their locations. Urban areas not encompassed by a MS4 service area were grouped into a "nonpoint source" category.

Total mercury and TSS concentration data were collected by Central Valley Water Board staff and the City and County of Sacramento from several urban waterways within or adjacent to the Delta. Figure 6.8 shows the urban areas and sampling locations, Figure H.1 in Appendix H illustrates the wet and dry weather concentrations by location, and Appendix L provides the concentration data used in Figure H.1. Data generation by analytical methods with detection limits less than 1 ng/l began in 1996. The total mercury concentrations ranged from a dry weather low of 1.06 ng/l (Arcade Creek) to a wet weather high of 1,138 ng/l (Strong Ranch Slough). The TSS concentrations ranged from a dry weather low of less than 3 mg/l (City of Sacramento Sump 111) to a wet weather high of 1,300 mg/l (Strong Ranch Slough). A visual inspection of the total mercury and TSS data suggests that the differences between the urban watersheds are not directly related to land use. Therefore, the data were averaged by wet and dry weather for each location (Table 7.7). The averages of these location-based wet and dry weather averages are assumed to represent runoff from all urban areas in or adjacent to the Delta.

To estimate wet weather mercury and TSS loads, the average wet weather concentrations were multiplied by the runoff volumes estimated for WY2000-2003 and WY1984-2003 for each MS4 area within the Delta. To estimate dry weather mercury and TSS loads, the dry weather concentrations were multiplied by the estimated dry weather urban runoff volume. Appendix E describes the methods used to estimate wet and dry weather urban runoff from urban areas within the Delta. Wet and dry weather mercury and TSS loads were summed to estimate the WY2000-2003 average annual loadings of 2.3 kg mercury and 7.5 Mkg/yr suspended sediment and WY1984-2003 average annual loadings of 2.4 kg mercury and 7.7 Mkg/yr TSS (Table 7.8). Urban land uses comprise a small portion of the Delta and contribute about 1% of the mercury load (Table 7.1). In contrast, approximately 320,000 acres of urban land – about 42% of all urban area within the Delta source region – are within 20 miles of the Delta boundary, about one day water travel time upstream. In addition, some of the urban watersheds outside the Delta discharge via sumps into Delta waterways. These discharges were not included in the Delta urban load estimate. As a result, the urban contribution to the Delta mercury load may be underestimated. To evaluate the potential contributions from upstream urban lands, the total mercury loadings from the two MS4 service areas with the greatest urban acreage immediately outside the Delta were estimated for the WY1984-2003 period. The sum of mercury loads from the Sacramento and Stockton MS4 areas may contribute more than 2% of loading to the Delta (Table 7.9). These loads are expected to increase as urbanization continues around the Delta.

Table 7.7: Summary of Urban Runoff Total Mercury and TSS Concentrations

Urban Watershed	# of Samples	Minimum Conc.	Average Conc.	Maximum Conc.
TOTAL MERCURY (ng/l)				
DRY WEATHER				
Arcade Creek	37	1.06	8.07	34.80
City of Sacramento Strong Ranch Slough	7	3.63	18.43	84.00
City of Sacramento Sump 104	7	1.61	7.78	24.30
City of Sacramento Sump 111	7	2.16	9.59	28.96
Tracy Lateral to Sugar Cut Slough	1	7.92	7.92	7.92
Average of Location Dry Weather TotHg Averages:			**10.36**	
WET WEATHER				
Arcade Creek	14	1.73	20.90	54.30
City of Sacramento Strong Ranch Slough	13	20.10	188.32	1137.90
City of Sacramento Sump 104	14	9.94	36.72	118.42
City of Sacramento Sump 111	13	10.68	28.56	65.23
Stockton Calaveras River Pump Station	5	14.18	26.07	49.71
Stockton Duck Creek Pump Station	1	13.57	13.57	13.57
Stockton Mosher Slough Pump Station	5	9.67	14.16	17.29
Stockton Smith Canal Pump Station	4	23.17	40.97	65.87
Tracy Drainage Basin 10 Outflow	3	8.78	12.13	16.12
Tracy Drainage Basin 5 Outflow	3	7.02	12.59	20.67
Tracy Lateral to Sugar Cut Slough	3	5.44	18.10	28.45
Average of Location Wet Weather TotHg Averages:			**37.46**	
TSS (mg/l)				
DRY WEATHER				
Arcade Creek	28	5.0	31.7	122.0
City of Sacramento Strong Ranch Slough	6	5.0	9.3	15.0
City of Sacramento Sump 104	7	4.0	7.6	12.0
City of Sacramento Sump 111	7	1.5	6.2	11.0
Tracy Lateral to Sugar Cut Slough	1	26.5	26.5	26.5
Average of Location Dry Weather TSS Averages:			**16.26**	
WET WEATHER				
Arcade Creek	12	7.0	99.5	320.0
City of Sacramento Strong Ranch Slough	13	23.0	208.7	1300.0
City of Sacramento Sump 104	14	31.0	104.3	270.0
City of Sacramento Sump 111	11	15.7	92.4	340.0
Stockton Calaveras River Pump Station	5	26.0	94.3	264.6
Stockton Duck Creek Pump Station	1	281.3	281.3	281.3
Stockton Mosher Slough Pump Station	5	6.0	19.6	34.0
Stockton Smith Canal Pump Station	4	76.0	125.8	184.6
Tracy Drainage Basin 10 Outflow	3	81.1	136.9	236.0
Tracy Drainage Basin 5 Outflow	3	26.1	77.5	148.1
Tracy Lateral to Sugar Cut Slough	3	6.3	153.7	342.9
Average of Location Wet Weather TSS Averages:			**126.7**	

Table 7.8: Average Annual Total Mercury and TSS Loadings from Urban Areas within the Delta/Yolo Bypass

MS4 Permittee	WY2000-2003		WY1984-2003	
	TotHg Load (kg/yr)	**TSS Load** (Mkg/yr)	**TotHg Load** (kg/yr)	**TSS Load** (Mkg/yr)
Contra Costa County	0.60	1.9	0.62	2.0
Lathrop	0.032	0.10	0.033	0.11
Lodi	0.006	0.021	0.007	0.022
Port of Stockton	0.047	0.15	0.049	0.16
Rio Vista	0.002	0.005	0.002	0.005
Sacramento MS4 Permit Area	0.21	0.68	0.22	0.71
San Joaquin Co MS4 Permit Area	0.35	1.2	0.37	1.2
Solano County	0.019	0.062	0.020	0.065
Stockton MS4 Permit Area	0.47	1.5	0.49	1.6
Tracy	0.21	0.69	0.22	0.72
West Sacramento	0.21	0.68	0.21	0.71
Yolo County	0.050	0.16	0.051	0.17
Urban Nonpoint Source (a)	0.10	0.33	0.10	0.33
Grand Total	2.3	7.5	2.4	7.8

(a) Urban areas not encompassed by a MS4 service area were grouped into a “nonpoint source” category within each Delta subarea.

Table 7.9: Comparison of WY1984-2003 Annual Delta Mercury and TSS Loads to Sacramento and Stockton Area MS4 Loads.

MS4 Service Area (a)	**Water Volume** (M acre-feet) (b)	**TotHg Load** (kg/year)	**TSS Load** (Mkg/yr)
Sacramento MS4 Urban Total	0.19	7.4	24
Stockton MS4 Urban Total	0.026	1.0	4.0
Total Delta Inputs (c)	23	400	1,080
Stockton & Sacramento Urban Runoff as % of Total Delta Inputs	**1.0%**	**2.1%**	**1.3%**

(a) The Sacramento and Stockton Area MS4s are the two MS4 service areas with the greatest urban acreage immediately upstream of the Delta, with urban land use areas of 160,000 and 25,000 acres, respectively.

(b) Refer to Appendix E for urban runoff volume estimates for wet and dry weather, which were summed to estimate the annual average water volumes shown above.

(c) These values represent the sum of all tributary and within-Delta total mercury and TSS sources shown in Table 7.1.

7.1.4 Atmospheric Deposition

Atmospheric deposition of mercury has not been measured in the Delta until very recently. Figure 7.3 illustrates wet deposition sampling locations in northern and central California available at the time the TMDL was developed, Appendix L provides the available total mercury concentration data, and Table 7.10 summarizes the data. Volume-weighted average total mercury concentrations ranged from 4.1 ng/l at Covelo to 13 ng/l at Sequoia National Park. To estimate wet deposition, the volume-weighted average concentration observed at the North Bay/Martinez station (7.4 ng/l) was used because the station is closest to, and typically upwind of, the Delta. Total mercury loading from precipitation on surface water in the Delta (direct deposition) was estimated by multiplying the average mercury concentration in North Bay/Martinez rainwater (Table 7.10) by the average rainfall volume to fall on Delta water surfaces during WY2000-2003. Loading from runoff of mercury-contaminated rain falling on land (indirect deposition) was estimated by multiplying the average mercury concentration in rainwater by the estimated runoff volume from non-urbanized land surfaces for WY2000-2003. Runoff from urban areas was not included because it is inherently incorporated in the estimates for loading from urban runoff described in Section 7.1.3. Appendix E describes the method used to estimate rainfall runoff volumes for the Delta. Table 7.11 lists the estimated mercury loads from direct and indirect wet deposition. Wet deposition (2.3 kg/yr) contributes approximately 1% of all mercury entering the Delta (Table 7.1).

There are several uncertainties inherent in the estimates of direct and indirect wet atmospheric deposition in the Delta. For example, the concentration of mercury in rain in the Delta had not been measured at the time this source analysis was developed and runoff coefficients have not been calculated to determine how much mercury falling on land is carried into surface water. However, these uncertainties are unlikely to have a substantial impact on the overall mercury budget for the Delta (Table 7.1) because atmospheric inputs account for only about 1% of the total mass balance. A recently completed CalFed study (Gill, 2008b) observed volume-weighted mercury concentrations in rain of 4.2 and 3.7 ng/l at Twitchell Island (western Delta) and Woodland (near the Yolo Bypass), respectively, which indicate that the estimate of wet deposition included in Table 7.1 may be over-estimated.

Dry mercury deposition rates were not estimated for the Delta because there was no information on airborne particulate mercury concentrations at the time this source analysis was developed. SFEI (2001) estimated that about five times more mercury is deposited on an annual basis in dry than in wet deposition in San Francisco Bay. If so, direct dry deposition rates in the Delta may be about 12 kg/yr or about 1 to 2% of the annual load. Dr. Gill (Texas A&M University) recently completed measuring dry mercury deposition rates in the Central Valley as part of CALFED project ERP-02-C06-B. At his Woodland monitoring location, Dr. Gill estimated dry deposition flux rates of 1.1 and 3.4 $\mu g/m^2/yr$ in the winter and summer, respectively, compared to his wet deposition flux rates of 2.0 and 0.10 $\mu g/m^2/yr$ in the winter and summer, respectively, which indicates that, on an annual basis, mercury loading to the Delta from dry deposition may be about equal to loading from wet deposition.

In an attempt to identify local – and therefore potentially controllable – sources of mercury in atmospheric deposition in the Delta and its tributary watersheds, mercury loads emitted by facilities that report emissions to the California Air Resources Board (ARB) were reviewed. The

ARB Emission Inventory Branch tracks mercury loading in air emissions in its California Emission Inventory Development and Reporting System database. ARB staff provided a database describing facilities that reported mercury emissions in 2002. Appendix J provides a summary of the types of facilities in each watershed and their estimated emission loads. The available data indicate that almost 10 kg of mercury were released in the Delta by sugar beet facilities, electric services, paper mills, feed preparation, and rice milling. About 113 kg of mercury were released in the tributary watersheds. Some facility categories appear to have relatively high mercury emissions compared to other types of facilities in the tributary watersheds: cement, concrete and paving mixture/block manufacturing facilities (51 kg); electrical services (19 kg); crematories (15 kg); and national security (13 kg). Emission loads in Appendix J are not incorporated in the mass budgets because their deposition rates are not known. Local air emissions of mercury warrant additional research.

Potentially uncontrollable sources of mercury (i.e., sources outside of the United States) in atmospheric deposition in the Delta and its tributary watersheds are discussed in Chapter 8, Section 8.4.3.5.

Table 7.10: Summary of Available Data Describing Mercury Concentrations in Wet Deposition in Northern and Central California.

Study [(a)]	**Station**	**Volume-Weighted Average TotHg Conc.** (ng/l)	**# of Samples**	**Collection Period**
San Francisco Bay Atmospheric Deposition Pilot Study (SFBADPS) [(b)]	North Bay	7.4	14	Aug. 1999 – Jul. 2000
	Central Bay	6.6	16	
	South Bay [(c)]	9.7	29	
National Atmospheric Deposition Program (NADP) Mercury Deposition Network (MDN)	San Jose [(c)]	10	86	Jan. 2000 – Dec. 2003
	Sequoia National Park [(d)]	13	5	Jul. 2003 – Dec. 2003
	Covelo [(e)]	4.1	60	Jan. 1998 – Sep. 2000

(a) Sources: NADP MDN – Sweet, 2000; NADP, 2004. SFBADPS – SFEI, 2001. Volume weighted average total mercury concentrations for the South Bay, Central Bay, and North Bay sites were calculated by the SFEI authors (SFEI, 2001). Volume weighted average total mercury concentrations for the San Jose, Sequoia National Park, and Covelo sites were calculated by Central Valley Water Board staff from the NADP data provided in Appendix L.

(b) The North Bay, Central Bay, and South Bay sites are located at Martinez, Treasure Island and Moffett Federal Airfield/NASA Ames Research Center near San Jose, respectively.

(c) In addition to being part of the SFBADPS, the South Bay site also became one of the NADP MDN stations. Co-location of mercury wet deposition sampling under the MDN/NADP with the Pilot Study at the South Bay site began in January 2000 and resulted in ten replicate field precipitation samples.

(d) Sequoia National Park is in the Sierra Nevada Mountains to the southeast of Fresno in the Tulare Basin, which is south of the San Joaquin Basin.

(e) Covelo is ~150 miles north of San Francisco Bay in the Coast Range.

Table 7.11: Average Annual Total Mercury Loads from Wet Deposition [(a)]

Period/Deposition Type [(b)]	WY2000-2003 Water Volume (acre-feet) [(c)]	WY2000-2003 TotHg (kg/year)	WY1984-2003 Water Volume (acre-feet) [(c)]	WY1984-2003 TotHg (kg/year)
Direct Deposition	88,669	0.81	91,960	0.84
Indirect Deposition	159,394	1.5	165,325	1.5
TOTAL	248,063	2.3	257,284	2.3

(a) The volume-weighted average concentration observed in the North Bay/Martinez (7.4 ng/l, Table 7.10) was used to estimate total mercury loading to the Delta.

(b) Direct deposition results from mercury-contaminated rain falling on Delta/Yolo Bypass surface waters. Indirect deposition results from runoff of mercury-contaminated rain falling on land surfaces in the Delta. Runoff from urban areas was not included because it is inherently incorporated in the estimates for loading from urban runoff described in Section 7.1.3.

(c) Refer to Appendix E for a description of the methods used to estimate rainfall runoff volumes.

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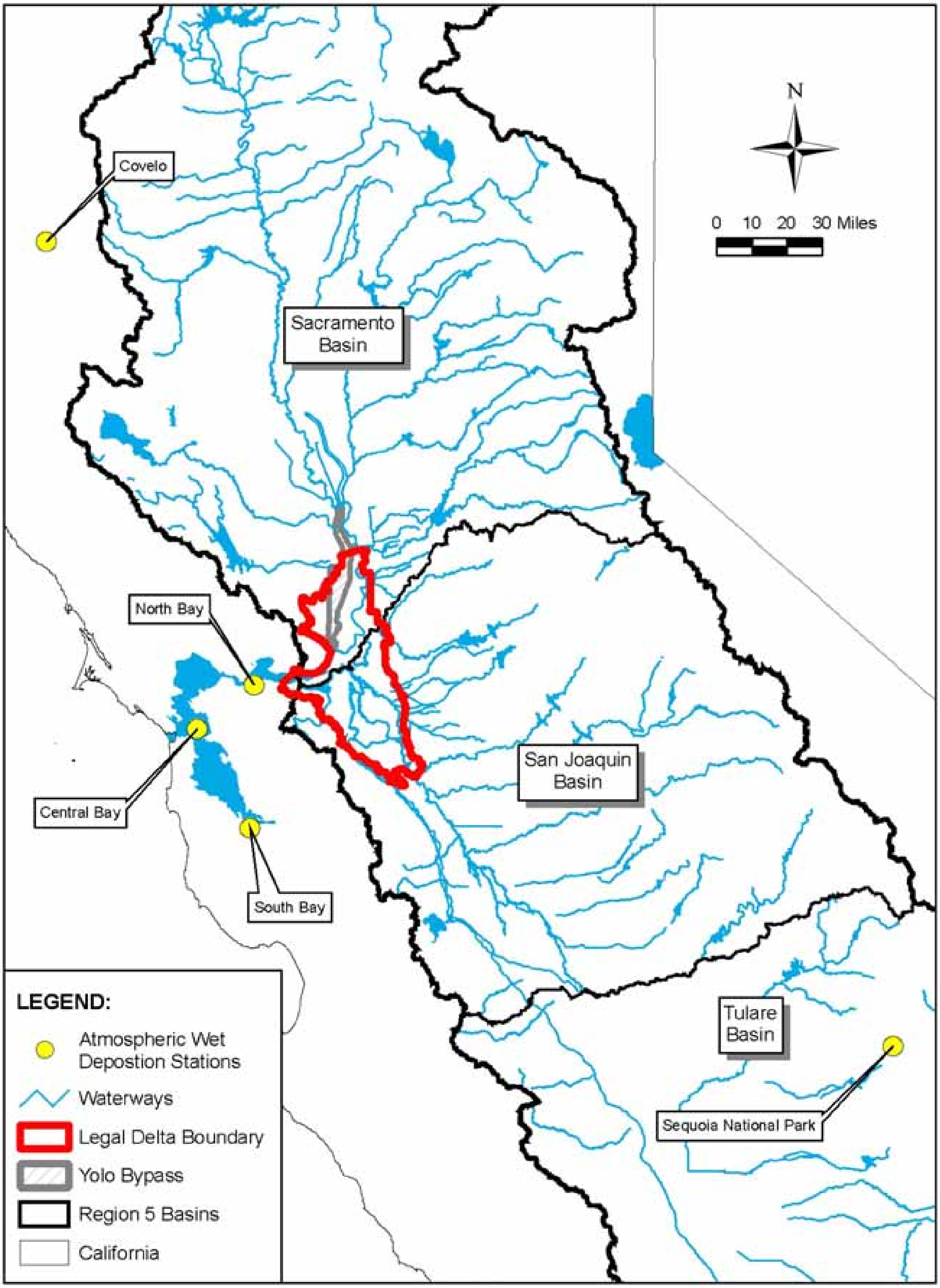

Figure 7.3: Wet Deposition Total Mercury Sampling Locations in Northern and Central California.

7.1.5 Other Potential Sources

Loading from Delta soils has not been evaluated. More than 70% of Delta lands have agricultural land uses and many of the urban areas in the Delta were once agricultural. Farming began in the Delta in 1849, about the same time that gold mining began in the Sierra Nevada Mountains (DWR, 1995). In 1861, the California legislature authorized the Reclamation District Act, which allowed drainage of Delta swampland and construction of levees; the extensive Delta levee system was mostly built between 1869 and 1880 (DWR, 1995). By 1852, hydraulic mining was the most common method for mining the placer gold deposits in the Sierra Nevada (Hunerlach *et al*., 1999) and continued until the Sawyer Decision outlawed the practice in 1884. Hydraulic gold mining resulted in the deposition of large amounts of silt and sand in Delta channels and upstream rivers (DWR, 1995). Much of these deposits may have been contaminated with mercury used to amalgamate gold. Therefore, some levees and Delta islands may have been constructed with mercury-contaminated sediment.

Barley and other grains have historically been common rotational crops in the Delta (Weir, 1952), and the seeds were treated with mercury-based fungicides before sowing (LWA, 2002). It is not known how much mercury was used in the Delta, but up to 38,000 kg of mercury may have been added in fungicides in the Sacramento Valley between 1921 and 1971 (LWA, 2002). Mercury is no longer used as an active ingredient in any pesticides (DPR, 2002).

Mercury has been measured in six soil samples in the Delta source region, mostly from agricultural fields (Bradford *et al.*, 1996). One sample was collected in the eastern Delta near White Slough north of Stockton (0.27 mg/kg) and five samples were collected within 10 miles of the Delta boundary (0.25, 0.34, and three results <0.2 mg/kg). The study authors concluded that there was no relationship between soil mercury levels and location and soil type. Some of the mercury concentrations are elevated above the proposed San Francisco Bay TMDL sediment objective of 0.2 mg/kg indicating that erosion in the Delta area may contribute to exceedances of the Bay area sediment objective.

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7.2 Total Mercury and TSS Losses

The following were identified as processes contributing to mercury loss in the Delta: flow to San Francisco Bay, water diversions to areas south of the Delta, removal of dredged sediments, and evasion of elemental mercury. Table 7.12 summarizes mercury and TSS losses by type.

Table 7.12: Average Annual Total Mercury and TSS Losses for WY2000-2003 and WY1984-2003.

	WY2000-2003				WY1984-2003			
	TotHg		TSS		TotHg		TSS	
	Load ± 95% CI (kg/yr)	% of All Losses	Load ± 95% CI (Mkg/yr)	% of All Losses	Load ± 95% CI (kg/yr)	% of All Losses	Load ± 95% CI (Mkg/yr)	% of All Losses
Outflow to San Francisco Bay	270 ±93	71%	930 ±283	67%	379 ±132	78%	1,309 ±398	75%
Dredging	57 ±71	15%	349	25%	57 ±71	12%	349	19%
Evasion	30	8%	- -	--	30	6%	--	--
State Water Project (a)	11 ±3	3%	46 ±22	3%	9 ±3	2%	38 ±18	2%
Delta Mendota Canal (a)	11 ±1	3%	62 ±9	5%	10 ±1	2%	60 ±9	4%
Sum of Losses	**379 ±112**	**100%**	**1,387 ±271**	**100%**	**485 ±143**	**100%**	**1,756 ±381**	**100%**

(a) The 95% confidence intervals (CI) were calculated for the State Water Project and Delta Mendota Canal loads using the method described in Appendix I.

7.2.1 Outflow to San Francisco Bay

Estimates of mercury and sediment exports from the Delta to San Francisco Bay are critical components of the Delta mercury TMDL for two reasons. First, outflow to San Francisco Bay is the primary export from the Delta and must be accurately measured to determine whether the Delta is a net source or sink for mercury and sediment. Second, the San Francisco Bay mercury TMDL assigned the Central Valley a mercury load allocation of 330 kg/yr. The allocation must be met either at Mallard Island or by a 110 kg reduction in incoming mercury loads to the Delta (Section 2.4.2.3).

Central Valley Water Board staff evaluated TSS and mercury levels in Central Valley outflows to San Francisco Bay by collecting samples at X2. Figure 6.9 in Chapter 6 illustrates a typical location of X2. Board staff conducted monthly mercury and TSS sampling at X2 from March 2000 to September 2001 (Foe, 2003) and from April 2003 to September 2003 (Appendix L). Table 7.13 and Figures I.4a and I.4b in Appendix I summarize the available total mercury and TSS concentration data for X2. Total mercury concentrations at X2 averaged 18.1 ng/l and ranged from 3.9 ng/l to 49.2 ng/l. The TSS concentrations at X2 averaged 62 mg/l and ranged from 27 mg/l to 168 mg/l. Net daily Delta outflow was obtained from the Dayflow model (Appendix E). Total mercury and TSS concentrations at X2 were regressed against Delta outflow to determine whether either could be predicted from flow. Neither regression was significant. Therefore, average mercury and TSS concentrations were multiplied by average annual water volume for WY2000-2003, WY1984-2003 and WY1995-2005 to estimate annual loads (Table 7.14). These estimates only account for advective or riverine transport and do not incorporate dispersive or tidal flux. Annual average mercury loads to San Francisco Bay were

270, 379, and 691 kg/yr for WY2000-2003, WY1984-2003 and WY1995-2000, respectfully (Tables 7.12 and 7.14).

Six studies (including this source analysis) have measured mercury and sediment loads to San Francisco Bay from the Delta (Table 7.14). The results are quite variable. Some of the variation is undoubtedly due to the fact that different studies have measured export rates in different hydrologic years. However, four studies estimated annual average mercury export rates for WY1995-2000. The values range between 270 ±91 and 691 ±240 kg/yr (Table 7.14). The rate developed by David and others (2009) may be the most accurate for several reasons. First, it incorporates estimates of tidal dispersion in their load calculations. Tidal dispersion at Mallard Island reduces export rates as incoming tides have a greater sediment and mercury concentration than outgoing ones. This reduces the net export rate and likely provides a more accurate estimate. Second, it measured mercury at Mallard Island. Third, it includes data collected during high flows. In contrast, the TMDL's source analysis uses sediment and mercury concentration data collected at X2. X2 is centered at Mallard Island but moves about 10 miles up and down the estuary depending on river outflow and tidal stage.
X2 measurements are appropriate for predicting biotic exposure of water column organisms, such as pelagic fish, to methylmercury. This was the primary objective of the study used to develop the TMDL's estimate. However, such measurements are undoubtedly less reliable than repeated water column measurements at Mallard Island for predicting mercury and sediment transport past the island.

To further complicate estimates of mercury loads to San Francisco Bay, all of the Mallard Island load estimates are based on the assumption that the channel at Mallard Island is well mixed. However, the results of a recent cross-section study suggest that mercury and suspended sediment concentrations are not homogenous across the Mallard channel and that caution should be used in estimating export loads from data collected at a single point (Louie *et al*., 2006). The error estimation method used by David and others (David *et al*., 2009) accounts for heterogeneity in the cross section at Mallard Island. None-the-less, it is recommended, until consensus is reached on 20-year export rates at Mallard Island, that compliance with the San Francisco mercury allocation to the Central Valley be determined by monitoring Delta inputs.

Table 7.13: Summary of Total Mercury and TSS Concentration Data for X2

	# of Samples [(a)]	**Min. Conc.**	**Ave. Conc.**	**Median Conc.**	**Max. Conc.**
TotHg (ng/l)	20	3.95	18.10	11.59	49.20
TSS (mg/l)	20	27.0	62.41	44.50	168.0

(a) Sampling at X2 took place between March 2000 and September 2003.

Table 7.14: Estimates of Delta Exports to San Francisco Bay

Study (a)	Sampling Location	Period	Average Water Year Hydrologic Index (b)	Average Annual Water Volume (M acre-feet) (c)	Average Annual TotHg Load ± 95% CI (kg)	Average Annual TSS Load ± 95% CI (kg)	TotHg:TSS (mg/kg)
Delta TMDL Program X2 Calculations	X2 (d)	WY2000-2003	7.3	12	270 ±93	930 ±283	0.29
		WY1984-2003	7.8	17	379 ±132	1,309 ±398	
		WY1995-2000	11.0	31	691 ±240	2,384 ±726	
Foe (2003)	X2	WY2001 (e)	5.8	7.2	122	473	0.26
S.F. Bay TotHg TMDL (2004)	Mallard Island	WY1995-2000	11.0	31	440 ±100	1,600 ±300	0.26 ±0.08
Leatherbarrow & others (2005), McKee & others (2006) (f)	Mallard Island	WY1999-2003	7.8	18	97 ±33	524 ±166	0.19
		WY2000-2003	7.3	12	83 ±28	450 ±140	0.18
		WY1995-2000	11.0	31	270 ±91	1,600 ±510	0.17
		WY1995-2003	9.6	24	201 ±68	1,202 ±381	0.17
Louie & others (2008)	Mallard Island	WY1984-2003	7.8	17	198 ±33	801 ±160	0.25
David & others (2009)	Mallard Island	WY2001	5.8	7.2	53 ±19	300 ±100	-
		WY2000-2003	7.3	12	89 ±32	450 ±150	-
		WY1995-2000	11.0	31	372 ±134	1,600 ±500	-
		WY1995-2006	9.6	24	260 ±94	1,200 ±400	0.20 (g)

(a) Sources: this report; Leatherbarrow and others, 2005; Johnson and Looker, 2004; Foe (CALFED), 2003.

(b) DWR calculated a hydrologic index for the Sacramento Valley (DWR, 2006; see Appendix E). "Normal" hydrologic conditions for the Sacramento Valley are represented by an index value of 7.8, "wet" is ≥9.2, "dry" is between 5.4 and 6.5, and "critical dry" is ≤5.4.

(c) All average annual water volumes are from the Dayflow model results for Delta outflows to San Francisco Bay.

(d) The 95% confidence intervals (CI) were calculated using the method described in Appendix I.

(e) Foe's 2003 CALFED study estimated monthly total mercury and TSS loads for March 2000 through September 2001, but did not include load estimates for November 2000. November total mercury and TSS loads for WY2001 were estimated by averaging the loads for October and December 2000.

(f) Leatherbarrow and others (2005) extrapolated total mercury loads from suspended sediment flux and suspended sediment mercury levels by adjusting for tidal dispersion and salinity, where for conductivity < 2 mS/cm, TotHg:TSS is 0.11 mg/kg, and conductivity > 2 mS/cm, TotHg:TSS is 0.29 mg/kg. Central Valley Water Board staff averaged the annual mercury and sediment load estimates provided by Leatherbarrow and others (2005) and McKee and others (2006) for WY1995 through 2003 to estimate average annual loads for the periods that correspond to the San Francisco Bay mercury TMDL study period (WY1995-2000) and the Delta mercury TMDL WY2000-2003 study period. Volume-weighted TotHg:TSS ratios for each period were calculated by dividing the average annual mercury load (kg) by average annual TSS load (Mkg).

(g) Flow-weighted average particulate concentration for WY2002-2006, the period during which the concentration data were collected.

7.2.2 Exports South of Delta

Water diversions to the San Joaquin Valley and southern California account for 4 to 6% of mercury exports from the Delta and 6 to 8% of TSS exports (Table 7.12). Delta Mendota Canal (DMC) and State Water Project (SWP) exports were evaluated by collecting water samples from the DMC canal off Byron highway (County Road J4) and from the input canal to Bethany Reservoir, respectively. Bethany is the first lift station on the State Water Project canal system and is about one mile south of Clifton Court Forebay in the Delta (Figure 6.9).

Central Valley Water Board staff collected monthly total mercury and TSS samples from the DMC and SWP between March 2000 and September 2001 (Foe, 2003) and between April 2003 and 2004 (Appendix L). Table 7.15 and Figures I.4a and I.4b in Appendix I summarize the data. DMC and SWP exported water volumes were obtained from the Dayflow model (Appendix E).

Total mercury and TSS concentrations were regressed against daily flow at both sites to determine whether concentrations could be predicted from flow. The regressions were not significant. Therefore, average mercury and TSS concentrations were multiplied by the WY2000-2003 and WY1984-2003 average annual water volume to estimate loads (Table 7.12): 11 and 10 kg/yr for WY2000-2003 and WY1984-2003, respectively, for the DMC; and 11 and 9 kg/yr for WY2000-2003 and WY1984-2003, respectively, for the SWP. For comparison, the 20-year average annual loads estimated by Louie and others (2008), which incorporate data for a variety of wet and dry years, are 11.4 ±1.7 kg/yr for the DMC and 6.6 ±2.0 kg/yr for the SWP; including data for wet years did not substantially change the load estimates for these exports.

Table 7.15: Summary of Total Mercury and TSS Concentration Data for Exports South of the Delta

Site	# of Samples [a]	Min. Conc.	Ave. Conc.	Median Conc.	Max. Conc.
Delta Mendota Canal					
TotHg (ng/l)	23	1.85	3.41	3.28	5.96
TSS (mg/l)	22	9.2	20.1	18.9	36.0
State Water Project					
TotHg (ng/l)	20	1.16	2.91	2.20	7.17
TSS (mg/l)	20	4.4	11.9	8.2	59.0

(a) Sampling of these exports took place between March 2000 and September 2003.

7.2.3 Dredging

Sediment is dredged from the Delta to maintain the design depth of ship channels and marinas. Dredge material is typically pumped to either disposal ponds on Delta islands or upland areas with monitored return-flow. Table 6.17 provides details on recent dredge projects in the Delta and Figure 6.9 shows their approximate location. The Sacramento and Stockton deep water channels have annual dredging programs; the locations dredged each year vary. Dredging occurs at other Delta locations when needed, when funds are available, or when special projects take place. Approximately 533,000 cubic yards of sediment are removed annually with about 199,000 cubic yards from the Sacramento Deep Water Ship Channel and about 270,000 cubic yards from the Stockton Deep Water Channel. Other minor dredging projects, mostly at marinas, remove an additional 64,000 cubic yards per year.

The amount of mercury removed annually by dredging was estimated by multiplying dredge volume at each project site by its average mercury concentration. Average mercury concentrations in the sediment for the project sites range from 0.04 to 0.41 mg/kg (dry weight). Two critical assumptions were made to calculate the total mercury removed from the Delta by dredging projects:

- Water content of the dredged material is 100% (50% water and 50% sediment by weight) (USACE, 2002); and

- There are about 570 kilograms of dry sediment per cubic yard of wet dredged material based on relative densities of water and sediment (Weast, 1981; Elert, 2002).

The calculations indicate that annual dredging in the Delta removes about 57 kg of mercury and 349 Mkg of sediment. This accounts for approximately 12 to 15% of all mercury exports and 19 to 25% of all sediment exports (Table 7.12). Board staff will continue to collect dredging data and evaluate the annual variability of the measurements.

7.2.4 Evasion

The loss of elemental mercury from water surfaces can be estimated on the basis of measured dissolved gaseous elemental mercury (DGM) concentrations, atmospheric mercury concentrations, and estimated wind speeds (Conaway *et al.*, 2003). Conaway and others (2003) estimated summer and winter loss rates for San Francisco Bay. The Bay has a surface area of approximately 1.24 x 10^9 square meters (~306,400 acres) and is estimated to lose about 190 kg/yr of mercury to the atmosphere (Johnson and Looker, 2004). To obtain an estimate of evasion in the Delta, it was assumed that the loss rate would be proportional to that of San Francisco Bay. The mercury lost from the Bay's surface (190 kg/year) was multiplied by the ratio of the water surface area of the Delta to that of the Bay (0.16). The result is an evasion rate of about 30 kg/yr or 6 to 8% of all mercury losses.

After this source analysis was developed, a recent CalFed study conducted measurements of DGM concentrations in surface waters just west of the legal Delta boundary (Mandeville Bay, Suisun Bay, and Honker Bay) and within the Delta (Little Break and Georgiana Slough) and used this information to model the air-water exchange flux of DGM, resulting in an estimated loss rate of 0.99 µg/m^2/yr (Gill, 2008c). There are approximately 235,778,006 m^2 of open water area in the Delta/Yolo Bypass (Table 6.4 in Chapter 6); when this area is multiplied by 0.99 µg/m^2/yr, the resulting loss load is 0.23 kg/yr, a substantially lower estimate than that calculated in the previous paragraph.

7.3 Total Mercury & Suspended Sediment Budgets

Delta mercury and suspended sediment assessments rely on a box model approach to approximate mass balances. Mass balances are useful because the difference between the sum of known inputs and exports is a measure of the uncertainty of the load estimates and can provide an indication of whether the Delta is depositional or erosional. The average annual water, mercury and TSS budgets for WY2000-2003 and WY1984-2003 are presented in Table 7.16.

The sum of water inputs and exports balance within 5%, indicating that all the major water sources and losses have been identified. In contrast, the mercury and TSS budgets do not balance and vary substantially depending on which estimates are used to characterize Delta outflows to San Francisco Bay. Table 7.16 incorporates the Delta TMDL Program's X2 and evasion calculations, which results in mercury and TSS budgets that indicate that exports are greater than imports. This would imply that the Delta is erosional. However, this conclusion should be viewed with caution because the export rates used in the calculation are greater than those measured by others and may be biased high.[42] The Table 7.16 budget results are also in conflict with the conclusions of two other studies. Wright and Schoellhamer (2005) determined that about 65% of the sediment entering the Delta was deposited there. Louie and others (2008) determined that 48% and 62% of the incoming mercury and suspended sediment loads, respectively, were deposited in the Delta. When the X2 and evasion load estimates shown in Table 7.16 are replaced with David and others (2009) Mallard Island load estimates (89 kg/yr and 450 Mkg/yr for WY2000-2003 mercury and sediment loads, respectively; 260 kg/yr and 1,200 Mkg/yr for WY1995-2006 mercury and sediment loads, respectively) and the updated evasion estimate provided in the previous section (0.23 kg/yr), the budget results are more comparable to the results of the Wright and Schoellhamer (2005) and Louie and others (2008) studies.

Table 7.16: Water, Total Mercury and TSS Budgets for the Delta for WY2000-2003 and WY1984-2003.

	Water Volume (M acre-feet/yr)		**Average Annual Load**			
			WY2000-2003		WY1984-2003	
	WY2000-2003	WY1984-2003	TotHg (kg/yr)	TSS (Mkg/yr)	TotHg (kg/yr)	TSS (Mkg/yr)
Inputs	20.07	23.64	221 ±4	1,081 ±28	403 ±7	2,164 ±51
Exports	18.99	23.29	377 ±112	1,387 ±271	484 ±143	1,756 ±381
Inputs - Exports	**1.08**	**0.35**	**-156**	**-306**	**-81**	**408**
Exports ÷ Inputs	**95%**	**99%**	**170%**	**128%**	**120%**	**81%**

7.4 Evaluation of Suspended Sediment Mercury Concentrations & CTR Compliance

The evaluation of mercury contamination on suspended sediment particles for each Delta input and export site – in tandem with the source load analyses described in Sections 7.1 and 7.2 – is used to identify locations for possible remediation. The recommended total mercury control strategy described in Chapter 8 focuses on sources that have large mercury loadings and suspended sediment with high mercury concentrations, the premise being that it will be more cost effective to focus cleanup efforts on watersheds that export large amounts of highly contaminated sediment. In addition, the strategy incorporates source reductions needed to meet and maintain compliance with the CTR throughout the Delta.

7.4.1 Suspended Sediment Mercury Concentrations

Table 7.17 lists mercury to TSS ratios for Delta sources and export sites calculated using three different methods. The three approaches provide a range of particulate mercury contamination fluxing past a site. First, the ratios (in mg/kg) were estimated by dividing average annual mercury load (kg) by average annual TSS load (Mkg). This relationship is the preferred approach for Delta tributaries with statistically significant mercury and TSS relationships with

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[42] For example, if Leatherbarrow and others' 2005 load estimates of 83 kg/yr mercury and 450 Mkg/yr TSS are incorporated in the WY2000-2003 budget in Table 7.16, inputs would exceed exports, implying that the Delta is depositional.

flow because it provides a flow-weighted estimate. The ratio was also estimated from the slope of the regression between mercury and TSS using paired samples. The least acceptable method is to take the median of the mercury to TSS ratios computed from individual paired samples. The median value tends to overemphasize low and moderate flows (the flows sampled most often) and not high flow events, which transport the majority of the suspended sediment and mercury. All three methods slightly overestimate particulate mercury (the focus of the San Francisco Bay sediment goal of 0.2 mg/kg) because none subtract the dissolved fraction from the total mercury concentration.

The San Francisco TMDL for mercury includes a sediment objective of 0.2 mg/kg (Johnson and Looker, 2004; SFBRWQCB, 2006). Mercury contamination on sediment (TotHg:TSS) in Delta outflow to San Francisco Bay averaged between 0.17 mg/kg and 0.30 mg/kg (Tables 7.14 and 7.17). The lower values are from estimates of mercury and suspended sediment loads at Mallard Island that attempt to better address tidal dispersion from the Bay area. The higher values are based on measurements taken in mid channel at X2. The higher values may overestimate the degree of mercury contamination being exported from the Central Valley to San Francisco Bay. The major source of mercury and sediment to the Delta is from the Sacramento Basin. Suspended sediment ratios for the Sacramento River and Yolo Bypass range between 0.16 and 0.24 mg/kg of mercury (Table 7.17), which are more similar to the flow-weighted average particulate concentration of 0.20 for WY2002-2006 calculated by David and others (2009) (see Table 7.14). These values are also consistent with bulk sediment concentrations in the Delta of 0.15 to 0.2 mg/kg determined by Slotton and others (2003) and Heim and others (2003). The results suggest that the contaminated sediment at X2 did not entirely originate from the Central Valley during the study period.

The X2 TotHg:TSS ratios of 0.28 to 0.30 mg/kg are similar to suspended sediment mercury concentrations of 0.33 mg/kg in San Pablo Bay (Schoellhamer, 1996) and bulk surficial sediment mercury concentrations in Suisun Bay of 0.3 to 0.35 ppm (Slotton *et al.*, 2003; Heim *et al.*, 2003). Hornberger and others (1999) report that the mercury concentration of sieved surficial sediment (<0.64 µm) in a core from Suisun Bay was 0.30 mg/kg; however, the concentration increased to 0.95 mg/kg at a depth of 30 cm. The mercury enriched zone persisted to a depth of about 80 cm before declining to a baseline concentration of 0.06 ±0.01 mg/kg. The increased mercury concentration at 30 cm was ascribed to deposition of mercury contaminated gold tailings. No current information is available on erosion rates in Suisun and Grizzly Bays but both embayments were eroding at the rate of 528 Mkg per year between 1942 and 1990 (Cappiella *et al.*, 2001). Therefore, a hypothesis is that the elevated mercury contamination on suspended sediment particles at X2 is the result of continuing erosion from Suisun Bay and possibly San Pablo Bay. Both embayments are within the legal jurisdiction of the San Francisco Bay Water Board and are part of its San Francisco Bay TMDL for mercury.

Urban runoff and almost all Delta inputs have mercury to TSS ratios greater than 0.2 mg/kg (Table 7.17). Exceptions are the San Joaquin River, Ulatis Creek, and Yolo Bypass. An evaluation of the tributary sources to the Sacramento River and Yolo Bypass indicates that all but the Sacramento River above Colusa, Sacramento Slough and Colusa Basin Drain have ratios greater than 0.2 mg/kg. A comparison of Table 7.5 and Table 7.17 indicates that several tributaries in the Sacramento Basin have high mercury to TSS ratios and large loads of mercury.

Cache Creek and Feather River have high ratios and high average annual total mercury loads. The American River and Putah Creek also have high ratios but comparatively smaller mercury loads. The Feather, American, Putah and Cache watersheds have waterways that are already identified on the 303(d) List as mercury-impaired. Having 303(d) Listed waterways and exports with elevated mercury to TSS ratios makes these watersheds attractive candidates for remediation efforts during the initial implementation phases of the Delta and upstream mercury control programs.

In contrast, the Sacramento River above Colusa and Sacramento Slough (which receives most of its annual flows when upper Sacramento River flood waters are diverted to Sutter Bypass) have mercury to TSS ratios (0.12 and 0.13 mg/kg, respectively) comparable to background levels but high mercury loads. This is because both are transporting large amounts of sediment. The 2002 LWA report noted a similar pattern in its evaluation of median mercury to TSS ratios for the Sacramento Basin. Suspended sediment mercury concentrations between 0.03 and 0.19 mg/kg may result from a combination of erosion of background soils and atmospheric deposition from regional and global mercury sources. Therefore, the low mercury to TSS ratios for the upper Sacramento River watershed may indicate, unless site-specific hot spots are found, that very little total mercury could be removed by means other than erosion control.

A recent CalFed study evaluated particulate mercury by subtracting the dissolved (filter passing) fraction from the total mercury concentration and developed ratios with suspended sediment concentration (particulate Hg:SSC) for different Central Valley watersheds to determine the basins exporting the most contaminated sediment and likely responsible for a disproportionate amount of the downstream methylmercury production (Louie *et al*., 2008). Although using an alternative method (analysis for SSC rather than TSS), the CalFed study also determined that the American River, Feather River, Cache Creek Settling Basin outflow, and Putah Creek have elevated particulate Hg:SSC ratios, and that the Cosumnes and Mokelumne Rivers upstream of their confluence had elevated Hg:SSC ratios, 0.28 mg/kg and 0.18 mg/kg, respectively. (For comparison, the total Hg:SSC values for the Cosumnes and Mokelumne Rivers calculated by Louie and others were 0.41 and 0.22 mg/kg, respectively.) Several watershed characteristics, including its high Hg:TSS ratio make the Cosumnes River, in addition to the before-mentioned watersheds, an attractive candidate for remediation efforts during the initial implementation phases of the Delta and upstream mercury control programs; these characteristics are discussed in Section 8.2 in Chapter 8.

The Louie and others 2008 CalFed study also developed Hg:SSC ratios for numerous sites in the upper Sacramento and San Joaquin watersheds; these will be useful for evaluating potential sources of mercury-contaminated sediment when TMDL control programs are developed for the upstream watersheds during the first phase of the Delta mercury control program's implementation.

Table 7.17: Mercury to Suspended Sediment Ratios for Delta Inputs and Exports

	# of TotHg/TSS Paired Samples	**Method A** (a) TotHg Load ÷ TSS Load		**Method B** Linear Regression Slope for Paired TotHg/TSS (b)	**Method C** Median of TotHg/TSS Paired Sample Results
		WY2000-2003	WY1984-2003		
DELTA INPUTS					
Bear/Mosher Creeks	4	0.12		0.07	0.24
Calaveras River	4	0.25		0.17	0.41
French Camp Slough	4	0.70		0.63	0.30
Marsh Creek	7	0.49		0.12	0.19
Mokelumne River downstream of the Cosumnes River	20	0.37		0.37	0.42
Morrison Creek (c)	15	0.18		0.15	0.22
Prospect Slough (Yolo Bypass)	44	0.19	0.17	0.18	0.20
Sacramento River (Freeport)	134	0.21	0.21	0.17	0.24
San Joaquin River	29	0.13	0.13	0.13	0.14
Ulatis Creek	4	0.13		0.11	0.14
Urban Runoff (d)	128 (123)	0.31		0.18 (0.22)	0.35
DELTA EXPORTS					
Outflows to San Francisco Bay (X2)	20	0.29		0.30	0.28
State Water Project	19	0.24		0.18	0.29
Delta Mendota Canal	22	0.18		0.16	0.18
Dredging (e)	*8 projects*	0.19		- - -	0.03 to 0.41
TRIBUTARIES TO THE SACRAMENTO BASIN [Sacramento River + Yolo Bypass]					
American River	109	0.50	0.27	0.20	0.41
Cache Creek Settling Basin	21	0.39	0.45	0.48	0.36
Colusa Basin Drain	56	0.09		0.09	0.07
Feather River	60	0.29	0.31	0.26	0.33
Natomas East Main Drain (Arcade Ck.)	8	0.64		0.38	0.45
Putah Creek	29	0.45	0.55	0.26	0.30
Sacramento River above Colusa	47	0.12	0.12	0.12	0.11
Sutter Bypass (Sacramento Slough)	52	0.14		0.13	0.13

(a) The preferred method for each monitoring location is highlighted in gray. If total mercury concentrations and TSS concentrations both correlated well with daily flow at a given monitoring location, Method A was the preferred method for estimating suspended sediment mercury concentrations. If the available concentration data for a location were too variable and/or sparse to reliably estimate annual average suspended sediment concentrations, none of the values were highlighted. The WY1984-2003 period was evaluated only for Sacramento Basin tributaries because the other tributary loads are based on average concentrations, resulting in the same TotHg:TSS ratios for both periods.

(b) Regressions between total mercury and TSS concentrations are illustrated in Appendix I.

(c) Appendix I provides the data for each Morrison Creek sampling location.

(d) Urban runoff samples were collected at eleven locations. Methods B and C were performed between the urban runoff total mercury and TSS concentration data with and without five dramatically different sample TotHg:TSS ratios observed for Strong Ranch Slough.

(e) Sediment mercury concentrations in dredged material varied substantially across the Delta. The range of project-specific average concentrations was 0.02 to 0.77 mg/kg. The volume-weighted average mercury concentration of all the dredged material was approximately 0.19 mg/kg.

7.4.2 Compliance with the USEPA's CTR

The USEPA's California Toxic Rule mercury criterion is 0.05 µg/L (50 ng/l) total recoverable mercury for freshwater sources of drinking water. The CTR criterion was developed to protect humans from exposure to mercury in drinking water and in contaminated fish. It is enforceable for all waters with a municipal and domestic water supply or consumption of aquatic organisms beneficial use designation. This includes all subareas of the Delta. The CTR does not specify duration or frequency. As noted in Chapter 2, the Central Valley Water Board has previously employed a 30-day averaging interval with an allowable exceedance frequency of once every three years for protection of human health.

Mercury samples were not collected at a sufficiently high frequency to evaluate compliance with a 30-day average interval. Data therefore do not exist to show whether the CTR has actually been exceeded. To evaluate compliance with the CTR, regression analyses of flow and concentration were used to estimate 30-day running averages. As described in Sections 7.1.1.1 through 7.1.1.3, total mercury concentrations measured in instantaneous grab samples at Delta and Sacramento Basin tributary locations near flow gages were regressed against daily flow to determine if total mercury concentrations for days with no concentration data could be predicted. Figures 7.4 and 7.5 illustrate the regression-based 30-day running averages for locations with statistically significant ($P<0.01$) TotHg/flow correlations. Appendix I provides the TotHg/flow regressions upon which the 30-day averages are based. Table 7.18 provides a summary of the CTR compliance evaluation.

A waterway location was considered to be in compliance if its regression-based 30-day average total mercury exceeded 50 ng/l no more than once in any three-year period. Some locations had total mercury/flow regressions that were not statistically significant; also, some locations with concentration data were not near a flow gage. Such locations on larger waterways (e.g., Mokelumne River and San Joaquin River) were considered likely to be in compliance if none of the grab samples had mercury concentrations that exceeded 50 ng/l. Locations on small tributaries that typically experience short-duration, storm-related high flow events (e.g., French Camp Slough and Ulatis Creek) were considered likely to be in compliance if none of the water samples had mercury concentrations exceeding 50 ng/l, or if the exceedances occurred only during peak storm flows.

The evaluation of regression-based 30-day running average total mercury concentrations and available grab sample total mercury results indicates that all sampled locations within the Delta – except possibly Prospect Slough and Marsh Creek – are in compliance with the CTR criterion for total mercury. Although none of the grab samples collected from Marsh Creek near Highway 4 exceeded 50 ng/l total mercury, the regression-based 30-day running averages indicated that the CTR criterion might have been exceeded during one period. However, only about three years of flow data were available for the Marsh Creek location; therefore, compliance with the CTR criterion cannot be adequately determined with available data. Marsh Creek is already identified on the 303(d) List as impaired by mercury. The future mercury TMDL monitoring program for Marsh Creek will conduct another evaluation of CTR compliance as more data become available and the TMDL can incorporate total mercury load reduction requirements as needed to comply with the CTR.

Evaluation of Yolo Bypass compliance with the CTR is complicated by the variety of watersheds that contribute water to it during varying hydrologic regimes. During low flow conditions, the Yolo Bypass receives flows from coastal mountain watersheds, particularly Cache Creek and Putah Creek, and other agricultural and native areas that drain directly to the bypass (Figure 7.1). During high flow conditions on the Sacramento River, excess flows from the upper Sacramento River, Sutter Bypass, Feather River, Colusa Basin, and American River watersheds may be routed down the Yolo Bypass at Fremont Weir, Sacramento Bypass and Knights Landing Ridge Cut. In a typical storm event, flows from the Cache Creek Settling Basin and other local sources reach the Yolo Bypass first, to be followed by lower concentration inputs from the Colusa Basin, Sacramento River and Feather River.

As indicated in Figure 7.4 and described in detail in Appendix E (Section E.2.2 and Figure E.3), the Yolo Bypass may not experience 30 days of continuous net outflow from Lisbon Weir upstream of Prospect Slough during dry years. In addition, storm data collected in 1995 indicate that total mercury concentrations in Prospect Slough (the primary outflow from the Bypass to the Delta) peak for a very short time. To evaluate conditions within the Bypass, the total mercury levels in tributary inputs to the Bypass were evaluated (Figure 7.5). The regression-based 30-day averages of predicted total mercury concentrations in the Sacramento River upstream of Colusa, Putah Creek and Feather River indicate that their flows are in compliance with the CTR criterion. However, the regression-based 30-day running average total mercury concentrations in Cache Creek Settling Basin outflows indicate that Cache Creek flows into the Yolo Bypass are not in compliance with the CTR criterion. This implies that when the Bypass is dominated by flows from Cache Creek, it may not be in compliance with the CTR criterion. Therefore, the Yolo Bypass area downstream of the Cache Creek Settling Basin probably does not meet the CTR criterion.

The Basin Plan Amendment for control of mercury in Cache Creek was adopted by the Central Valley Water Board in October 2005. As outlined in the Cache Creek TMDL Basin Plan Amendment report (Cooke and Morris, 2005), implementation actions would enable CTR compliance in outflows from Cache Creek. In order to meet the mercury loading allocation assigned to the Central Valley by the San Francisco Bay mercury TMDL control program, the total mercury reduction strategy described in Chapter 8 (Section 8.2) assigns a 110 kg/yr load reduction to tributary inputs to the Delta, a 28% load reduction compared to the current 20-year average input of 395 kg/yr (see Table 7.1). Initial reduction efforts should focus on watersheds that contribute the most mercury-contaminated sediment to the Delta and Yolo Bypass, such as the Cache Creek, American River, Putah Creek, Cosumnes River, and Feather River watersheds. These waterways, except the Cosumnes River, are already identified on the 303(d) List as impaired by mercury. If future monitoring indicates that Cache Creek Settling Basin outflows to the Yolo Bypass do not comply with the CTR even after proposed total mercury reductions are achieved, and other reductions designed to accomplish safe fish tissue methylmercury levels in Cache Creek are achieved, additional reductions will be required.

Key points for the total mercury source analysis are listed after Figures 7.4 and 7.5 and Table 7.18.

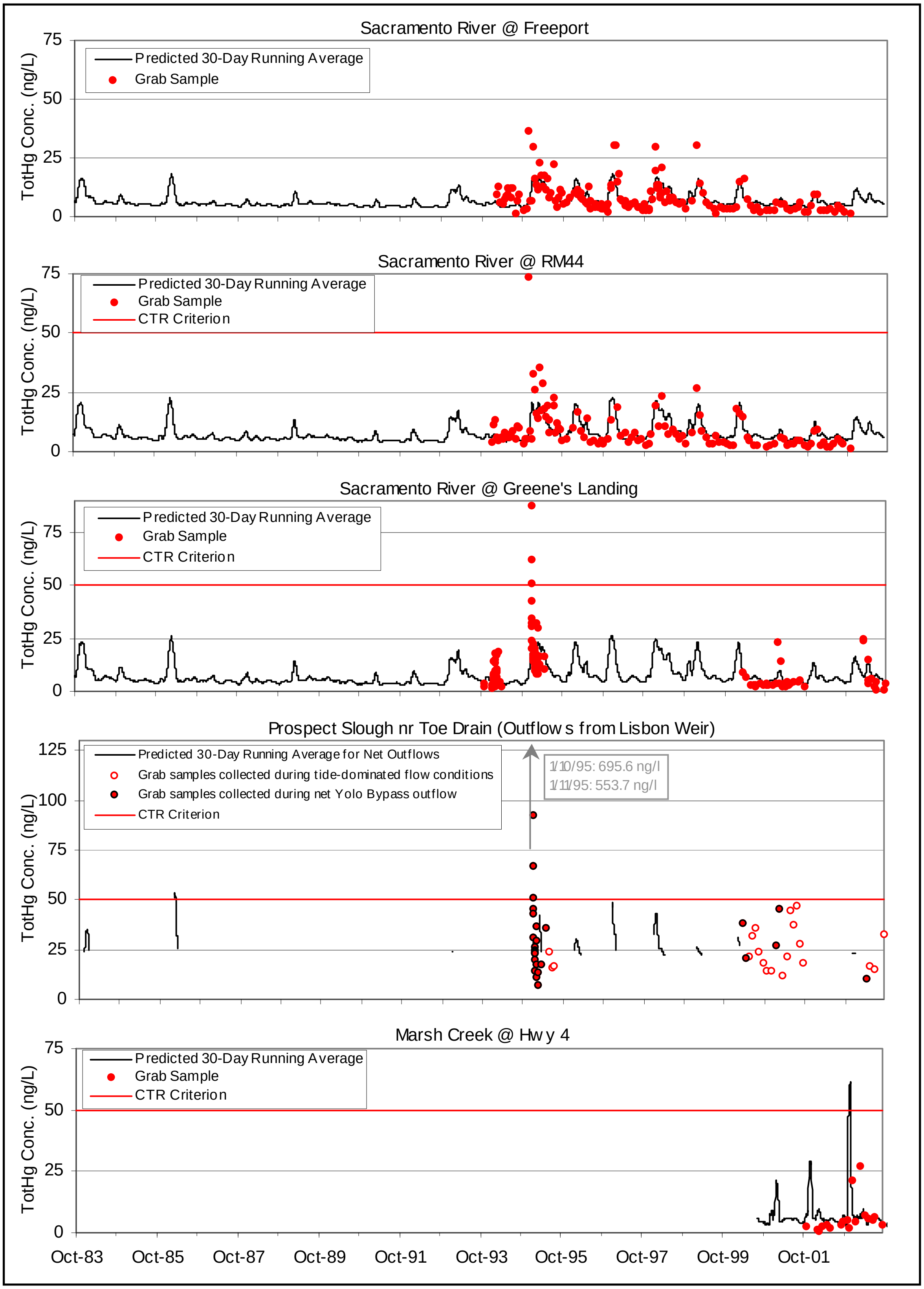

Figure 7.4: Grab Sample and Regression-Based 30-Day Running Average Total Mercury Concentrations for Delta Locations with Statistically Significant (P<0.05) Aqueous TotHg/Flow Correlations

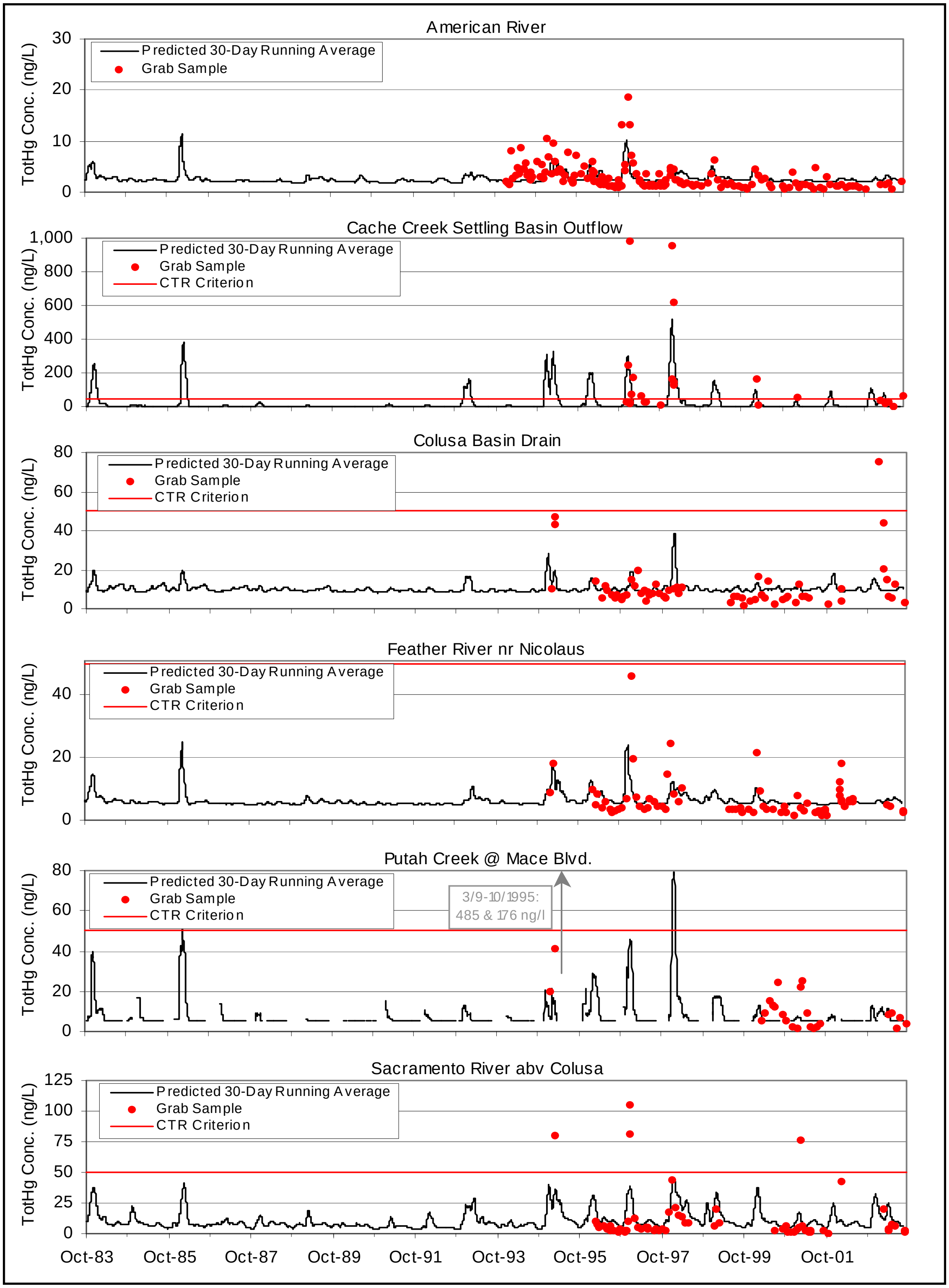

Figure 7.5: Grab Sample and Regression-Based 30-Day Running Average Total Mercury Concentrations for Sacramento Basin Tributary Locations with Statistically Significant (P<0.05) Aqueous TotHg/Flow Correlations

Table 7.18: Evaluation of CTR Compliance at Delta and Sacramento Basin Tributary Locations

Site	Is TotHg/Flow Regression Significant? (a)	Does Predicted 30-Day Average TotHg Concentration Ever Exceed the CTR (50 ng/l)? (a)	# of Grab Samples > 50 ng/l	Is the Site in Compliance with CTR?
DELTA LOCATIONS				
Bear/Mosher Creeks (b)	- - -	- - -	0	Likely Yes
Calaveras River @ RR u/s West Lane (b)	- - -	- - -	0	Likely Yes
Delta Mendota Canal	No	- - -	0	Likely Yes
French Camp Slough near Airport Way	- - -	- - -	1	Likely Yes
Marsh Creek @ Hwy 4	Yes	Once in 3 year record.	0	***Possibly Not***
Mokelumne River @ I-5	No	- - -	0	Likely Yes
Morrison Creek (c)	- - -	- - -	0	Likely Yes
Outflow to San Francisco Bay	No	- - -	0	Likely Yes
Prospect Slough (Yolo Bypass) (d)	Yes	Once (d).	5	***Possibly Not***
Sacramento River @ Freeport (e)	Yes	No.	0	Yes
Sacramento River @ Greene's Landing (e)	Yes	No.	4	Yes
Sacramento River @ RM44 (e)	Yes	No.	1	Yes
San Joaquin River @ Vernalis	No	- - -	0	Likely Yes
State Water Project	No	- - -	0	Likely Yes
Ulatis Creek near Main Prairie Rd	- - -	- - -	2	Likely Yes
SACRAMENTO BASIN TRIBUTARIES (f)				
American River @ Discovery Park	Yes	No.	0	Yes
Cache Creek d/s Settling Basin	Yes	In 11 of 20 years.	15	***No***
Colusa Basin Drain	Yes	No.	2	Yes
Feather River near Nicolaus	Yes	No.	0	Yes
Natomas East Main Drain (g)	- - -	- - -	1	Unknown
Putah Creek @ Mace Blvd. (h)	Yes	Twice, not within 3 years.	4	Likely Yes
Sacramento River above Colusa	Yes	No.	4	Yes
Sacramento Slough near Karnak (i)	No	- - -	0	Likely Yes

Table 7.18 Footnotes:

(a) Flow gage data were not available for most of the small tributary outflows to the Delta. All of the regressions for sampling locations near a flow gage were based on 20-year flow datasets except for Marsh Creek, for which only a 3-year dataset was available. Regressions were considered statistically significant for R^2 values with $P < 0.05$. Appendix I provides the regression plots.

(b) Only wet weather events were sampled on the Calaveras River and Bear and Mosher Creeks in Stockton. The one wet weather Mosher Creek sample result was combined with the Bear Creek dataset to evaluate compliance for both creeks.

(c) Concentration data collected at multiple sites on lower Morrison Creek were compiled to evaluate compliance.

(d) Sampling took place at Prospect Slough (export location of the Yolo Bypass) both when there were net outflows from tributaries to the Yolo Bypass and when there was no net outflow (i.e., the slough's water was dominated by tidal waters from the south). The regression analysis focuses only on the conditions when there was net outflow from the Yolo Bypass. Available flow information (Appendix E) indicates that during many years, the Yolo Bypass does not have a net outflow that lasts for 30 days or more.

(e) The Sacramento River sampling locations at Freeport and River Mile 44 (RM44) are upstream and downstream, respectively, of the outfall for the SRCSD WWTP. Greene's Landing is about nine miles downstream of the RM44 sampling location. Concentration data collected at all three sites were regressed against the flow data recorded at the Freeport gage, as no other gages are operational in this river reach. Appendix L provides the TotHg concentration data available for all three locations.

(f) Flows from the listed tributary watersheds may be diverted to the Yolo Bypass during high flow conditions via Knights Landing Ridge Cut, Fremont Weir and Sacramento Weir. The Coon Creek/Cross Canal watershed also contributes to the Sacramento River downstream of the Feather River but no aqueous TotHg data are available for its discharges.

(g) No concentration or flow data gage data were available for Natomas East Main Drain outflows. The SRWP, USGS and City of Roseville collected TotHg concentration data on Arcade Creek near Norwood and Del Paso Heights and Dry Creek. It was assumed that this dataset characterizes NEMD outflows.

(h) The predicted 30-day concentrations for Putah Creek are based on modeled flows (see Appendix E) estimated since the June 2006 draft TMDL Report. Although the regression between modeled flow and concentration is statistically significant ($P < 0.05$), there is greater uncertainty in the predicted 30-day concentrations. Two grab samples collected from a storm event in March 1995 and two grab samples from a storm event in February 2004 had TotHg concentrations greater than 50 ng/l: March 9 and 10, 1995: 485 and 176 ng/l; and February 18 and 25, 2004: 126 and 53 ng/l. Figure 7.5 does not illustrate grab samples collected after WY2003.

(i) Sacramento Slough near Karnak is the low flow channel for Sutter Bypass.

Key Points

- The primary sources of total mercury in the Delta include tributary inflows from upstream watersheds, atmospheric deposition, urban runoff, and municipal and industrial wastewater. Losses include flow to San Francisco Bay, water exports to southern California, removal of dredged sediments and evasion.
- The Sacramento Basin (Sacramento River + Yolo Bypass) contributed 83 to 87% of the mercury load to the Delta. Most of the material was transported during high flows.
- Estimated mercury exports rates to San Francisco Bay are quite variable. This precludes accurate calculations of erosion/deposition rates in the Delta and assessment of compliance with the proposed San Francisco Bay mercury allocation to the Central Valley at Mallard Island.
- The Cache Creek, Feather River, American River, Cosumnes River, and Putah Creek watersheds had both relatively large mercury loadings and high mercury to TSS ratios, making them attractive candidates for remediation efforts during the initial implementation phases of the Delta and upstream mercury control program.

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8 METHYLMERCURY ALLOCATIONS, TOTAL MERCURY LIMITS & MARGIN OF SAFETY

This chapter presents recommended point and nonpoint methylmercury allocations and watershed total mercury limits for methyl and total mercury sources to the Delta. Reductions in ambient water methylmercury concentrations are required to reduce methylmercury concentrations in fish. Reductions in total mercury loads are needed to enable water and fish methylmercury reductions and to comply with the USEPA's CTR criterion for human protection and the San Francisco Bay mercury TMDL control program's total mercury allocation for the Central Valley. Section 8.1 describes the proposed methylmercury load and waste load allocations for within-Delta and tributary inputs. Section 8.2 describes the proposed watershed total mercury limit. Sections 8.3 and 8.4 describe the associated margin of safety and inter-annual and seasonal variability.

The methylmercury allocations and total mercury limits described in this chapter reflect the preferred implementation alternative described in Chapter 4 of the draft Basin Plan Amendment staff report and are designed to address the beneficial use impairment in all subareas of the Delta as well as in the San Francisco Bay. However, as described in the draft Basin Plan Amendment report, a number of alternatives are possible. The Central Valley Water Board will consider a variety of allocation strategies and implementation alternatives as part of the Basin Plan amendment process.

8.1 Methylmercury Load Allocations

Since the June 2006 draft TMDL and Basin Plan Amendment staff reports issued for scientific peer review, staff made the following changes to this section in response to comments made by the scientific peer reviewers and other agencies and stakeholders:

- Developed allocations only for dischargers within the legal Delta and the Yolo Bypass (including the portion north of the legal Delta), versus the legal Delta and all dischargers within 30 miles of the legal Delta boundary.
- Provided additional explanation of, and calculations for, the proposed methylmercury allocations to more directly address expected increases in source loading from predicted population growth and wetland restoration efforts and to acknowledge the efforts of those point sources whose effluent quality demonstrates good performance.
- Changed the methylmercury allocation strategy such that all point and nonpoint sources have load-based (versus load- and concentration-based) allocations to allow for a greater range of implementation options.
- Established percent allocations for tributary inputs based on a methylmercury concentration of 0.05 ng/l (rather than 0.06 ng/l, the proposed methylmercury goal for ambient water) to reserve assimilative capacity for methylmercury flux from sediments in open-water and wetland habitats and agricultural lands, and point source discharges within the Delta/Yolo Bypass with discharge methylmercury concentrations that exceed 0.06 ng/l.

- Re-calculated all allocations based on existing methylmercury discharge concentrations rounded to two decimal places and existing methylmercury loads rounded to two significant digits.
- Re-organized the text to avoid redundancy with allocation strategy explanations provided in Chapter 4 of the draft Basin Plan Amendment staff report and to improve clarity.

Since the February 2008 draft TMDL and Basin Plan Amendment staff reports issued for public review, staff made the following changes to this section in response to input from the 2008-2009 Stakeholder Process and written stakeholder comments submitted before the April 2008 hearing meeting:

- Adjusted the method for calculating the waste load allocations for NPDES facilities to better address regionalization efforts and population growth.
- Updated the waste load allocations for NPDES facilities to reflect that several facilities no longer discharge to surface waters and that new facility discharges have begun since the TMDL period, WY2000-2003.
- Added to text to clarify how the waste load allocations are applied to MS4 service areas and other point and nonpoint sources.
- Adjusted the load allocations for tributary inputs and open-water habitat in all Delta subareas to incorporate the same percent reductions required for other point and nonpoint sources that discharge to those subareas (rather than setting tributary input allocations equal to the load calculated using a methylmercury concentration of 0.05 ng/l, and setting open water allocations equal to existing average annual methylmercury loads, as was done in the February 2008 draft report).
- Added text to clarify how waste load and load allocations are calculated.

8.1.1 Definition of Assimilative Capacity

A water body's loading capacity (assimilative capacity) represents the maximum rate of loading of a pollutant that the water body can assimilate without violating water quality standards. A TMDL typically represents the sum of all individual allocations of the water body's assimilative capacity and must be less than or equal to the assimilative capacity. Allocations are divided among "waste load allocations" for point sources and "load allocations" for nonpoint sources including natural background. The TMDL is the sum of these components:

Equation 8.1:

$$\text{TMDL} = \text{Waste Load Allocations} + \text{Load Allocations}$$

For the Delta methylmercury TMDL, waste load allocations apply to discharges from existing and future NPDES-permitted WWTPs and MS4s within the Delta and Yolo Bypass. Load allocations apply to methylmercury flux from existing and future wetland and open-water sediments and agricultural lands and atmospheric deposition within the Delta and Yolo Bypass, as well as to tributary inputs to the Delta/Yolo Bypass. Natural background sources include atmospheric deposition, methylmercury flux from wetland and open-water sediments, and runoff from upland areas that existed prior to human-related pollution emissions such as mercury-contaminated sediment from historical mining activities in the tributary watersheds, mercury emissions from local and international industrial and municipal sources, and water management activities. Natural background sources are incorporated in the load allocations for wetlands, open water, and atmospheric deposition because data were not available to distinguish between natural background and nonpoint sources.

A TMDL need not be stated as a daily load (Code of Federal Regulations, Title 40, §130.2[i]). Other measures are allowed if appropriate. The methylmercury allocations proposed in Table 8.4 at the end of Section 8.1.3 are expressed in terms of average annual loads because the adverse effects of mercury occur through long-term bioaccumulation. The allocations are intended to represent annual averages and account for both seasonal and long-term variability. The annual load and waste load allocations can be expressed in daily terms by simply dividing each allocation by 365.[43] However, to best attain and maintain the proposed fish tissue objectives, staff recommends that the allocations be implemented as average annual loads.

Methylmercury allocations were made in terms of the existing assimilative capacity of each of the different Delta subareas. A methylmercury TMDL must be developed for each Delta subarea because the sources and percent reductions needed to meet the proposed implementation goal are different in each subarea. The linkage analysis (Chapter 5) described the calculation of an implementation goal for methylmercury in ambient water that is linked to the fish tissue methylmercury targets. The recommended implementation goal is an annual average concentration of 0.06 ng/l methylmercury in unfiltered water. This goal describes the assimilative capacity of Delta waters in terms of concentration (Section 5.2). Central Valley Water Board staff anticipates that as the average concentration of methylmercury in each Delta subarea decreases to the safe aqueous goal, the targets for fish tissue will be attained. To determine necessary reductions, the existing average aqueous methylmercury levels in each Delta subarea were compared to the methylmercury goal (Table 8.1).

The amount of reduction needed in each subarea is expressed as a percent of the existing concentration. As noted in the linkage analysis, the aqueous methylmercury goal was developed using water data for March to October 2000 because this was the only period for which there was overlap between water data and the lifespan of the fish. Table 8.1 compares the proposed goal to average methylmercury concentrations for March to October 2000 (Scenario A) and for March 2000 to April 2004 (Scenario B). Scenario B is based on a much larger dataset and includes values for all seasons. However, the percent reductions are similar for both scenarios and range from 0 to 80% for the different subareas. Therefore, staff recommends the use of the proposed reductions listed in Scenario B for the calculation of assimilative capacity.

The assimilative capacity of each subarea (Table 8.2) was determined using the proposed reductions listed in Scenario B in Table 8.1 (except for the Central and West Delta subareas, as

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[43] In its November 2006 memorandum concerning appropriate time increments for TMDLs, the USEPA recommended that States provide written documentation regarding how the TMDL allocations can be expressed in daily terms (USEPA, 2006).

discussed in the next paragraphs), the sum of existing annual methylmercury inputs from identified sources (see Table 8.4 at the end of Section 8.1.3) and the following equation:

Equation 8.2: *(using the Sacramento subarea as an example)*

$$
\begin{aligned}
\begin{array}{c}\text{Assimilative}\\ \text{Capacity (g/yr)}\end{array} &= \begin{array}{c}\text{Existing MeHg}\\ \text{Inputs (g/yr)}\end{array} - \left[\begin{array}{c}\text{\% Reduction Needed to}\\ \text{Meet Proposed Goal}\end{array} * \begin{array}{c}\text{Existing MeHg}\\ \text{Inputs (g/yr)}\end{array}\right] \\
&= 2{,}418 \text{ g/yr} - (44\% * 2{,}418 \text{ g/yr}) \\
&= 1{,}354 \text{ g/yr}
\end{aligned}
$$

The subareas on the eastern boundary of the Delta require substantial reductions in fish and aqueous methylmercury levels. In contrast, ambient methylmercury concentrations in the Central and West Delta subareas equal or approach the proposed aqueous methylmercury goal of 0.06 ng/l, resulting in the need for little-to-no reductions in methylmercury inputs to these subareas. The Central and West Delta subareas receive methylmercury from within-subarea sources, tributaries that drain directly to the subareas, and flows from upstream Delta subareas. The Central Delta subarea receives flows from the Sacramento, Yolo Bypass, Mokelumne, and San Joaquin subareas. The West Delta subarea receives flows from the Central Delta and Marsh Creek subareas. These within-Delta flows have not yet been quantified because additional data are needed for loss rates across the subareas. However, methylmercury in these subarea inflows are expected to decrease substantially (e.g., 40-80%) as upstream methylmercury and mercury management practices take place because methylmercury source load reductions ranging from 44 to 80% are required for the upstream subareas to achieve their assimilative capacities. In addition, the primary within-subarea source of methylmercury in the Central and West Delta subarea is flux from open-water habitat sediments (Table 8.4), which is expected to decrease as mercury reduction projects take place in the tributary watersheds that result in decreasing the mercury concentration of sediment deposited in the Central and West Delta subareas. Therefore, staff recommends that no reduction be required for point and nonpoint source methylmercury discharges within the Central and West Delta subareas. Section 8.1.2 describes an allocation strategy that ensures that fish and water methylmercury concentrations in these subareas remain in compliance with the proposed fish tissue objectives and methylmercury goal for water. The Central Valley Water Board can consider modification of the allocation strategy and the creation of new allocations (e.g., for within-Delta flows between subareas) during the program review proposed to take place in about seven years based on existing and new information that becomes available.

The following three sections describe the strategy and calculations used to determine specific allocations for point and nonpoint sources listed in Table 8.4 for each of the subareas.

Table 8.1: Aqueous Methylmercury Reductions Needed to Meet the Proposed Methylmercury Goal of 0.06 ng/l. (a)

	Delta Subarea						
	Central Delta	Marsh Creek	Mokelumne River	Sacramento River	San Joaquin River	West Delta	Yolo Bypass
A. Scenario Based on March to October 2000 Aqueous MeHg Data (b)							
Average Aqueous MeHg Concentration (ng/l)	0.055	0.224	0.140	0.120	0.147	0.087	0.305
Percent Reduction Needed to Meet the Proposed MeHg Goal	0%	73%	57%	50%	59%	31%	80%
B. Scenario Based on March 2000 to April 2004 Aqueous MeHg Data (b)							
Average Annual Aqueous MeHg Concentration (ng/l)	0.060	0.224	0.166	0.108	0.160	0.083	0.273
Percent Reduction Needed to Meet the Proposed MeHg Goal	0%	73%	64%	44%	63%	28%	78%

(a) The amount of reduction needed in each subarea is expressed as a percent of the existing methylmercury concentration. For example, the percent reduction needed for the Marsh Creek subarea Scenario A is calculated by: (0.244 - 0.06) / 0.244 = 73%. The average March to October 2000 methylmercury concentration for the Central Delta is below the proposed implementation goal of 0.06 ng/l. As a result, Scenario A calculations for the Central Delta result in negative numbers: A (1): (0.055 - 0.06)/0.055 = -9%. No reduction is needed under Scenario A or B for Central Delta ambient methylmercury.

(b) Average concentrations are based on unfiltered MeHg concentration data collected at the following locations: Delta Mendota Canal and State Water Project (Central Delta); Marsh Creek at Highway 4; Mokelumne River near I-5; Sacramento River at Freeport, RM44 and Greene's Landing; San Joaquin River near Vernalis; outflow to San Francisco Bay measured at X2, usually near Mallard Island (West Delta); and Prospect Slough near Toe Drain (Yolo Bypass). The values for the Central Delta, Mokelumne River, Sacramento River, San Joaquin and West Delta subareas are described in Section 5.1 and Table 5.1 in Chapter 5 and are based on monthly average concentrations so that the average concentrations for each study period are not influenced by the unequal number of samples collected in each month. The Yolo Bypass average concentrations also are based on monthly average concentrations. The sampling frequency on Marsh Creek was inadequate to develop averages for each study period, much less to pool data by month; therefore, the average of all available concentration data was used in both scenarios. The Yolo Bypass and Marsh Creek data are described in Chapter 6, Section 6.2.1 and Table 6.3. It was assumed that the sampling locations are representative of the subareas in which they occur.

Table 8.2: Assimilative Capacity Calculations for Each Delta Subarea.

Delta Subarea	**Existing Average Annual MeHg Conc. (a)** (ng/l)	**% Reduction Needed to Achieve Proposed Goal of 0.06 ng/l (a)**	**Existing Annual MeHg Load from Identified Sources (b)** (g/yr)	**Assimilative Capacity** (g/yr)
Central Delta	0.060	0%	668	668
Marsh Creek	0.224	73%	6.14	1.66
Mokelumne River	0.166	64%	146	52.6
Sacramento River	0.108	44%	2,475	1,385
San Joaquin River	0.160	63%	528	195
West Delta	0.083	0%	330	330
Yolo Bypass [North & South]	0.273	78%	1,068	235

(a) No percent reductions are proposed for the Central and West Delta subareas because their fish tissue and aqueous methylmercury levels either currently achieve or are expected to achieve safe levels when actions are implemented to reduce upstream aqueous methylmercury levels. Proposed reductions for other subareas are from Table 8.1 Scenario B.

(b) "Existing Annual MeHg Load" represents the sum of all identified inputs to each subarea (Chapter 6 and Table 8.4).

8.1.2 Allocation Strategy

Table 8.4 at the end of Section 8.1.4 lists waste load and load allocations for each point and nonpoint methylmercury input by subarea and reflects the preferred implementation alternative and resulting allocation strategy described in Chapter 4 of the draft Basin Plan Amendment staff report. This section summarizes key elements of the preferred allocation strategy developed in the draft Basin Plan Amendment staff report. Section 8.1.3 provides detailed explanations of calculation methods for NPDES facility waste load allocations. Section 8.1.4 describes the equations used to calculate the load and waste load allocations for nonpoint and point sources in each Delta subarea.

The available science is adequate to establish individual allocations for point sources in the Delta/Yolo Bypass and tributary inputs to the Delta/Yolo Bypass, and general (subarea) methylmercury allocations for nonpoint sources within the Delta/Yolo Bypass. The preferred allocation strategy specifies the following:

- Atmospheric deposition and discharges from urban areas outside of MS4 service areas in all Delta subareas have load allocations set at their existing average annual methylmercury loads.
- All point and nonpoint sources in the Central and West Delta subareas have waste load and load allocations set at their existing average annual methylmercury loads to ensure that compliance with the fish tissue objectives is maintained.
- Waste load and load allocations integrate expected expansions to existing sources and new sources.
- Waste load allocations acknowledge the efforts of those point sources whose effluent quality demonstrates good performance, and require improvement by other dischargers.

Anticipated population growth, regional water management changes, and wetland restoration efforts could result in increases in methylmercury loading to the Delta. For example, increasing populations will result in increasing total mercury and methylmercury discharges from municipal WWTPs and urban runoff. The California Department of Finance predicts that populations in the Delta/Yolo Bypass counties[44] will increase 76% to 213% by 2050 (CDOF, 2007), with an average increase of about 120%. (For more discussion on potential regional changes, see Section 8.4.3, “Regional and Global Change”.)

The allocations for each existing source apply to the sum of its existing discharge and any expansion to its discharge in the future, with the exceptions noted in Section 8.1.3. The recommended open-water and wetland methylmercury allocations apply to all wetlands and open-water habitat acreage in each Delta subarea, including current wetlands and future wetland restoration projects. The subarea load allocations for agricultural lands apply to the net difference between methylmercury loads discharged by agricultural lands during the irrigation season and methylmercury loads in irrigation water applied to the agricultural lands. Similarly, the subarea load allocations for wetlands apply to the net difference between methylmercury

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[44] The CDOF predicts the following population increases by 2050: Contra Costa County - 89%, Sacramento County - 76%, San Joaquin County - 213%, Solano County - 105%, and Yolo County - 93% (CDOF, 2007).

loads discharged by wetlands and methylmercury loads in the wetlands' source water (surface water, groundwater and precipitation). The load allocations for agricultural lands, wetlands, and open-water habitat do not include methylmercury loading from atmospheric wet deposition.

The MS4 waste load allocations apply to all urban land use areas within MS4 service areas within each Delta subarea and similarly address loading from current and future urban areas within the MS4 service areas, including but not limited to Caltrans facilities and rights-of-way (NPDES No. CAS000003), public facilities, properties proximate to banks of waterways, industrial facilities, and construction sites. The MS4 waste load allocations do not apply to non-urban land uses within MS4 service areas. The load allocations for agricultural lands, wetlands, and open-water habitat include methylmercury loading from agricultural lands, wetlands, and open water habitat within MS4 service areas. Some MS4s service areas span multiple Delta subareas and therefore have multiple subarea allocations and are listed more than once. The waste load allocations do not apply to urban land within the MS4 service areas that are outside of the legal Delta and Yolo Bypass boundaries. The Contra Costa County MS4 discharges to both the Delta and San Francisco Bay; the subarea allocations in Table 8.4 apply only to the portions of the MS4 service area that discharge to the Delta within the Central Valley Water Quality Control Board's jurisdiction. The waste load allocations for urban land within MS4 service areas include methylmercury loading from atmospheric wet deposition, consistent with how allocations were developed for the recently-adopted San Francisco Bay and Guadalupe River Watershed mercury TMDLs (Johnson and Looker, 2004; SFBRWQCB, 2008). Urban areas were not included in the atmospheric wet deposition load calculations to avoid double-counting. Urban areas not encompassed by a MS4 service area were grouped into a "urban runoff (nonpoint source)" allocation for each Delta subarea, consistent with USEPA's requirements and guidance for establishing waste load allocations for storm water sources (USEPA, 2002).

Staff recommends that methylmercury waste load allocations for NPDES facilities apply to their annual (calendar year) discharge methylmercury loads with one exception. Staff recommends that assessment of compliance with the waste load allocation for the Oakwood Lake Subdivision Mining Reclamation discharges (CA0082783) be assessed as a five-year average annual methylmercury load because its discharges result from flood-control pumping, which can fluctuate with short-term and long-term precipitation patterns. Similarly, annual loads for tributary inputs, urban discharges, open-water habitat, and atmospheric deposition are based on water years 2000 through 2003, a relative dry period, and expected to fluctuate with rainfall and river flow conditions and other environmental factors. As a result, staff recommends that assessment of compliance with load allocations for the tributary inputs, urban areas outside of MS4 service areas, open-water habitat, and atmospheric deposition, and waste load allocations for the MS4s, be based on five-year average annual loads. As described in the draft Basin Plan Amendment staff report, staff recommends that a Delta mercury control program review take place in about seven years, during which the allocations can be revised to include available wet year data and other new information.

Methylmercury data were not available for inputs to the Yolo Bypass from Willow Slough and runoff from the Dixon area. The average methylmercury concentration for Ulatis Creek was used to estimate their inputs to the Yolo Bypass because they have similar land uses as the Ulatis Creek watershed. This assumption, and the resulting tributary load allocations, may need to be re-evaluated during the control program review. In addition, no methylmercury load estimates were made for other small drainage areas for which no methylmercury concentration data were available: Manteca-Escalon, Bethany Reservoir, Antioch, and Montezuma Hills areas). These areas contribute only about one third of a percent of all water inputs to the Delta/Yolo Bypass. Their methylmercury inputs to the Delta and Yolo Bypass are encompassed by the margin of safety incorporated in all other allocations (see Section 8.3 for more information about the margin of safety). Their potential methylmercury loading will be evaluated during the control program review and allocations assigned as needed.

8.1.3 Calculation Methods for NPDES Facility Waste Load Allocations

Staff assumed that, in general, NPDES-permitted WWTP discharges throughout the Delta/Yolo Bypass would increase by 120%. Staff assumed that half of that growth will be addressed by expansions to existing facilities in each Delta subarea, and that the remaining half will be serviced by new facilities in each subarea. Table 8.3 at the end of this section illustrates WWTP effluent volumes discharged to each Delta subarea (based on volumes identified in Table 6.5 in Chapter 6 for WWTPs that were discharging to surface water during the WY2000-2003 TMDL period), the amount of discharge volume increase expected in each subarea, and the discharge volume that staff assumed will be addressed by existing and new facilities.

Results from methylmercury monitoring by NPDES facilities in the Delta and upstream tributary watersheds indicate that many facilities have average effluent methylmercury levels that approach or are less than the proposed implementation goal for unfiltered methylmercury in Delta waters (0.06 ng/l), while other facilities have much higher methylmercury levels (see Chapter 6 and Appendix G in the TMDL Report and Bosworth *et al*., 2010). This indicates that some discharges, though they contribute methylmercury loading to the Delta, may act as dilution because of their low methylmercury concentrations.

Staff recommends that source discharges with average methylmercury concentrations below the proposed aqueous methylmercury goal of 0.06 ng/l be considered dilution and assigned a waste load allocation based on their existing discharge methylmercury concentration. There are four NPDES-permitted facilities that discharged during the WY2000-2003 TMDL period with effluent that had methylmercury concentrations less than 0.06 ng/l that still (as of February 2010) discharge to surface water: Brentwood WWTP, Deuel Vocational Institute WWTP, Oakwood Lake Subdivision Mining Reclamation, and Woodland WWTP. The “Concentration Used to Calculate Allocation” in Table 8.4 for these sources was set at the existing discharge methylmercury concentration for each of these dischargers.

Conceptually, there is no need to limit the loading from sources that act as dilution, given the overall extent of impairment throughout the Delta. However, to enable the calculation of allocations required for other sources, load-based allocations must be calculated even for those sources that act as dilution. Staff assumed that the three municipal WWTPs with discharges less than 0.06 ng/l would increase their discharge volume by 60% to account for future population growth, with one exception. The Central Valley Water Board recently adopted new waste discharge requirements for the City of Woodland WWTP (Order No. R5-2009-0010) that allow it to increase its design daily average effluent flow capacity from 7.8 mgd to 10.4 mgd. As a result, staff used 10.4 mgd rather than 160% of the WY2005 effluent flow (1.6 * 6.05 mgd =

9.7 mgd). Staff calculated the methylmercury waste load allocations for the Brentwood WWTP and Deuel Vocational Institute WWTP shown in Table 8.4 by multiplying their existing average effluent methylmercury concentrations by their current discharge volumes (shown in Table 8.3) multiplied by 160%.

Staff also calculated "Unassigned NPDES Facility Allocations" in Table 8.4 for each subarea to address new NPDES discharges. Staff assumed that new WWTPs would be designed to discharge effluent with methylmercury concentrations equal to or less than 0.06 ng/l, and calculated the "Unassigned WWTP allocations" by multiplying the predicted volumes shown in Table 8.3a by 0.06 ng/l methylmercury. As discussed in the footnotes for Table 8.3a, the predicted volumes have been modified since the February 2008 draft report to account for new facility discharges to surface water that recently began or are about to begin and therefore were given facility-specific allocations in Table 8.4.

To calculate allocations for WWTPs with effluent methylmercury concentrations greater than 0.06 ng/l, staff used the existing effluent volumes (rather than multiply the existing volumes by 160%) and the percent allocation calculation method described in the next section. Although these facilities may need to increase their discharged effluent volumes in response to population growth in their service areas, increased effluent volumes at their existing effluent concentrations, if allowed, would worsen the methylmercury impairment. Conceptually, the discharge volume from a WWTP that has an average effluent methylmercury concentration greater than 0.06 ng/L could be allowed to increase so long as its methylmercury load does not increase. [45] This approach is consistent with State Water Board Resolution No. 2005-0060,[46] which required the San Francisco Bay Water Board to incorporate provisions that acknowledge the efforts of those point sources whose effluent quality demonstrates good performance, and require improvement by other dischargers, when establishing waste load allocations.

Several municipal WWTPs in the Delta/Yolo Bypass have ceased discharging to surface waters, others have begun discharging, one is expected to begin discharging in the near future, and two have had substantial changes in their effluent methylmercury levels since WY2003. In summary:

- The San Joaquin County Service Area 31 Flag City WWTP, Walnut Grove WWTP, West Sacramento WWTP, and Rio Vista Trilogy WWTP have ceased discharging to surface water;
- The Mountain House WWTP and Northwest WWTP began discharging to surface water;
- The Ironhouse Sanitary District WWTP is expected to begin discharging to the San Joaquin River within the West Delta subarea within the next year; and

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[45] Discharge volume from a WWTP that has average effluent methylmercury concentrations greater than 0.06 ng/l could be allowed to increase so long as its load does not increase above its wasteload allocation. For example, an increase in volume would necessitate a decrease in methylmercury concentration to maintain the load allocation so that the increased volume does not cause an increase in receiving water methylmercury concentration. Under circumstances described in the following pages, WWTPs that expand their discharge may also be allotted a portion of the "Unassigned NPDES Facility Allocations". If an offset program is developed, another option could be for such a WWTP to compensate for increases in its load by completing offset projects upstream.

[46] On September 7, 2005, the State Water Board adopted Resolution No. 2005-0060 ("Remand Order") remanding the San Francisco Bay Water Board's San Francisco Bay Mercury TMDL Amendment with requirements for specific revisions to the TMDL and associated implementation plan.

- The Stockton WWTP and SRCSD Sacramento River WWTP have had substantial reductions in their effluent methylmercury concentrations and loads in recent years.

Because the West Sacramento and Walnut Grove WWTPs discharged to surface waters during the TMDL period, WY2000-2003, their effluent methylmercury loads shown in Table 6.5 are included in the Table 6.2 load summary in Chapter 6. However, as part of regionalization efforts, SRCSD's Sacramento River WWTP now receives influent that had been treated by the West Sacramento and Walnut Grove WWTPs. To address this change, the "Existing Average Annual MeHg Load" in Table 8.4 for the SRCSD Sacramento River WWTP reflects the sum of the effluent methylmercury loads presented in Table 6.5 for the SRCSD Sacramento River, West Sacramento and Walnut Grove WWTPs (160, 0.39, and 0.24 g/yr, respectively, for a sum of 160.63, rounded to 161 g/yr for allocation calculations); this sum was then multiplied by the "Percent Allocation" to calculate the waste load allocation for the SRCSD Sacramento River WWTP. The 2008-2009 Stakeholder Process's NPDES Facility Workgroup evaluated several methods to calculate allocations that would fairly and equitably address regionalization efforts and selected this as the preferred method.

The San Joaquin County Service Area 31 Flag City WWTP was discharging to surface water during the WY2000-2003 period. As a result, its effluent methylmercury load is included in the Table 6.2 summary in Chapter 6. However, the discharger recently completed the construction of a pump station and dual forcemain project that allows for discharge of the Flag City wastewater to the City of Lodi White Slough WWTP. As of 10 April 2008, all wastewater flows from the Flag City area are being directed to the Lodi WWTP, and the Flag City WWTP's discharge to surface waters has ceased. To address this change, the "Existing Average Annual MeHg Load" in Table 8.4 for the Lodi and Flag City WWTPs were summed (0.93 and 0.0066 g/yr, for a sum of 0.94 g/yr) and then multiplied by the "Percent Allocation" to calculate the waste load allocation for the Lodi WWTP. This is the same method used to address the regionalization of the SRCSD and West Sacramento WWTPs.

If other NPDES facilities that have allocations in Table 8.4 regionalize or otherwise consolidate after the adoption of this TMDL, their waste load allocations can be summed.

In 2007 the Trilogy WWTP was closed and the Northwest WWTP began to discharge in its place. Central Valley Water Board Order No. R5-2004-0092 considers the closure of the Trilogy WWTP coinciding with the start-up of the Northwest WWTP as a change in treatment process and location rather than as a new treatment plant. To address this change, the "Existing Average Annual MeHg Load" in Table 8.4 reflects the annual methylmercury load discharged by the Trilogy WWTP, which discharged 0.1 mgd. The Northwest WWTP has not yet completed effluent methylmercury monitoring; however, it has treatment processes in place that have resulted in very low effluent methylmercury concentrations at other WWTPs (see Section 6.2.3.1 in Chapter 6 for more discussion about Northwest WWTP treatment processes and effluent methylmercury concentrations observed at WWTPs with similar treatment processes). As a result, the allocation for the Northwest WWTP in Table 8.4 is based on its current start-up capacity of 1 mgd, which is 10 times greater than the Trilogy WWTP discharge, and the current calibration standard for methylmercury analysis (0.05 ng/l), which results in a load of 0.069 g/yr. Because it is likely that the estimated effluent load for the Northwest WWTP may be an overestimate, given the very low effluent methylmercury concentrations observed at WWTPs that employ similar treatment processes, its allocation may include a margin of safety. As described in the draft Basin Plan Amendment staff report, staff recommends that a control program review take place after additional Delta-specific studies are completed, during which the Northwest WWTP allocation can be adjusted if needed.

The Mountain House CSD WWTP was not discharging to surface water prior to March 2007 and therefore was not identified in the source analysis for the TMDL period, WY2000-2003. The Mountain House CSD WWTP now discharges to Old River within the San Joaquin River subarea. Because it is now discharging to surface water and has submitted effluent methylmercury concentration data for its discharge (see Section 6.2.3.1 and Appendix L), staff calculated a waste load allocation for its discharge. Between August 2007 and May 2009, 21 monthly effluent samples were analyzed for methylmercury. Four results were reported as equal to the detection limit (0.05 ng/l) and 17 results were reported as "ND" (nondetect) with a method detection limit of 0.05 ng/l. The allocation was calculated using a methylmercury concentration of 0.05 ng/l and the facility's average dry weather design flow of 5.4 mgd to obtain a waste load allocation of 0.37 g/year.

The Ironhouse Sanitary District submitted a Report of Waste Discharge in June 2007 and in April 2008 received a NPDES permit (NPDES No. CA0085260) to discharge up to 4.3 mgd of treated wastewater from the Ironhouse Sanitary District (ISD) WWTP to the San Joaquin River off of Jersey Island in the West Delta subarea. As of February 2010, the ISD had not yet submitted a request for surface water discharge; however, it is expected to begin discharging within the next year. In the February 2008 draft TMDL report, the "unassigned allocation" for the West Delta subarea was based on the expected design flow for the ISD WWTP. Because the ISD WWTP has since received a NPDES permit to discharge, Table 8.4 now includes a waste load allocation specific to the ISD WWTP. The ISD has designed its new WWTP to include: coarse screening, grit removal, fine screening, anoxic basins, aeration basins, membrane filtration and UV disinfection. The effluent will be nitrified and denitrified and meet California Code of Regulations Title 22 disinfection requirements for both the surface water discharge and land disposal. Table 23 in "*A Review of Methylmercury and Inorganic Mercury Discharges from NPDES Facilities in California's Central Valley*" (Bosworth *et al.*, 2010) indicated that WWTPs that employed nitrification/denitrification, filtration and UV disinfection had effluent methylmercury concentrations that ranged from nondetect to 0.078 ng/l and average and median effluent methylmercury concentrations of 0.029 and 0.020 ng/l, respectively, based on three facilities and 21 samples, 11 of which had methylmercury concentrations less than the method detection limit. In the absence of monitoring data, it may not be reasonable to calculate a waste load allocation for the ISD WWTP based on a concentration that is less that the current calibration standard for methylmercury analysis (0.05 ng/l). As a result, its waste load was estimated using a concentration of 0.05 ng/l and discharge volume of 4.3 mgd to obtain an annual load of 0.030 g/year.

Any new NPDES-permitted facilities that begin to discharge after this TMDL is adopted but are not identified in Table 8.4 would be allotted a portion of the "unassigned allocation" for the subarea where their discharges are located, so long as the sum of the new facilities' discharge methylmercury loads does not exceed the unassigned allocations. "New" facilities could include newly built facilities that have not previously discharged to land or water as well as existing facilities that previously discharged to land and then began to discharge to surface water or diverted discharges to another facility that discharges to surface water as part of ongoing regionalization efforts. In addition, staff recommends that existing facilities also be allotted a portion of the unassigned allocations in the subareas where they discharge if they expand beyond their allocations listed in Table 8.4 so long as the additional allocation does not exceed the product of the net increase in flow volume and 0.06 ng/l methylmercury. The 2008-2009 Stakeholder Process's NPDES Facility Workgroup evaluated several approaches for allowing access to the "unassigned allocations" that would fairly and equitably address regionalization efforts and new discharges from existing and newly-built facilities and selected this as the preferred approach. The sum of all new and/or expanded methylmercury discharges from NPDES facilities within each Delta subarea must not exceed the Delta subarea-specific waste load allocation listed in Table 8.4.

Two WWTPs, the City of Stockton WWTP and the SRCSD Sacramento River WWTP, have had marked decreases in effluent methylmercury concentrations and loads in recent years. As discussed previously in Chapter 6 (Section 6.2.3.1), upgrades to the City of Stockton WWTP completed in September 2006 appear to have led to reductions in total mercury and methylmercury as well as ammonia. A comparison of WWTP effluent methylmercury data collected before (August 2004-July 2005) and after (January-July 2009) the treatment plant upgrade indicates that since the WWTP was upgraded, average methylmercury effluent concentrations decreased by 91%. SRCSD's Sacramento River WWTP had effluent methylmercury data for 2001-2007 that illustrated a marked decrease in effluent methylmercury and total mercury concentrations with time. During the April 2008 Board hearing meeting for the Delta mercury control program, the SRCSD District Engineer testified that implementation of the Be Mercury Free Program to reduce inorganic mercury sources to SRCSD's WWTP resulted in reductions in both inorganic mercury and methylmercury discharges from the WWTP. Although more recent effluent data for the Stockton WWTP and SRCSD WWTP discharges indicate a change in the nature of their discharges, the allocations in Table 8.4 were calculated using the earlier data (August 2004 to July 2005 for the City of Stockton; December 2000 to June 2003 for the SRCSD WWTP) because the earlier data are more representative of conditions during the TMDL period, WY2000-2003. In addition, this approach ensures that the dischargers are not unfairly penalized for making early improvements to their discharges.

The City of Davis WWTP (CA0079049) has two discharge locations; wastewater is discharged from Discharge 001 to the Willow Slough Bypass upstream of the Yolo Bypass and from Discharge 002 to the Conaway Ranch Toe Drain in the Yolo Bypass. The methylmercury load allocation listed in Table 8.4 applies only to Discharge 002, which discharges seasonally from about February to June. Discharge 001 is encompassed by the Willow Slough watershed methylmercury allocation. Discharge 001 will be assigned an individual allocation when a control program is developed for the upstream watersheds.

As noted in Section 6.2.3, two of the NPDES-permitted facilities in the Delta are power or heating/cooling facilities that use ambient water for cooling water, Mirant Delta LLC Contra Costa Power Plant and the State of California Heating/Cooling Plant. Methylmercury loads and concentrations in heating/cooling and power facility discharges vary with intake water conditions; the facilities do not appear to act as a source of methylmercury to the Delta. Staff recommends that such facilities have concentration-based allocations equal to 100% of their intake methylmercury concentrations, so that their discharge allocations equal the detected methylmercury concentration found in their intake water. Outflows from the Mirant Delta plant were not incorporated in the allocation calculations for other sources in Section 8.1.4 and are not listed in Table 8.4. A concentration-based allocation for the Mirant Delta plant is listed in Table B in the proposed Basin Plan amendments provided at the beginning of the draft Basin Plan Amendment staff report. The State of California Heating/Cooling Plant recently ceased discharging and as a result is not assigned an allocation in the proposed Basin Plan amendments.

GWF Power Systems (CA0082309), in the West Delta subarea, acquires its intake water from sources other than ambient surface water and therefore was incorporated in the allocation calculations in Section 8.1.4. GWF effluent methylmercury concentrations are less than the analytical method detection limit (0.03 ng/l; see Table 6.5 in Chapter 6). As a result, staff recommends that its allocation be equal to an annual load of 0.0052 g/yr, calculated by using the methylmercury method detection limit (0.03 ng/l) and GWF's design flow (0.125 mgd) to accommodate potential growth.

Discharge methylmercury data were not available for the Lincoln Center Groundwater Treatment Facility in Stockton, which discharges treated groundwater to Fourteenmile Slough in the Central Delta subarea. Other groundwater treatment facility discharges monitored to date have average methylmercury concentrations below current method detection limits (< 0.03 ng/l; Bosworth *et al.*, 2010). As a result, staff recommends that allocation for the Lincoln Center Facility be equal to an annual load of 0.018 g/yr, calculated by using the design flow (0.43 mgd) and the methylmercury method detection limit (0.03 ng/l). This allocation can be modified at the end of Phase 1, after facility-specific discharge methylmercury data is collected.

Discharge volumes and methylmercury data were not available for the Metropolitan Stevedore Company (CA0084174), a marine bulk commodity terminal on leased land at the Port of Stockton in the Central Delta subarea. Staff recommends that a methylmercury waste load allocation specifically for non-storm water discharges from the Metropolitan Stevedore Company be established in its NPDES permit once it completes at least three sampling events for methylmercury in its discharges. Its discharge will be allotted a portion of the "unassigned allocation" for the Central Delta subarea.

As described in Section 8.1.3, several NPDES-permitted facilities have waste load allocations based on 160% of their existing loads or on their permitted design flows, rather than on their existing discharges. On Table 8.4, their allocations are shown as having two components, their existing loads and their allowable increase ("allowable future growth"). This was done so that a summary table (Table 8.5) could be created that clearly identifies the sum of allowable discharge load increases in each subarea. These two components are summed for each facility-specific allocation for compliance purposes in Table B in the proposed Basin Plan amendments provided at the beginning of the draft Basin Plan Amendment staff report. The "allowable future growth" component of the Northwest WWTP allocation (0.065 g/yr) is based on the difference between the estimated load discharged by the Trilogy WWTP during the WY2000-2003 TMDL period (0.0041 g/yr) and the Northwest WWTP's allocation calculated from its average dry weather flow start-up capacity of 1 mgd and 0.05 ng/l (0.069 g/yr). Because the Mountain House CSD WWTP and Ironhouse Sanitation District WWTP did not discharge to surface water during the WY2000-2003 TMDL period, they have only "allowable future growth" allocations in Table 8.4. The “unassigned allocations” in Table 8.4 are also listed as “allowable future growth”.

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Table 8.3a: Total Existing Municipal WWTP Effluent Volume Discharged to Each Delta Subarea, Predicted Increases Due to Population Growth, and Volumes and Methylmercury Loads Predicted to Be Discharged by New WWTPs.

Subarea	**Existing Effluent Volume** (mgd) [(a)]	**Predicted Increase** (mgd) [(b)]	**Effluent Volume Predicted to Be Discharged by New WWTPs** (mgd) [(c)]	**Effluent MeHg Load Predicted to Be Discharged by New WWTPs** (g/yr) [(d)]
Central Delta [(f)]	6.1	7.3	3.7	0.31
Marsh Creek	3.1	3.7	1.9	0.16
Sacramento River	170	204	102	8.5
San Joaquin River	43	52	20.6 [26] [(e)]	1.7
West Delta [(f)]	0 [(g)]	6.9 [(g)]	2.6 [(g)]	0.22
Yolo Bypass	8.5	10.2	5.1	0.42

(a) "Existing Effluent Volume" is the sum of effluent volumes discharged by municipal WWTPs in each Delta subarea that discharged during the TMDL period, WY2000-2003, except for the West Delta subarea.

(b) Staff assumed that, in general, NPDES-permitted WWTP discharges throughout Delta/Yolo Bypass would increase by 120% in response to predicted population growth in the region.

(c) Staff assumed that half of the predicted 120% population growth would be addressed by expansions to existing facilities in each Delta subarea, and that the remaining half would be serviced by new facilities in each subarea. Staff predicted discharge volumes to be serviced by new WWTPs by multiplying the "Existing Effluent Volume" discharged to each subarea by 0.6.

(d) "Effluent MeHg Load Predicted to Be Discharged by New WWTPs" was calculated by multiplying the predicted effluent volumes by 0.06 ng/l methylmercury. These loads are the basis for the "Unassigned NPDES Facility Allocations" in Table 8.4.

(e) The Mountain House CSD WWTP recently began to discharge to surface water. To address this new discharger, staff included a facility-specific allocation for the Mountain House CSD WWTP in Table 8.4 and subtracted its design flow of 5.4 mgd from the predicted volume for new WWTPs in the San Joaquin River subarea in this table.

(f) As noted in the previous section, ambient methylmercury concentrations in the Central and West Delta subareas equal or approach the proposed aqueous methylmercury goal of 0.06 ng/l, resulting in the need for little-to-no reductions in methylmercury inputs to these subareas. As a result, staff recommended that methylmercury source inputs to these subareas have allocations set at 100%. The Central Delta subarea receives flows from the Sacramento, Yolo Bypass, Mokelumne, and San Joaquin subareas. The West Delta subarea receives flows from the Central Delta and Marsh Creek subareas. These subarea inflows are expected to decrease substantially (e.g., 40-80%) as upstream mercury management practices take place because methylmercury source load reductions ranging from 44 to 80% are required for the upstream subareas to achieve their assimilative capacities. These reductions will provide ample assimilative capacity for the Unassigned NPDES Facility Allocations based on the "Effluent MeHg Load Predicted to Be Discharged by New WWTPs".

(g) There are no WWTPs currently discharging in the West Delta subarea. However, the Ironhouse Sanitary District submitted a Report of Waste Discharge in 2007 and in April 2008 received a NPDES permit to discharge up to 4.3 mgd of treated wastewater from the Ironhouse Sanitary District (ISD) WWTP to the San Joaquin River within the West Delta subarea. The ISD WWTP will likely begin discharging to the San Joaquin River sometime in 2010 and was given its own waste load allocation in Table 8.4. The ISD WWTP waste load allocation was calculated using its design flow rather than its expected initial discharge flow and therefore its allocation will address expected population growth for its service area. Staff calculated the "Predicted Increase" for the West Delta subarea by multiplying 4.3 mgd by 60% (rather than 120%) and adding the result (2.6 mgd) to 4.3 mgd, for a total of 6.9 mgd. Staff calculated the "Effluent Volume Predicted to Be Discharged by New WWTPs" using 2.6 mgd because the ISD WWTP allocation will accommodate expected population growth in its service area. Staff expects that the ISD WWTP allocation and "unassigned allocation" based on 2.6 mgd will provide adequate accommodation for future population growth. This is because a nearby wastewater district (the Delta Diablo Sanitation District (DDSD), which discharges with the jurisdiction of the San Francisco Bay Water Board) has expressed interest in importing treated water from the Ironhouse Sanitary District for recycling (Darling, 2008). As described in the draft Basin Plan Amendment staff report, staff recommends that a Delta mercury control program review take place in about 7 years, during which the methods for calculating the unassigned allocations can be revised if needed.

Table 8.3b: Predicted Effluent Volumes Used to Calculate Corresponding Methylmercury Loads for Municipal WWTPs that Discharge Effluent with Average Methylmercury Concentrations Less than 0.06 ng/l.

Permittee [(a)]	**NPDES Permit No.**	**Existing Effluent Volume** (mgd)	**Predicted Effluent Volume Used To Calculate MeHg Loads for Allocations in Table 8.4** [(a)] (mgd)
Brentwood WWTP	CA0082660	3.1	5.0
Deuel Vocational Inst. WWTP	CA0078093	0.47	0.75
Woodland WWTP	CA0077950	6.05	10.4

(a) Staff assumed that, in general, NPDES-permitted WWTP discharges throughout Delta/Yolo Bypass would increase by 120% in response to predicted population growth in the region. Staff assumed that half of the population growth would be addressed by expansions to existing facilities in each Delta subarea, and that the remaining half would be serviced by new facilities in each subarea. Discharges from WWTPs with effluent methylmercury concentrations less than 0.06 ng/l act as dilution. Staff recommends that these facilities be assigned allocations calculated using their existing effluent methylmercury concentrations. To determine loads for use in Table 8.4, discharge volumes for these WWTPs were multiplied by 160% to allow for volume and load increases due to predicted population growth, with one exception. The Central Valley Water Board recently adopted new waste discharge requirements for the City of Woodland WWTP that allow it to increase its design daily average effluent flow capacity from 7.8 mgd to 10.4 mgd. As a result, staff used 10.4 mgd rather than 160% of the WY2005 effluent flow (1.6 * 6.05 mgd = 9.7 mgd).

8.1.4 Percent Allocation Calculations

As described in Section 8.1.2, the following sources have allocations set equal to 100% of their existing methylmercury loads: atmospheric deposition and discharges from urban areas outside of MS4 service areas in all Delta subareas; and all point and nonpoint sources in the Central and West Delta subareas. Also, as described in Section 8.1.3, several NPDES-permitted facilities have waste load allocations based on 160% of their existing loads or on their permitted design flows, rather than on their existing discharges.

Allocations for point and nonpoint sources that have their allocations set equal to 100% of their existing effluent methylmercury loads and point sources (NPDES facilities) that are allowed to increase their discharges because they act as dilution are referred to as "Pre-determined Allocations". The following equation was used to determine the percent allocations and corresponding allocation loads for all other point and nonpoint sources needed to achieve the assimilative capacity in each Delta subarea identified in Table 8.2:

Equation 8.3: *(using the San Joaquin subarea as an example)*

Percent Allocation =

$$= \frac{\text{Assimilative Capacity – Sum of Pre-determined Allocations}}{\text{All existing loads – Sum (Existing loads for sources with Pre-determined Allocations)}}$$

$$= \frac{195\ \text{g/yr} - (2.7\ \text{g/yr} + 0.0022\ \text{g/yr} + 0.021\ \text{g/yr} + 0.38\ \text{g/yr} + 0.37 + 1.7\ \text{g/yr})}{528\ \text{g/yr} - (2.7\ \text{g/yr} + 0.0022\ \text{g/yr} + 0.013\ \text{g/yr} + 0.38\ \text{g/yr})}$$

$$= 36.2\%$$

* Explanation: *As shown in Table 8.4e, allocated methylmercury loads for atmospheric deposition and nonpoint urban runoff were set at existing levels (2.7 g/yr and 0.0022 g/yr, respectively). Deuel Vocational Institute WWTP and Oakwood Lake Subdivision Mining Reclamation have average*

discharge methylmercury concentrations less than 0.06 ng/l, and existing annual loads of 0.013 g/yr and 0.38 g/yr, respectively. Both are assigned allocations based on their existing methylmercury concentrations. The Deuel Vocational Institute WWTP's corresponding allocation load of 0.021 g/yr incorporates a percent allocation of 160%. An allocation load of 0.37 g/yr was reserved for the Mountain House CSD WWTP, which began discharging effluent to surface water after the WY2000-2003 TMDL period; the Mountain House CSD WWTP has effluent with low methylmercury concentrations (≤ 0.05 ng/l). In addition, an allocation load of 2.2 g/yr was reserved for new NPDES-permitted discharges expected to service population growth in the San Joaquin subarea ("unassigned NPDES Facility allocation", see Table 8.3).

The percent allocations were applied to every point source discharge methylmercury concentration and load – except those with Pre-determined Allocations – within each subarea to calculate corresponding waste load allocations using Equations 8.4 and 8.5. Methylmercury inputs from agricultural lands, wetlands, and open-water habitat are based on methylmercury loads produced *in situ* and therefore do not have corresponding concentrations. As a result, the percent allocations were applied to such nonpoint source loads within each subarea to calculate corresponding load allocations using only Equation 8.5.

Equation 8.4:
(using City of Stockton WWTP in the San Joaquin subarea as an example)

MeHg Concentration Used to Calculate Allocation (ng/l) =

= % Allocation * Existing average annual effluent MeHg conc.

= 36.2% * 0.94 ng/l

= 0.34 ng/l

Equation 8.5:

MeHg Waste Load Allocation (g/yr)=

= % Allocation * Existing average annual effluent MeHg load

= 36.2% * 36 g/yr

= 13 g/yr

Sometimes Equation 8.4 resulted in an average methylmercury concentration less than 0.06 ng/l, the proposed implementation goal for ambient water. The preferred allocation strategy described in the draft Basin Plan Amendment staff report entails that no discharger (e.g., WWTPs and MS4s) be required to reduce its discharge average methylmercury concentration to less than 0.06 ng/l. If Equation 8.4 resulted in a value less than 0.06 ng/l for a particular point source discharge, the "Concentration Used to Calculate Allocation" was set at 0.06 ng/l and the allocation percent and equivalent load were calculated using the following equations:

Equation 8.6a: *(using the City of Tracy WWTP in the San Joaquin subarea as an example)*

$$\text{\% Allocation} = \frac{\text{Proposed ambient water implementation goal}}{\text{Existing average annual effluent MeHg Conc.}}$$

= 0.06 ng/l ÷ 0.14 ng/l

= 43%

Equation 8.6b:

$$\begin{aligned}\text{MeHg Allocation Load (g/yr)} &= \text{\% Allocation} * \text{Existing Annual MeHg Load}\\ &= 43\% * 1.8\ \text{g/yr}\\ &= 0.77\ \text{g/yr}\end{aligned}$$

Allocations for sources calculated using Equations 8.6a and 8.6b were then treated as "Pre-determined Allocations" and included in Equation 8.3 to re-calculate the percent allocation. The ultimate purpose of this iterative set of calculations is to ensure that the sum of all methylmercury inputs to each Delta subarea does not exceed the assimilative capacity so that the proposed implementation goal for ambient water and proposed fish tissue mercury targets can be achieved in each subarea. Percent allocations often were calculated to one or more decimal places in order to equitably address a broad range of source loads in a manner that enabled the allocations to be summed without introducing substantial rounding errors.

Table 8.4 is split into separate sections for each Delta subarea. The loads in the "MeHg Load/ Waste Load Allocation (g/yr)" column sum to the assimilative capacity for each subarea. Several loads in this column have more than two significant figures in order to avoid rounding errors when comparing the sum of the loads to the assimilative capacity. For compliance assessment purposes, staff recommends that all loads be rounded to two significant figures. In addition, for NPDES facilities that have two components to their allocations (existing and allowable future growth), the two components should be summed for compliance purposes. The methylmercury concentrations listed in the "MeHg Conc. Used to Calculate Allocation (ng/l)" column should not be used as effluent limits and should not be used to assess compliance with the load-based allocations.

Table 8.5 provides a summary of the sums of existing source loads and allocations for each subarea.

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Table 8.4a: Allocations for Methylmercury Sources to the Central Delta Subarea

MeHg Source	**Tributary or Permittee**	**Permit #**	**Existing Average Annual MeHg Conc.** (ng/l)	**Existing Average Annual MeHg Load** (g/yr)	**Percent Allocation**	**MeHg Conc. Used to Calculate Allocation** (ng/l)	**MeHg Load/ Waste Load Allocation** (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA* [(a)]	37	100%	*NA*	37
Atmospheric Deposition			*NA*	7.3	100%	*NA*	7.3
Open Water Habitats			*NA*	370	100%	*NA*	370
Wetland Habitats			*NA*	210	100%	*NA*	210
Tributary Inputs	Bear/Mosher Creeks		0.31	11	100%	0.31	11
	Calaveras River		0.14	26	100%	0.14	26
Urban runoff (nonpoint source)			0.24	0.14	100%	0.24	0.14
WASTE LOAD ALLOCATIONS							
NPDES Facilities	Discovery Bay WWTP	CA0078590	0.18	0.37	100%	0.18	0.37
	Lincoln Center Groundwater Treatment Facility	CA0084255	0.030	0.010	100%	0.030	0.010
	Lincoln Center Groundwater Treatment Facility (allowable future growth)	CA0084255	*NA*	*NA*	100%	0.030	0.0080
	Lodi White Slough WWTP	CA0079243	0.15	0.94	100%	0.15	0.94
	Metropolitan Stevedore [(b)]	CA0084174	*To be determined.* [(b)]				
	Unassigned NPDES Facility Allocation (allowable future growth)		*NA*	*NA*	100%	0.06	0.31
NPDES MS4s	Contra Costa (County of)	CAS083313	0.24	0.75	100%	0.24	0.75
	Lodi (City of)	CAS000004	0.24	0.053	100%	0.24	0.053
	Port of Stockton MS4	CAS084077	0.24	0.39	100%	0.24	0.39
	San Joaquin (County of)	CAS000004	0.24	0.57	100%	0.24	0.57
	Stockton Area MS4	CAS083470	0.24	3.6	100%	0.24	3.6
CENTRAL DELTA SUBAREA TOTAL:			**0.060**	**668**	**100%**	**0.060**	**668**

(a) NA: not applicable.

(b) No methylmercury or discharge volume data are available for Metropolitan Stevedore (CA0084174), a marine bulk commodity terminal in the Central Delta subarea. Staff recommends that a methylmercury waste load allocation specifically for non-storm water discharges from the Metropolitan Stevedore Company be established in its NPDES permit once it completes at least three sampling events for methylmercury in its discharges. Its discharge will be allotted a portion of the “unassigned allocation” for the Central Delta subarea.

Table 8.4b: Allocations for Methylmercury Sources to the Marsh Creek Subarea

MeHg Source	Tributary or Permittee	Permit #	Existing Average Annual MeHg Conc. (ng/l)	Existing Average Annual MeHg Load (g/yr)	Percent Allocation	MeHg Conc. Used to Calculate Allocation (ng/l)	MeHg Load/ Waste Load Allocation (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA* [a]	2.2	18%	*NA*	0.40
Atmospheric Deposition			*NA*	0.23	100%	*NA*	0.23
Open Water Habitats			*NA*	0.18	18%	*NA*	0.032
Wetland Habitats			*NA*	0.34	18%	*NA*	0.061
Tributary Inputs	Marsh Creek		0.25	1.9	18%	0.045	0.34
WASTE LOAD ALLOCATIONS							
NPDES Facilities	Brentwood WWTP	CA0082660	0.02	0.086	100%	0.02	0.086
	Brentwood WWTP (allowable future growth)	CA0082660	*NA*	*NA*	100%	0.02	0.054
	Unassigned NPDES Facility Allocation (allowable future growth)		*NA*	*NA*	100%	0.06	0.16
NPDES MS4s	Contra Costa (County of)	CAS083313	0.24	1.2	25%	0.06	0.30
MARSH CREEK SUBAREA TOTAL:			**0.224**	**6.14**	**27%**	**0.060**	**1.66**

(a) NA: not applicable.

Table 8.4c: Allocations for Methylmercury Sources to the Mokelumne/Cosumnes Rivers Subarea

MeHg Source	Tributary or Permittee	Permit #	Existing Average Annual MeHg Conc. (ng/l)	Existing Average Annual MeHg Load (g/yr)	Percent Allocation	MeHg Conc. Used to Calculate Allocation (ng/l)	MeHg Load/ Waste Load Allocation (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA* [a]	1.6	35.7%	*NA*	0.57
Atmospheric Deposition			*NA*	0.29	100%	*NA*	0.29
Open Water Habitats			*NA*	4.0	35.7%	*NA*	1.4
Wetland Habitats			*NA*	30	35.7%	*NA*	11
Tributary Inputs	Mokelumne River		0.17	110	35.7%	0.086	39.3
Urban (nonpoint source)			0.24	0.018	100%	0.24	0.018
WASTE LOAD ALLOCATIONS							
NPDES MS4s	San Joaquin (County of)	CAS000004	0.24	0.045	35.7%	0.12	0.016
MOKELUMNE/COSUMNES RIVERS SUBAREA TOTAL:			**0.166**	**146**	**36%**	**0.060**	**52.6**

(a) NA: not applicable.

Table 8.4d: Allocations for Methylmercury Sources to the Sacramento River Subarea

MeHg Source	**Tributary or Permittee**	**Permit #**	**Existing Average Annual MeHg Conc.** (ng/l)	**Existing Average Annual MeHg Load** (g/yr)	**Percent Allocation**	**MeHg Conc. Used to Calculate Allocation** (ng/l)	**MeHg Load/ Waste Load Allocation** (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA* (a)	36	55.51%	*NA*	20
Atmospheric Deposition			*NA*	5.6	100%	*NA*	5.6
Open Water Habitats			*NA*	140	55.51%	*NA*	78
Wetland Habitats			*NA*	94	55.51%	*NA*	52
Tributary Inputs	Morrison Creek		0.10	7.5	55.51%	0.056	4.2
	Sacramento River		0.10	2,026	55.51%	0.056	1,125
Urban (nonpoint source)			0.24	0.62	100%	0.24	0.62
WASTE LOAD ALLOCATIONS							
NPDES Facilities	Rio Vista WWTP	CA0079588	0.16	0.10	55.51%	0.089	0.056
	Rio Vista Trilogy / Northwest WWTP	CA0083771	0.06	0.0041	100%	0.06	0.0041
	Rio Vista Northwest WWTP (allowable future growth)	CA0083771	*NA*	*NA*	100%	0.05	0.065
	Sacramento Combined WWTP	CA0079111	0.54	0.95	55.51%	0.30	0.53
	SRCSD Sacramento River WWTP	CA0077682	0.72	161	55.51%	0.40	89
	Unassigned NPDES Facility Allocation (allowable future growth)		*NA*	*NA*	100%	0.06	8.5
NPDES MS4s	Rio Vista (City of)	CAS000004	0.24	0.014	55.51%	0.13	0.0078
	Sacramento Area MS4	CAS082597	0.24	1.8	55.51%	0.13	1.0
	San Joaquin (County of)	CAS000004	0.24	0.19	55.51%	0.13	0.11
	Solano (County of)	CAS000004	0.24	0.073	55.51%	0.13	0.041
	West Sacramento (City of)	CAS000004	0.24	0.65	55.51%	0.13	0.36
	Yolo (County of)	CAS000004	0.24	0.073	55.51%	0.13	0.041
SACRAMENTO RIVER SUBAREA TOTAL:			**0.108**	**2,475**	**56%**	**0.060**	**1,385**

(a) NA: Not applicable.

Table 8.4e: Allocations for Methylmercury Sources to the San Joaquin River Subarea

MeHg Source	Tributary or Permittee	Permit #	Existing Average Annual MeHg Conc. (ng/l)	Existing Average Annual MeHg Load (g/yr)	Percent Allocation	MeHg Conc. Used to Calculate Allocation (ng/l)	MeHg Load/ Waste Load Allocation (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA* (a)	23	36.1%	*NA*	8.3
Atmospheric Deposition			*NA*	2.7	100%	*NA*	2.7
Open Water Habitats			*NA*	48	36.1%	*NA*	17
Wetland Habitats			*NA*	43	36.1%	*NA*	16
Tributary Inputs	French Camp Slough		0.14	11	36.1%	0.051	4.0
	San Joaquin River		0.16	356	36.1%	0.058	129
Urban (nonpoint source)			0.24	0.0022	100%	0.24	0.0022
WASTE LOAD ALLOCATIONS							
NPDES Facilities	Deuel Vocational Institute WWTP	CA0078093	0.02	0.013	100%	0.02	0.013
	Deuel Vocational Institute WWTP (allowable future growth)	CA0078093	*NA*	*NA*	100%	0.02	0.008
	Manteca WWTP	CA0081558	0.22	1.4	27%	0.06	0.38
	Mountain House CSD WWTP	CA0084271	*NA*	*NA*	100%	0.05	0.37
	Oakwood Lake Subdivision Mining Reclamation	CA0082783	0.03	0.38	100%	0.03	0.38
	Stockton WWTP	CA0079138	0.94	36	36.1%	0.34	13
	Tracy WWTP	CA0079154	0.14	1.8	43%	0.06	0.77
	Unassigned NPDES Facility Allocation (allowable future growth)		*NA*	*NA*	100%	0.06	1.7
NPDES MS4s	Lathrop (City of)	CAS000004	0.24	0.27	36.1%	0.087	0.097
	Port of Stockton MS4	CAS084077	0.24	0.010	36.1%	0.087	0.0036
	San Joaquin (County of)	CAS000004	0.24	2.2	36.1%	0.087	0.79
	Stockton Area MS4	CAS083470	0.24	0.50	36.1%	0.087	0.18
	Tracy (City of)	CAS000004	0.24	1.8	36.1%	0.087	0.65
SAN JOAQUIN RIVER SUBAREA TOTAL:			**0.160**	**528**	**37%**	**0.060**	**195**

(a) NA: Not applicable.

Table 8.4f: Allocations for Methylmercury Sources to the West Delta Subarea

MeHg Source	**Tributary or Permittee**	**Permit #**	**Existing Average Annual MeHg Conc.** (ng/l)	**Existing Average Annual MeHg Load** (g/yr)	**Percent Allocation**	**MeHg Conc. Used to Calculate Allocation** (ng/l)	**MeHg Load/ Waste Load Allocation** (g/yr)
LOAD ALLOCATIONS							
Agricultural Drainage			*NA* [a]	4.1	100%	*NA*	4.1
Atmospheric Deposition			*NA*	2.4	100%	*NA*	2.4
Open Water Habitats			*NA*	190	100%	*NA*	190
Wetland Habitats			*NA*	130	100%	*NA*	130
Urban (nonpoint source)			0.24	0.066	100%	0.24	0.066
WASTE LOAD ALLOCATIONS							
NPDES Facilities	GWF Power Systems	CA0082309	0.03	0.0019	100%	0.03	0.0019
	GWF Power Systems (allowable future growth)	CA0082309	*NA*	*NA*	100%	0.03	0.0033
	Ironhouse Sanitation District (allowable future growth)	CA0085260	*NA*	*NA*	100%	0.05	0.030
	Mirant Delta LLC Contra Costa Power Plant [b]	CA0004863	*Concentration-based allocation*. [b]				
	Unassigned NPDES Facility Allocation (allowable future growth)		*NA*	*NA*	100%	0.06	0.22
NPDES MS4s	Contra Costa (County of)	CAS083313	0.24	3.2	100%	0.24	3.2
WEST DELTA SUBAREA TOTAL:			**0.083**	**330**	**100%**	**0.060**	**330**

(a) NA: not applicable.

(b) Methylmercury loads and concentrations in heating/cooling and power facility discharges vary with intake water conditions; the facilities do not appear to act as a source of methylmercury to the Delta. Staff recommends that Mirant Delta LLC Contra Costa Power Plant a have concentration-based allocation equal to 100% of its intake methylmercury concentrations, so that its discharge allocation equals the detected methylmercury concentration found in its intake water. Outflows from the Mirant Delta plant were not incorporated in the allocation calculations for other sources. A concentration-based allocation for the Mirant Delta plant is listed in Table B in the proposed Basin Plan amendments provided at the beginning of the draft Basin Plan Amendment staff report.

Table 8.4g: Allocations for Methylmercury Sources to the Yolo Bypass Subarea

MeHg Source	**Tributary or Permittee**	**Permit #**	**Existing Average Annual MeHg Conc.** (ng/l)	**Existing Average Annual MeHg Load** (g/yr)	**Percent Allocation**	**MeHg Conc. Used to Calculate Allocation** (ng/l)	**MeHg Load/ Waste Load Allocation** (g/yr)
	LOAD ALLOCATIONS						
Agricultural Drainage			*NA*	19	21.5%	*NA*	4.1
Atmospheric Deposition			*NA*	4.2	100%	*NA*	4.2
Open Water Habitats			*NA*	100	21.5%	*NA*	22
Wetland Habitats			*NA*	480	21.5%	*NA*	103
Tributary Inputs	Cache Creek Settling Basin Outflow		0.50	140	21.5%	0.108	30
	Dixon Area		0.24	3.6	21.5%	0.052	0.77
	Fremont Weir		0.10	180	21.5%	0.022	39
	Knights Landing Ridge Cut		0.19	100	21.5%	0.041	22
	Putah Creek		0.18	11	21.5%	0.039	2.4
	Ulatis Creek		0.24	9.5	21.5%	0.052	2.1
	Willow Slough		0.24	18	21.5%	0.052	3.9
	WASTE LOAD ALLOCATIONS						
NPDES Facilities	Davis WWTP [(a)]	CA0079049	0.61	0.78	21.5%	0.13	0.17
	Woodland WWTP	CA0077950	0.03	0.25	100%	0.03	0.25
	Woodland WWTP (allowable future growth)	CA0077950	*NA*	*NA*	100%	0.03	0. 18
	Unassigned NPDES Facility Allocation (allowable future growth)		*NA* [(b)]	*NA*	100%	0.06	0.42
NPDES MS4s	Solano (County of)	CAS000004	0.24	0.085	25%	0.06	0.021
	West Sacramento (City of)	CAS000004	0.24	1.1	25%	0.06	0.28
	Yolo (County of)	CAS000004	0.24	0.33	25%	0.06	0.083
YOLO BYPASS [North & South] SUBAREA TOTAL:			**0.273**	**1,068**	**22%**	**0.060**	**235**

(a) The City of Davis WWTP (CA0079049) has two discharge locations; wastewater is discharged from Discharge 001 to the Willow Slough Bypass upstream of the Yolo Bypass and from Discharge 002 to the Conaway Ranch Toe Drain in the Yolo Bypass. The methylmercury load allocation listed in this table applies only to Discharge 002, which discharges seasonally from about February to June. Discharge 001 is encompassed by the Willow Slough watershed methylmercury allocation and will be assigned a facility-specific allocation when a control program is developed for the upstream watersheds.

(b) NA: Not applicable.

Table 8.5: Methylmercury Load and Waste load Allocations for Each Delta Subarea by Source Category

Source Type	**DELTA SUBAREA**													
	Central Delta		**Marsh Creek**		**Mokelumne River**		**Sacramento River**		**San Joaquin River**		**West Delta**		**Yolo Bypass**	
	Current Load (g/yr)	Allocation (g/yr)	Current Load (g/yr)	Allocation (g/yr)	Current Load (g/yr)	Allocation (g/yr)	Current Load (g/yr)	Allocation (g/yr)	Current Load (g/yr)	Allocation (g/yr)	Current Load (g/yr)	Allocation (g/yr)	Current Load (g/yr)	Allocation (g/yr)
Methylmercury Load Allocations														
Agricultural drainage [(d)]	37	37	2.2	0.40	1.6	0.57	36	20	23	8.3	4.1	4.1	19	4.1
Atmospheric wet deposition	7.3	7.3	0.23	0.23	0.29	0.29	5.6	5.6	2.7	2.7	2.4	2.4	4.2	4.2
Open water	370	370	0.18	0.032	4.0	1.4	140	78	48	17	190	190	100	22
Tributary Inputs [(a)]	37	37	1.9	0.34	110	39	2,034	1,129	367	133			462	100
Inputs from Upstream Subareas	(b)	(b)	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	(b)	(b)	- - -	- - -
Urban (nonpoint source)	0.14	0.14	---	---	0.018	0.018	0.62	0.62	0.0022	0.0022	0.066	0.066	---	---
Wetlands [(d)]	210	210	0.34	0.061	30	11	94	52	43	16	130	130	480	103
Methylmercury Waste Load Allocations														
NPDES facilities [(a)]	1.3	1.3	0.086	0.086	0	0	162	90	40	15	0.0019	0.0019	1.0	0.42
NPDES facilities future growth [(a)]	---	0.32 [(b)]	---	0.21	---	0	---	8.6	---	2.1	---	0.25 [(b)]	---	0.60
NPDES MS4 [(a)]	5.4	5.4	1.2	0.30	0.045	0.016	2.8	1.6	4.8	1.7	3.2	3.2	1.5	0.38
Total Loads [(c)] (g/yr)	**668**	**668**	**6.14**	**1.66**	**146**	**52.6**	**2,475**	**1,385**	**528**	**195**	**330**	**330**	**1,068**	**235**

(a) Values shown for Tributary Inputs, NPDES Facilities, NPDES Facilities Future Growth, and NPDES MS4 represent the sum of several individual discharges. See Table 8.4 for allocations for the individual discharges that should be used for compliance purposes.

(b) The Central Delta subarea receives flows from the Sacramento, Yolo Bypass, Mokelumne, and San Joaquin subareas. The West Delta subarea receives flows from the Central Delta and Marsh Creek subareas. These within-Delta flows have not yet been quantified because additional data are needed for loss rates across the subareas. However, these subarea inflows are expected to decrease substantially (e.g., 40-80%) as upstream mercury management practices take place. As a result, reductions for sources within the Central and West subareas and tributaries that drain directly to these subareas are not required. The Central Valley Water Board can consider modification of the allocation strategy and the creation of new allocations (e.g., for within-Delta flows between subareas) during the program review proposed to take place in about seven years based on existing and new information that becomes available.

(c) The sum of all allocations for each subarea equals the assimilative load capacity for that subarea. Because calculations were completed prior to rounding, some columns may not add to totals.

(d) The load allocations apply to the net methylmercury loads, where the net loads equal the methylmercury load in outflow minus the methylmercury loads in source water (e.g., irrigation water and precipitation).

8.2 Total Mercury Load Reduction Requirement for Tributary Watersheds

Methylmercury production is a positive linear function of the inorganic mercury content of sediment (see Chapter 3). Inorganic mercury load reductions elsewhere have resulted in decreases in fish tissue methylmercury concentrations (Table 3.1). It is expected that similar reductions in fish tissue concentration also will occur in the Delta once the mercury content of its sediment decreases. Staff recommends that inorganic (total) mercury requirements be implemented by the Delta mercury control program in addition to the methylmercury allocations for several reasons: (1) to maintain compliance with the USEPA's criterion of 50 ng/l for total mercury in the water column; (2) to prevent increases in total mercury discharges resulting from population growth and other land use changes, which could cause increases in aqueous and fish methylmercury in the Delta, thereby worsening the impairment; (3) to comply with the San Francisco Bay TMDL allocation to the Central Valley; and (4) to help enable compliance with the open-water methylmercury load allocations described in the previous section. The TMDL for San Francisco Bay assigned the Central Valley a five-year average total mercury load allocation of 330 kg/yr or a decrease of 110 kg/yr (Section 2.4.2.3).

As described in Chapter 4 of the draft Basin Plan Amendment staff report, the preferred TMDL implementation alternative entails:

- NPDES Permitted Facilities in the Delta and Yolo Bypass: Implement pollutant minimization programs and maintain performance-based total mercury load limits during the first phase of Delta TMDL control program implementation.
- NPDES Permitted (MS4) Urban Runoff Dischargers in the Delta and Yolo Bypass: Implement best management practices (BMPs) to control erosion and sediment discharges consistent with their existing permits and orders with the goal of reducing mercury discharges (all MS4s), and implement mercury-specific pollution prevention measures and BMPs to minimize inorganic mercury discharges (the largest three MS4s [Sacramento, Contra Costa and Stockton MS4s]).
- Nonpoint Sources in the Delta and Yolo Bypass: Implement reasonable, feasible actions to reduce sediment in runoff with the goal of reducing inorganic mercury loading to the Yolo Bypass and Delta, in compliance with existing Basin Plan objectives and requirements, and Irrigated Lands Regulatory Program requirements.
- Tributary Watershed Inputs to the Delta and Yolo Bypass: Total mercury load reduction of a minimum of 110 kg/yr.

This section of the TMDL report reviews how the total mercury load reduction requirement maybe achieved in tributary watersheds. Total mercury reduction strategies for point and nonpoint sources in the Delta and Yolo Bypass are described in Chapter 4 of the draft Basin Plan Amendment staff report.

The total mercury source analysis described in Chapter 7 indicates that almost all the total mercury loading (>97%) to the Delta and Yolo Bypass comes from tributary inputs. It could be argued that assigning total mercury load reduction requirements could wait until the upstream TMDLs are developed. Also, there is limited information available about total mercury loads contributed by individual sources in the tributary watersheds. However, there is abundant information about which watersheds contribute the most mercury-contaminated sediment. In addition, substantial mercury reductions – 110 kg/yr – are required for Central Valley inputs to the San Francisco Bay by the San Francisco Bay mercury control program. It is likely that total mercury reduction efforts in the watersheds, and subsequent methylmercury reductions in open-water, wetland and agricultural areas in the Delta, will take place more quickly if watershed total mercury load reduction requirements are included in the Delta mercury control program.

A reduction of 110 kg/yr represents about a 28% decrease in the 20-year average annual loading[47] from Delta tributaries (Table 7.1). Initial reduction efforts should focus on watersheds that export the largest volume of highly contaminated sediment, such as the Cache Creek, Feather River, American River, Cosumnes River, and Putah Creek watersheds (refer to Sections 7.1.1 and 7.4.1 and Tables 7.5 and 7.17 in Chapter 7).

The Cache Creek Settling Basin (CCSB) is a 3,600-acre structure located at the base of the Cache Creek watershed. The U.S. Army Corp of Engineers initially constructed the CCSB in 1937 to contain sediment and maintain the flood capacity of the Yolo Bypass. The CCSB was modified in 1993 to increase its sediment trapping efficiency. However, no provision was made for removing the additional trapped material.

Most of the mercury in Cache Creek is transported on sediment. Therefore, an increase in sediment trapping also results in deposition and retention of mercury. The CCSB currently traps about half of the sediment and mercury transported by Cache Creek (Foe and Croyle, 1998; CDM, 2004; Cooke *et al.*, 2004; CDM, 2004; Appendices F and I). The rest is exported to the Delta through the Yolo Bypass.

Trapping efficiency calculations vary based on the period evaluated and the calculation method. For example, Board staff estimated that the basin receives about 224 kg/yr total mercury from the Cache Creek watershed and discharges about 118 kg/yr to the Yolo Bypass (a trapping efficiency of about 47%), based on annual load estimates for a 20-year period (WY1984-2003, a period with an even mix of wet and dry years) derived from statistically-significant correlations between water column total mercury concentrations and flows (refer to Chapter 7 and Appendix I for load calculation methods). CDM estimated that about 64% of the sediment and total mercury mass input to the basin is trapped when the volumes of sand, uncompacted silt and clay are converted to sediment mass over a modeled 35-year period (see CDM, 2004b, Table 4-3). Although trapping efficiency calculations vary, they all indicate that substantial mercury loads are currently trapped in the basin. However, even though the basin traps a large portion of the mercury that comes into it, Cache Creek still accounts for about 60% of all inorganic mercury that enters the Yolo Bypass.

The sediment/mercury trapping efficiency of the CCSB is expected to decrease as it fills and may reach zero in about 35 years unless a maintenance program is instituted to periodically remove material (CDM, 2004). A non-operational CCSB would result in a mercury discharge to the Yolo Bypass and Delta of about 224 kg/yr, an addition of 106 kg/yr mercury loading (Table 7.6b).

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[47] Year-to-year loads are expected to fluctuate with rainfall and river flow conditions and other environmental factors.

Two sets of actions are considered in the draft Basin Plan Amendment staff report (Chapter 4 and Appendix C) for the Cache Creek Settling Basin that would reduce mercury discharges to the Yolo Bypass and Delta. First, mercury loads entering the CCSB from the Cache Creek watershed could be reduced. The Basin Plan Amendment for control of mercury in Cache Creek was adopted by the Central Valley Water Board in October 2005. Implementation actions described in the Basin Plan Amendment report would reduce mercury loads *entering* the Cache Creek Settling Basin by about 60 kg/year (Cooke and Morris, 2005), from a 20-year average of 224 kg/yr to 164 kg/yr. Assuming a long-term basin trapping efficiency of about 47%, the watershed implementation actions would reduce basin total mercury mass discharges to the Yolo Bypass by about 31 kg/yr. Approximately 25 kg of the 60 kg/year reduction in the Cache Creek watershed may come from instituting control programs at all major mercury mines in the watershed.[48] The remainder of the reduction will be achieved by control of erosion in mercury-enriched areas and by remediation/removal of contaminated floodplain sediment in the Cache Creek canyon and in Bear Creek. However, most the total mercury load now leaving the CCSB appears to originate from erosion of mercury contaminated sediment downstream of the mines. The Cache Creek mercury control program requires studies to evaluate in-stream sediment control options. It is unclear whether environmentally acceptable, cost effective control programs can be developed to significantly curtail the movement of this material.

A second set of actions could focus on decreasing the mercury load leaving the Cache Creek Settling Basin. A program should be instituted to (a) periodically excavate the material presently accumulating in the CCSB, and (b) make additional modifications to the CCSB to increase trapping efficiency. Initial modeling results indicate that CCSB operation and design could be modified to improve the mercury mass trapping efficiency of the CCSB from to about 75% (CDM, 2004, Table 4-3, Alternative 5 - Excavate and Raise Weir Early). Decreasing mercury inputs to the CCSB from 224 to 164 kg/yr through the watershed control program and increasing the trapping efficiency of the CCSB from 47% to 75% results in an export to the Yolo Bypass of 41 kg/yr, which represents a decrease of 77 kg/yr from current loading. This reduction is approximately 70% of the 110-kg/yr reduction required by the San Francisco Bay mercury TMDL. Based on these calculations, the February 2008 Basin Plan Amendment draft staff report included a numeric total mercury load limit of 41 kg/yr for outflow from the Cache Creek Settling Basin to the Yolo Bypass.

However, after the release of the February 2008 draft report, DWR staff indicated that a more comprehensive feasibility study must take place to determine whether a 75% trapping efficiency is possible and to incorporate a stakeholder process so that local communities' concerns about potential flood hazards resulting from modifying the basin can be addressed. The 2008-2009 Stakeholder Process participants (including staff from the Central Valley Water Board, DWR and other agencies responsible for basin operations and other stakeholders) developed recommendations for Basin Plan amendment requirements that entail evaluating and implementing feasible total mercury load reductions for basin outflows up to and including a 50% reduction from existing loads in place of a numeric load limit. A 50% reduction in existing loads (118 kg/yr) results in a total mercury load to the Yolo Bypass of about 59 kg/yr, compared to the 41 kg/yr described in the previous paragraph.

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[48] The mines are located in Harley Gulch, Sulfur and Bear Creeks and Clear Lake.

Table 8.6 provides a preliminary scoping of potential watershed total mercury load reductions (including the Cache Creek watershed) based on the assumption that it will be possible to reduce mercury loads from watersheds that discharge mercury-contaminated sediment (as indicated by relatively high TotHg:TSS ratios) by at least 50%. Staff used a 50% reduction rate because in watersheds with known, significant anthropogenic sources of mercury (primarily mining), the anthropogenic contribution is more than 50% of the total concentration of mercury in sediment. For example, the Feather River, American River, Cosumnes River have suspended sediment mercury concentrations that are more than twice the mercury concentration of suspended sediment in the Sacramento River upstream of Colusa, a watershed with a much lower density of mine sites (see Table 8.6 at the end of this section and Table 14 in Louie and others' 2008 CalFed study). The sum of potential reductions based on this assumption is about 125 kg/yr. A 50% reduction in total mercury loads contributed by the four watersheds that discharge sediment that is most highly contaminated with mercury – Feather River, Cache Creek, American River and Putah Creek – alone would result in a 104 kg/yr reduction.

The suite of potential total mercury reduction actions identified by the "Regional Mercury Load Reduction Evaluation, Central Valley, California", completed by Tetra Tech EM Inc. under contract to the USEPA (Tetra Tech, 2008), and the review of reasonably foreseeable methods of compliance in Chapter 4 of the draft Basin Plan Amendment staff report, indicates that the potential reductions outlined in Table 8.5 may be possible. However, additional feasibility analyses and stakeholder input are needed in order to evaluate alternatives, funding sources, and potential environmental concerns associated with potential projects.

Given these factors, staff recommends that the Delta mercury control program include a 110 kg/yr total mercury reduction requirement assigned jointly to the tributaries that drain to the Delta to ensure compliance with the San Francisco Bay mercury control program's requirements for the Central Valley. Initial reduction efforts should focus on the four watersheds that discharge the most highly-contaminated sediment (Feather River, Cache Creek, American River and Putah Creek, all in the Sacramento Basin). Although it is not as large a source of total mercury loading, the Cosumnes River watershed in the San Joaquin Basin also would be an effective candidate for total mercury reduction projects because of its high mercury concentrations in suspended sediment. Several other watershed characteristics make the Cosumnes River an attractive candidate for remediation efforts during the initial implementation phases of the Delta and upstream mercury control programs:

- As described in Section 7.1.1.2, not only does the Cosumnes River watershed have a history of hydraulic gold mining, it exports six times as much mercury to the Delta as the Mokelumne River watershed and is the largest river on the west-slope Sierra Nevada without a major dam, allowing unimpaired downstream movement of storm runoff.
- The highest fish tissue levels observed in the Delta were in the lower Cosumnes River (Davis *et al*., 2008; Slotton *et al*., 2007). Extensive multi-year and seasonal fish mercury monitoring conducted in the lower Cosumnes River after the development of this TMDL source analysis observed small fish mercury levels that were 5 to 29 times the small fish mercury objective proposed in Chapter 3 of the draft Basin Plan Amendment report (Slotton *et al.*, 2007). Slotton and others (2007, pages 58-59) observed extreme (400-500%) increases in silverside mercury at the Cosumnes site in July 2006, when

concentrations in 45-75 mm (2-3 inch) silversides reached levels averaging an "astounding" 0.869 ppm, with individual fish as high as 2.0 ppm. According to the authors, "these were concentrations that should be of serious concern, particularly in relation to wildlife exposure." Slotton and others (2007) noted that their extensive seasonal sampling indicated that the very high 2006 silverside mercury concentrations in the lower Cosumnes River were traceable to an extreme, seasonal pulse event of highly elevated exposure linked to episodic flooding of the Cosumnes floodplain and observed that other small fish species with slower turnover rates than silversides (e.g., juvenile bass and prickly sculpin) exhibited much slower declines from peak mercury levels, with highly elevated concentrations persisting for many months.

- Foe and others' 2008 CalFed study found that water methylmercury concentrations in the Cosumnes River were the highest of any tributary to the Delta, consistent with the fish tissue data. The mean and 95% confidence limits for the Cosumnes and Mokelumne Rivers are 0.38±0.12 and 0.11±0.01 ng/l methylmercury, respectively (Foe *et al*., 2008, Table 2), compared to 0.17 ng/l methylmercury for the Mokelumne River downstream of its confluence with the Cosumnes River (Table 6.2 in Chapter 6).
- As illustrated in Figure 6.3, the lower Cosumnes River has numerous wetland areas, and large wetland restoration efforts are planned for the lower Cosumnes River watershed within the Delta in the near future (e.g., Turner, 2009).

Staff recommends that compliance with the proposed 110 kg/yr total mercury reduction requirement be assessed for the tributary inputs based on WY1984-2003 average annual loads. This 20-year period includes a mix of wet and dry years that is statistically similar to water years in the Sacramento Basin in the last 100 years. The proposed reduction will enable Delta waters to maintain compliance with the CTR criterion of 50 ng/l (Section 7.4 in Chapter 7).

Additional total mercury and methylmercury reductions likely will be needed from most if not all of the watersheds to address the methylmercury impairment in each area of the Delta subareas and impairments specific to upstream watersheds. Specific limits for individual watershed exports should not be defined in the Delta mercury control program in order to allow for greater flexibility in developing upstream control strategies. Feasibility studies may show that particular projects could reduce mercury loads by more than 50% without causing other environmental impacts. However, the sum of the load reductions for the watershed exports needs to equal a minimum of 110 kg/yr. Most of the watersheds that drain to the Delta contain waterways already identified on the CWA Section 303(d) List as impaired by mercury. Hence, most will be the focus of future watershed-specific TMDL programs. Specific load reductions for each watershed will be assigned in control programs for the upstream watersheds.

It is important to note that implementing only the inorganic mercury reductions described above will not adequately reduce methylmercury levels in the Delta in the near term (the proposed compliance date in the proposed Basin Plan amendments in the draft Basin Plan Amendment staff report is 2030). Because movement of contaminated sediment in the river channels is relatively slow, it is expected to take many years (e.g., a century or more) before the full benefit of inorganic mercury reductions in tributaries is seen in the Delta. (For additional discussion of the estimated time to reduce inorganic mercury inputs and attain fish tissue objectives, please refer to "Staff's Initial Responses to Board and Stakeholder Questions and Comments at the

April 2008 Hearing", items 3 and 44, available on the Board website.) In addition, many of the tributary input methylmercury allocations developed in Section 8.1 entail methylmercury load reductions of 60% to 80%. Assuming that inorganic mercury loads could be reduced by 50% in these tributaries, reducing inorganic mercury alone would be insufficient to achieve the allocations. Staff expects that methylmercury management practices <u>and</u> very aggressive implementation of inorganic mercury reduction projects will be needed in the tributary watersheds, along with natural erosion, to achieve the tributary methylmercury load allocations.

Table 8.5: Preliminary Evaluation of Potential Watershed Total Mercury Load Reductions

Basin	**Watershed**	**303(d) Listed for Mercury Impairment**	**Annual TotHg Load** (kg/yr)	**TotHg:TSS** (mg/kg)	**Potential % Reduction & Corresponding Load Reduction** (a) (kg/yr)	
Sacramento (b)	**American River**	√	**14**	**0.27**	**50%**	**7**
	Cache Creek Settling Basin	√	**118**	**0.45**	**50%**	**59**
	Colusa Basin Drain	(Proposed)	13	0.09	5%	0.65
	Feather River	√	**67**	**0.31**	**50%**	**34**
	Morrison Creek		0.83	0.15	20%	0.17
	Natomas East Main Drain		3.0	0.38 – 0.64	50%	1.5
	Putah Creek	√	**8.8**	**0.55**	**50%**	**4.4**
	Sacramento River above Colusa	√	151	0.12	5%	7.6
	Sacramento Slough / Sutter Bypass	√	25	0.13	5%	1.3
	Ulatis Creek		2.2	0.11	5%	0.11
San Joaquin (c)	French Camp Slough		1.7	0.30 - 0.70	50%	0.85
	Marsh Creek	√	0.54	0.12 - 0.45	50%	0.27
	Cosumnes River upstream of I-5		**48**	**0.41**	**50%**	**24**
	Mokelumne River upstream of the Cosumnes River	√	8.4	0.22	50%	2.3
	San Joaquin River	√	29	0.13	5%	1.5

(a) For scoping purposes only, a conservative 50% reduction was assumed to be likely needed for watershed total mercury loads in order to achieve tributary input allocations assigned by the Delta TMDL as well as to address upstream impairments. A lower percent reduction was assumed for watersheds that may discharge less mercury-contaminated material, as indicated by low TotHg:TSS ratios. Greater or lesser reductions may be determined to be necessary once upstream feasibility analyses have taken place as part of upstream control programs. Total mercury loads were obtained from Tables 7.1 and 7.6b, and TotHg:TSS ratios were obtained from Table 7.17; values for the Cosumnes and Mokelumne Rivers were obtained from Louie and others' 2008 CalFed study. The annual TotHg loads represent the average annual loads estimated for WY1984-2003. This 20-year period includes a mix of wet and dry years that is statistically similar to what has occurred in the Sacramento Basin over the last 100 years. Annual loads are expected to fluctuate with rainfall and river flow conditions and other environmental factors.

(b) A total mercury load estimate is not available for Willow Slough, which drains to the Yolo Bypass in the Sacramento Basin. As a result, although it has a methylmercury allocation that requires substantial reductions, it is not included in this table.

(c) The Calaveras River and Bear and Mosher Creeks in the San Joaquin Basin drain to the Central Delta subarea. Methylmercury allocations for these watersheds do not entail reductions; as a result, they are not included in this table.

8.3 Margin of Safety

Implicit and explicit margins of safety are included in the aqueous methylmercury goal for the Delta. In addition, while not a direct margin of safety, the implementation plan (Chapter 4 in the draft Basin Plan Amendment staff report) calls for updated fish advisories in the Delta and an expanded outreach program to educate humans fishing in the Delta.

The proposed aqueous methylmercury goal of 0.06 ng/l (Chapter 5) incorporates an explicit margin of safety of approximately 10%. The linkage analysis (Section 5.2) predicted a safe level of 0.066 ng/l for average aqueous methylmercury, from which 0.006 was subtracted to provide a margin of safety.

In addition, there is an implicit margin of safety for wildlife species that consume Delta fish. As outlined in the previous paragraph, the aqueous methylmercury goal corresponds to 0.24 mg/kg mercury in large TL4 fish, which was calculated for the protection of humans consuming about one meal per week. As shown in Table 4.9 (Chapter 4), the wildlife targets for smaller and lower trophic level fish correspond to large TL4 fish mercury levels that range from 0.30 mg/kg (for Western grebe) to 1.12 mg/kg (for Western snowy plover). These values correspond to 350-mm largemouth bass mercury levels of 0.31 and 1.34 mg/kg. When entered into the regression equation for largemouth bass and unfiltered average aqueous methylmercury (Figure 5.2[A]), these values translate to aqueous methylmercury concentrations of 0.08 ng/l and 0.19 ng/l, allowing a margin of safety of 25% or more, depending on the wildlife species.

8.4 Seasonal & Inter-annual Variability

8.4.1 Variability in Aqueous Methyl and Total Mercury

Mercury loads in Delta tributary inputs fluctuate because of seasonal and inter-annual variation. Winter precipitation increases the sediment and total mercury loads entering the Delta through erosion and re-suspension of sediment. Most of the total mercury coming from tributaries and direct surface runoff enters the Delta during high flow events. In contrast, methylmercury production is typically higher during the summer months. In addition, greater total mercury and methylmercury loads enter the Delta during wet water years.

Seasonal and inter-annual variability in methylmercury loads were accounted for in the source analysis and methylmercury load allocations by evaluating annual average loads for Delta sources and losses for WY2000 to 2003, a relatively dry period that encompasses the available concentration data for the major Delta inputs and exports. Twenty-year average, annual loads of total mercury were estimated for tributary loads based on flow and precipitation records for WY1984-2003. This 20-year period includes a mix of wet and dry years that is statistically similar to what has occurred in the Sacramento Basin over the last 100 years. However, insufficient data were available at the time the TMDL was developed to estimate 20-year average annual loads for methylmercury sources. Methylmercury allocations and total mercury limits will be re-evaluated as additional information becomes available. Future monitoring programs will accommodate long-term inter-annual variability by evaluating whether sources are meeting allocations on a multi-year basis.

8.4.2 Variability in Biota Mercury

Seasonal and inter-annual variation also occurs in biota. Slotton and others (2003) found that Delta species exhibited both seasonal and inter-annual variability in mercury body burden. Corbicula (clams) had higher mercury concentrations in the spring while inland silversides (representative forage fish species) were higher in fall. In addition, silverside bioaccumulation was greater in 1998 than in 1999 and 2000 at many locations in the Delta. Davis and others (2002) measured higher mercury concentrations in similar sized largemouth bass in 1999 than in 2000. The researchers noted that the winter of 1997 was very wet and speculated that the high flows may have introduced significant quantities of "new" mercury that was methylated and incorporated into forage fish in 1998. Predacious fish like largemouth bass, which feed upon silversides, took an additional year to reflect the higher methylmercury concentrations.

Seasonal and inter-annual variability in large fish was accounted for in the numeric targets and linkage analysis by using data collected over multiple years. Future monitoring will accommodate seasonal and inter-annual variability by sampling large fish about every ten years.

8.4.3 Regional and Global Change

Several ongoing regional and global changes may affect methyl and total mercury loading in the Delta. This section identifies several of these. Central Valley Water Board will continue to research regional and global changes that may affect efforts to achieve the proposed fish tissue targets and incorporate new information and strategies with extensive stakeholder input during periodic Delta TMDL control program reviews using an adaptive management approach throughout the implementation of the control program.

8.4.3.1 Population Growth

The Delta and its tributary watersheds are experiencing substantial population growth. Population in the Central Valley increased by about 20% between 1990 and 2000 (AFT, 2006; CDOF, 2004). This resulted in the conversion of about 98,000 acres of agricultural land to urban uses (AFT, 2006). Four of the five fastest growing cities in the Sacramento Valley are located within about one day's travel time (about 20 to 30 miles by water) of the Delta. The California Department of Finance predicts that populations in the Delta/Yolo Bypass counties[49] will increase 76% to 213% by 2050 (CDOF, 2007), with an average increase of about 120%.

Increasing populations will result in increased discharges from municipal wastewater treatment plants. In addition, urbanization increases both volume and discharge velocity of runoff because of the increase in impervious surfaces. Urbanization also tends to increase pollutant loading because impervious surfaces neither absorb water nor remove pollutants, and urban development tends to create new anthropogenic mercury pollution sources. As Chapters 6 and 7 indicate, urban runoff in the Sacramento, Stockton and Tracy areas has higher

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[49] The CDOF predicts the following population increases by 2050: Contra Costa County - 89%, Sacramento County - 76%, San Joaquin County - 213%, Solano County - 105%, and Yolo County - 93% (CDOF, 2007).

methylmercury and total mercury concentrations than ambient river concentrations. However, little is known about how the conversion of agricultural land to urban uses affects methylmercury concentration.

A study of annual and seasonal trends in atmospheric mercury deposition in Maryland found a marked urban influence on mercury deposition; wet depositional fluxes at the urban site were two to three times higher than at the rural sites (Mason *et al.*, 2000). The Maryland study authors noted that local point sources such as air emissions from waste incinerators and power plants may contribute to the mercury deposition at the urban study site. Also, as noted in Chapter 4 in the draft Basin Plan Amendment staff report, reactive gaseous mercury (RGM) is thought to be emitted primarily from anthropogenic point sources or formed by oxidation reactions of gaseous elemental mercury with ozone, hydroxyl radical, nitrate, hydrogen peroxide, and/or halogen containing compounds (e.g., Peterson *et al*., 2009). RGM is more likely than other mercury fractions to be converted to methylmercury that is bioaccumulated in aquatic food chains (Whalin *et al*., 2007). Ground-level ozone is a potent irritant that causes lung damage and a variety of respiratory problems; ozone is the main component of smog and is formed by the reaction of hydrocarbons with nitrogen oxides in the presence of sunlight (USEPA OTAQ, 2007). In typical urban areas, a significant fraction of hydrocarbons comes from cars, buses, trucks, and nonroad mobile sources such as construction vehicles and boats powered by hydrocarbon-based fuels such as gasoline and diesel (USEPA OTAQ, 2007). As a result, increasing vehicle exhaust associated with urbanization would lead to increases in the hydrocarbon emissions, which subsequently could increase the formation of ground-level ozone and the formation of RGM.

MS4 allocations apply to all urban acreage within MS4 service areas within each Delta subarea and apply to the sum of methylmercury loads in existing urban acreage runoff and in runoff from future urbanized lands within the MS4 service areas. Staff assumed that, in general, NPDES-permitted municipal WWTP discharges throughout the Delta/Yolo Bypass would increase by 120%. Staff assumed that half of that growth will be addressed by expansions to existing facilities in each Delta subarea, and that half will be serviced by new facilities in each subarea. As described in Section 8.1.2 and shown in Tables 8.3 and 8.4, the allocation strategy incorporates the assumption that existing municipal WWTPs will increase their discharge volumes by 60% and reserves assimilative capacity for new WWTP discharges.

Chapter 4 in the draft Basin Plan Amendment staff report reviews possible implementation strategies to address the methylmercury allocations and total mercury limits for municipal WWTP discharges and urban runoff in the Delta region.

8.4.3.2 Restoration of Wetlands

Research conducted in the Delta and elsewhere has found that wetlands are efficient sites for methylmercury production. There are currently about 26,600 acres of wetlands within the Delta/Yolo Bypass (USFWS, 2006). The Record of Decision for the CALFED Bay-Delta Program commits it to restore 30,000 to 45,000 acres of fresh, emergent tidal wetlands, 17,000 acres of fresh, emergent nontidal wetlands, and 28,000 acres of seasonal wetlands in the Delta by 2030 (CALFED Bay-Delta Program, 2000a). This is a total of 75,000 to 90,000 acres of additional seasonal and permanent wetlands in the Delta, which represents about a three to four times increase in wetland acreage from current conditions. The Bay Delta Conservation Plan (BDCP) effort also identifies "priority projects" for near-term implementation that may increase the acreage of wetland and seasonally flooded habitat in the Delta (e.g., BDCP, 2010). In addition, the newly-established Federal Bay-Delta Leadership Committee's work plan of short-term actions may include expediting habitat restoration projects that are ready to move forward, including coordination with BDCP. (Refer to Sections 6.4.8 and 6.4.9 in Chapter 6 of the draft Basin Plan Amendment staff report for more information about the BDCP and Federal Bay-Delta Leadership Committee.)

Many of the proposed restoration sites are downstream of mercury-enriched watersheds. Marsh restoration efforts below mercury enriched watersheds are proposed for the following locations: Yolo Bypass downstream of Cache and Putah Creeks; Dutch Flats downstream of the Mount Diablo Mercury mine in the Marsh Creek watershed; and Staten Island and the Cosumnes River Wildlife Refuge near the confluence of the Cosumnes River and Mokelumne River.

Mass balance calculations indicated that methylmercury flux from wetland sediments may account for approximately 983 g/year of methylmercury (see Table 6.2 in Chapter 6), or about 19% of the total methylmercury budget for the Delta. A doubling to tripling in methylmercury loading from wetland sediments could increase overall Delta loading by about 16 to 27%. The linkage relationship suggests that such an increase could result in a 28 to 48% increase in mercury concentrations in standard 350-mm largemouth bass (Figure 5.3). CalFed study results released since the TMDL was developed indicate that some wetlands may contribute less methylmercury loading than assumed for the TMDL calculations, and that some wetlands may act as a methylmercury sink. Board staff will continue to track wetland methylmercury research and work with wetland managers and other stakeholders to incorporate new information into the TMDL control program using an adaptive management approach. Chapter 4 in the draft Basin Plan Amendment staff report provides a description of staff's suggested Central Valley Water Board policy for new wetland creation as well as a schedule for TMDL and control program reviews, during which the implementation strategy and allocations can be modified by the Board as needed to reflect new information.

8.4.3.3 Water and Flood Management Changes

As described in Chapter 3, the transport and deposition of mercury-contaminated sediment and water management activities contribute to the Delta fish mercury impairment. Several state and federal projects affect the transport of mercury and the production and transport of methylmercury in the Delta, including but not limited to:

- Operations to maintain current or future salinity standards in the Delta;
- Current water deliveries to, diversions from, and storage within the Delta;
- Yolo Bypass flood conveyance; and
- Dredging projects throughout the Delta and Yolo Bypass to maintain channel levees for flood conveyance, depths of deep water ship channels, and marina depths.

The source analyses, linkage analysis, methylmercury allocations and total mercury reduction requirements described in this TMDL are based on present water management practices and channel configurations. However, there are several water and flood management projects being evaluated by federal and state agencies that have the potential to affect methylmercury levels in Delta fish and water, including but not limited to:

- Water supply reliability projects. Public Policy Institute of California and University of California researchers outlined in a 2007 report (Lund *et al*., 2007) a range of potential alternatives for managing the Delta's water supply that could involve:
  - Maintaining the Delta as a fresh water body, e.g., by maintaining and strengthening the current levee system, or strategically focusing levee improvements in key areas and allowing lower-reliability levees to fail, which would lead to some Delta islands flooding;
  - Allowing the Delta to fluctuate between high and low levels of salinity, e.g., by supporting water supply exports with peripheral or through-Delta aqueducts that would allow water exports to circumvent the central Delta on their way to the lower San Joaquin River or directly to Central Valley Project and State Water Project intakes on the southern edge of the Delta, or by creating a major, semi-isolated freshwater conveyance corridor by armoring select islands and tide-gating selected channels within the central-eastern Delta; or
  - Moving toward a Delta that provides high levels of fresh water as needed, e.g., by only allowing exports during times of high discharge of fresh water (generally winter and spring), or otherwise managing the Delta to favor key Delta aquatic and terrestrial species, which would likely result in fluctuating salinity levels in the western Delta and many islands eventually becoming flooded.

  Governor Arnold Schwarzenegger's Delta Vision process concluded at the end of 2008 with a suite of strategic recommendations for long-term, sustainable management of the Delta. The December 2008 Delta Vision Committee Implementation Report identified "fundamental actions" such as:

  - A new system of dual water conveyance through and around the Delta to protect beneficial uses of water, with the goal of breaking ground for new conveyance improvements in 2011;
  - Additional surface and groundwater storage to allow greater system operational flexibility, including surface storage feasibility studies completed for Sites Reservoir, Los Vaqueros expansion, and the San Joaquin River Basin;
  - Revision of the San Joaquin River flow objectives by the State Water Board to improve Delta water quality, as well as the development and implementation of instream flow requirements for the Delta and its tributaries;
  - Strengthen the Delta levee system; and
  - By 2012 develop and implement Total Maximum Daily Load programs for the Delta and its tributary areas to eliminate water quality impairments, including but not limited to reduction of organic and inorganic mercury entering the Delta from tributary watersheds.

  This TMDL report and associated Basin Planning process fulfills the above fundamental action of developing and implementing a mercury TMDL for the Delta. However, the specific details of the other fundamental actions identified by the Delta Vision Committee or possible alternatives (e.g., as identified in Lund and others' 2007 report), and possible affects on methylmercury levels in Delta water and fish, are not yet known.

- The Sacramento Deep Water Ship Channel Deepening Project, which involves dredging to deeper depths than done in the past to allow deeper-hulled cargo ships to access the Sacramento port. The 2010 Civil Works budget included $10 million for re-launching the Sacramento Deep Water Ship Channel deepening project. As noted on a May 2009 Port of Sacramento press release, the project would involve deepening the 43-mile ship channel connecting the Port of West Sacramento and San Francisco Bay from 30 feet to 35 feet along its entire length. The channel-deepening project, which was initially started in 1989 but later stopped due to since-resolved utility issues, is scheduled to begin in 2010 with completion targeted for 2013. The federal Civil Works funding would support the first phase of construction (Port of West Sacramento, 2009). The project could affect conditions within the ship channel as well as entail increased discharges of return water with elevated methylmercury concentrations from dredge material disposal areas. (See Section 6.2.7 in Chapter 6 for a review of recent return water methylmercury monitoring efforts.)
- Fremont Weir modification to increase flows in the Yolo Bypass. The Blue Ribbon Task Force Delta Vision Strategic Plan included the recommendation to increase the inundation frequency of the Yolo Bypass to promote primary and secondary productivity and splittail spawning by modifying the Fremont Weir. The BDCP has continued to forward the concept of lowering a portion of the Fremont Weir and installing an operable gate facility (often referred to as creating a "notch" in the weir) to increase periods of Yolo Bypass inundation to support native fisheries, particularly splittail and Chinook salmon, through managed flow releases down the Bypass (e.g., BDCP, 2009, Table 3.3 Conservation Measure WOCML2). However, the Lower Yolo Bypass Planning Forum identified several concerns, one of which is the potential increases of methylmercury (Lower Yolo Bypass Planning Forum, 2008).
- The San Joaquin River Restoration Program (SJRRP), a comprehensive long-term effort to restore flows to the San Joaquin River from Friant Dam to the confluence of Merced River. "Interim Flows" began in October 2009. Monitoring is needed to determine how increasing flows (and inundation of associated floodplains) will affect methylmercury levels in San Joaquin River and Delta water and fish.
- The South Delta Improvement Project (SDIP), which is intended to mitigate the water supply and water quality impacts associated with increasing the maximum allowable diversion capacity into Clifton Court Forebay, from which the State Water Project pumps its water. The SDIP could entail the construction of a series of permanent barriers that would reduce the amount of San Joaquin River flow diverted down Old River towards the pumps and away from the San Joaquin River near Stockton. Operation of the permanent barriers would control the ratio of San Joaquin to Sacramento River water in much of the southern Delta. Sulfate concentrations in the San Joaquin are about seven times higher than in the Sacramento River. Therefore, operation of the permanent barriers could exert a strong influence on sediment sulfate concentrations in the southern Delta and may influence ambient methylmercury levels. (See Section 4.3.12.4 in Chapter 4 of the draft Basin Plan Amendment staff report for more discussion on the SDIP.)

To better enable the evaluation and mitigation of negative impacts on water and fish methylmercury levels in the Delta from future water and flood management and dredging projects, Board staff worked with stakeholders to develop language for the proposed Basin Plan amendments included in the draft Basin Plan Amendment report that:

- Assigns the open water methylmercury allocations jointly to the State Lands Commission, the Department of Water Resources, and the Central Valley Flood Protection Board. The open water allocations apply to the methylmercury load that fluxes to the water column from sediments in open-water habitats within channels and floodplains in the Delta and Yolo Bypass. The open water allocations also apply to activities such as water management and storage in and upstream of the Delta and Yolo Bypass; maintenance of and changes to salinity objectives; dredging and dredge materials disposal, dewatering and reuse; and management of flood conveyance flows.
- Requires State and Federal agencies whose projects affect the transport of mercury and the production and transport of methylmercury through the Yolo Bypass and Delta, or manage open water areas in the Yolo Bypass and Delta, to conduct methylmercury control studies during the first phase of the TMDL implementation period.
- Requires State and Federal agencies to include requirements for projects under their authority to implement methylmercury reductions as necessary to comply with the allocations by 2030.

State and Federal agencies required to participate in the control studies and efforts to reduce open water methylmercury include but are not limited to the California Department of Water Resources, State Lands Commission, Central Valley Flood Protection Board, State Water Resources Control Board, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation. State and federal projects include projects related to flood conveyance, water management, and salinity control that have the potential to increase ambient mercury and/or methylmercury levels in the Delta or Yolo Bypass.

Water management activities also affect the residence time of water in the Delta, which affects the methylmercury loss rate across the Delta from photodegradation and sediment deposition. Changes in water management activities that reduce the methylmercury loss rate across the Delta could result in increases in ambient water and fish methylmercury concentrations even if the activities do not cause an increase in methylmercury source inputs. The 2003 and 2008 CalFed studies indicate that loss processes are an important component of the Delta methylmercury mass balance and resulting fish methylmercury concentrations in different areas of the Delta (see Chapters 3, 5 and 6). It is critical that state and federal agencies evaluate the effect of future water management projects on methylmercury loss processes in the Delta because (1) the suite of activities that affect production processes may be different from the suite of activities that affect loss processes, (2) different agencies may be responsible for these different activities, and (3) as a result, tracking activities that affect methylmercury inputs and methylmercury loss may provide better direction for a variety of methylmercury control methods. The proposed Basin Plan amendment language described in the previous paragraphs was purposefully written in way that encompasses activities that affect methylmercury production, transport, and loss processes.

Board staff will continue to coordinate with the State and Federal agencies to evaluate the potential effects of future water and flood management projects and dredging projects and adapt the Delta mercury control program as needed to incorporate new information and control strategies during program reviews.

8.4.3.4 Decreasing Sediment Loads

The sediment load in the Sacramento River decreased by about 50% between 1957 and 2001 (Wright and Schoellhamer, 2004). The decrease is believed to be caused by the trapping of sediment in reservoirs, a decrease in erodible material from hydraulic mining, changes in land use, and construction of levees (Wright and Schoellhamer, 2004; James, 2004). Mercury loads are likely to have also decreased during the same period because much of the inorganic mercury is transported on sediment particles. It is not known what the magnitude of the decrease in mercury loading has been and whether it will continue in the future. The decrease in sediment loading suggests that the relative proportion of erodible material from upstream watersheds may also be changing. The present 20-year volume-weighted average mercury to TSS ratio of sediment entering the Delta is approximately 0.18 mg/kg. This value may change depending on the new sources of sediment. The mercury content of surficial sediment is important, as it is one of the major factors controlling methylmercury production. Methylmercury production in Delta/Yolo Bypass sediment now accounts for about 36% of the methylmercury in the Delta (Figure 6.11). It is not clear how this proportion may change in the future.

8.4.3.5 Climate Change

Climate change models have predicted several scenarios for global, national and local changes that could affect the Delta, including several direct, individual and cumulative impacts. Warmer temperatures, water abundance and quality, changes in precipitation patterns, frequency and intensity of weather events, and sea level rise are just some of the changes that could impact the Delta, its water supply, habitats, and biota (CAT, 2006; CEC, 2006a and 2008; TRNA, 2009; Brekke *et al.*, 2004; Knowles and Cayan, 2002; Miller *et al.*, 2003; Service, 2004; Stewart *et al.*, 2004). In addition to warmer storms, the Sierra Nevada snow pack, California's largest surface "reservoir" has been reducing each year (CAT, 2006; CAPCOA, 2009; TRNA, 2009). Typically, snowmelt provides an annual average of 15 million acre feet of water between April and July each year (DWR, 2008; TRNA, 2009). Models project the Sierra Nevada snowpack will decrease by 25% to 40% by 2050, which would likely result in regions that rely on surface water for domestic, industrial, and agricultural supply needing to turn to groundwater or additional diversions from the Delta (DWR, 2008; TNRA, 2009). Changes in rainfall and runoff patterns combined with warmer temperatures are expected to change the intensity and frequency of flood events (CAPCOA, 2009).

Drier years could result in more frequent and intense wildfires, depleting the carbon storage that wildlands and forests provide (CAPCOA, 2009; CAT, 2006; CEC, 2006a and 2006c). Warmer temperatures may increase evapotranspiration rates and extend growing seasons, which would require more water (CAPCOA, 2009). High frequency flood events will most likely increase, changing watershed vegetation and erosion patterns (CAPCOA, 2009; CEC 2006a and 2008). Flooding and wildfires would increase sedimentation rates, which would likely negatively affect reservoir capacity, wildlife habitat and fisheries, and water quality and would likely alter the channel shapes and depths in the Delta. Changes in water quality could include changes in streamflow patterns, dissolved oxygen, and temperatures; higher turbidity; and concentrated pulses of pollutants, all of which could stress fish and increase growth of algae in surface water bodies (DWR 2008; TRNA, 2009). Sea level rise is already occurring; the exact rate is unknown but it is correlated to the melting rate of the ice sheets on the western Antarctica and Greenland, and could result in abrupt changes in sea level conditions (CAT, 2006; CEC, 2006b). Sea level rise would likely ultimately result in increased salt water intrusion in the Delta (CEC, 2006a, 2006d, and 2008; TRNA, 2009).

Other indirect effects of climate change in California that could affect the Delta, and therefore the proposed mercury control program, may include public health impacts; recreational availability; changes in growth rates of weeds, pests, and disease; shifts in distribution and abundance of biota; and response by biota to elevated carbon dioxide levels (CAT, 2006; CAPCOA, 2009; CEC, 2006a).

The net results of climate change may have unpredictable consequences on ecological processes in the Delta including the synthesis and bioaccumulation of methylmercury. The source analyses, linkage analysis, methylmercury allocations and total mercury reduction requirements described in this TMDL are based on present climate conditions. Staff will re-evaluate source analyses and linkage relationships associated with changing environmental conditions as more information becomes available in the future.

8.4.3.6 Global Mercury Emissions

Because of the complexity of atmospheric mercury sources, and because the Central Valley Water Board has limited jurisdiction over these sources, there is greater uncertainty about whether these sources can be addressed in a timely manner. Total mercury concentrations in precipitation in Oregon and rural northern California are consistently very low and, along with Newfoundland, are usually the lowest values in North America (Prestbo and Gay, 2009). Atmospheric wet deposition of methylmercury and total mercury directly to the Delta/Yolo Bypass makes up only about 1% or less of all methylmercury and total mercury loading to the Delta/Yolo Bypass (see Tables 6.2 and 7.1 in the TMDL Report).

However, a rough estimate of the annual contribution of total mercury from atmospheric wet deposition in the tributary watersheds for water year 2001 indicated that wet deposition could account for 23 to 69% of the total incoming total mercury load to the Delta (Foe, 2003). In addition, recent studies indicate that mercury in atmospheric deposition in northern California comes from both local sources (e.g., municipal and industrial emissions, historic mercury and gold mine sites, forest fires, and naturally mercury-enriched geologic formations) and sources outside of California and the United States (e.g., coal-burning power plants in Asia, gold and mercury production, cement production, volcanic emissions, oceans and biomass burning (e.g., forest fires and biofuel to produce energy) (e.g., Prestbo and Gay, 2009; Peterson *et al*, 2009; Jaffe *et al*., 2005; Pacyna *et al.*, 2006; Weiss-Penzias *et al.*, 2007; Seigneur *et al.*, 2004; Steding and Flegal, 2002; Coolbaugh *et al*., 2002; Nacht *et al*., 2004). The largest emissions of mercury to the global atmosphere occur from combustion of fossil fuels, mainly coal in utility, industrial, and residential boilers; as much as two thirds of the total emission of about

2,190 tons of mercury emitted from all anthropogenic sources worldwide in 2000 came from combustion of fossil fuels (Pacyna *et al.*, 2006).

Key Points

- Methylmercury allocations are divided among "waste load allocations" for point sources and "load allocations" for nonpoint sources. The TMDL is the sum of these components. The allocation strategy used in this chapter is based on staff's recommended strategy described in Chapter 4 of the draft Basin Plan Amendment staff report and is designed to remedy the beneficial use impairment in all subareas of the Delta. Total mercury limits were developed to maintain compliance with the USEPA's CTR for total mercury in the water column and to achieve the San Francisco Bay mercury control program's total mercury allocation for the Central Valley, as well as to help enable methylmercury reductions in Delta water and fish.

Methylmercury:

- Methylmercury allocations were made in terms of the existing assimilative capacity of the different Delta subareas. The recommended goal for ambient water is an average annual concentration of 0.06 ng/l methylmercury in unfiltered water (Chapter 5). This goal describes the assimilative capacity of Delta waters in terms of concentration and encompasses a margin of safety of approximately 10%. Central Valley Water Board staff anticipates that as the average concentration of methylmercury in each Delta subarea decreases to the aqueous goal, the targets for fish tissue will be attained.
- To determine necessary reductions, the existing average aqueous methylmercury levels in ambient water in the Delta subareas were compared to the methylmercury goal. The amount of reduction needed in each subarea is expressed as a percent of the existing concentration. Percent reductions required to meet the goal ranged from 0% in the Central Delta subarea to more than 70% in the Yolo Bypass and Marsh Creek subareas.

Total Mercury:

- Central Valley Water Board staff recommends that the 110 kg total mercury reduction allocated by the San Francisco Bay mercury control program to the Central Valley be met by reductions in total mercury entering the Delta from tributary inputs because within-Delta sources comprise only a couple percent of total mercury inputs. Initial mercury reduction efforts should focus on the watersheds that export the largest volume of highly contaminated sediment. Additional reductions may be recommended in future phases of the Delta mercury implementation program and upstream control programs to achieve the proposed methylmercury allocations for open-water and wetland habitat in the Delta/Yolo Bypass and to address mercury impairments in the upstream watersheds.

Options to Consider

- The methylmercury allocations described in this chapter reflect the preferred implementation alternative described in Chapter 4 of the draft Basin Plan Amendment staff report and are designed to address the beneficial use impairment in all subareas of the Delta. However, as described in the draft Basin Plan Amendment staff report, a number of alternatives are possible. The Central Valley Water Board will consider a variety of allocation strategies and implementation alternatives as part of the Basin Plan amendment process.
- Likewise, a variety of total mercury reduction strategies are possible. A total mercury load reduction strategy was developed to comply with the San Francisco Bay mercury TMDL allocation for to the Central Valley and the USEPA's criterion for human health protection, and to help enable compliance with the proposed methylmercury allocations for open-water habitat in the Delta and Yolo Bypass. Staff applied the San Francisco Bay TMDL's allocated reduction of 110 kg total mercury reduction to tributary inputs to the Delta/Yolo Bypass because within-Delta sources comprise only a couple percent of total mercury inputs. Initial mercury reduction efforts should focus on the watersheds that export the largest volume of highly contaminated sediment such as the Cache Creek, Feather River, American River, Cosumnes River, and Putah Creek watersheds. Chapter 4 of the draft BPA staff report describes additional strategies for minimizing increases from total mercury sources that may increase as a result of population growth and regional water management changes.

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A. WATERWAYS WITHIN THE SACRAMENTO-SAN JOAQUIN DELTA

This appendix lists the Sacramento-San Joaquin Delta and Yolo Bypass waterways to which the proposed TMDL fish tissue targets (a.k.a. water quality objectives for methylmercury in fish) apply. These waterways are distinct, readily identifiable water bodies within the boundaries of the “legal” Delta (as defined in California Water Code Section 12220) and Yolo Bypass north of the Delta that are hydrologically connected by surface water flows (not including pumping) to the Sacramento and/or San Joaquin Rivers. Table A.1 lists all the waterways in alphabetical order with Yolo Bypass waterways north of the legal Delta boundary listed at the end. Figures A.1 through A.3 show the locations of the waterways.

The methylmercury allocations proposed for the Delta methylmercury control program are specific to Delta subareas, which are shown on Figure A.4. Table A.2 lists the waterways within each of the subareas.

Table A.1: Delta and Yolo Bypass Waterways

Map Label # / Waterway Name

1. Alamo Creek
2. Babel Slough
3. Barker Slough
4. Bear Creek
5. Bear Slough
6. Beaver Slough
7. Big Break
8. Bishop Cut
9. Black Slough
10. Broad Slough
11. Brushy Creek
12. Burns Cutoff
13. Cabin Slough
14. Cache Slough
15. Calaveras River
16. Calhoun Cut
17. Clifton Court Forebay
18. Columbia Cut
19. Connection Slough
20. Cosumnes River
21. Crocker Cut
22. Dead Dog Slough
23. Dead Horse Cut
24. Deer Creek (Tributary to Marsh Creek)
25. Delta Cross Channel
26. Disappointment Slough
27. Discovery Bay
28. Donlon Island
29. Doughty Cut
30. Dry Creek (Marsh Creek tributary)
31. Dry Creek (Mokelumne River tributary)
32. Duck Slough
33. Dutch Slough
34. Elk Slough
35. Elkhorn Slough
36. Emerson Slough
37. Empire Cut
38. Fabian and Bell Canal
39. False River
40. Fisherman's Cut
41. Fivemile Creek
42. Fivemile Slough
43. Fourteenmile Slough
44. Franks Tract
45. French Camp Slough
46. Georgiana Slough

Map Label # / Waterway Name

47. Grant Line Canal
48. Grizzly Slough
49. Haas Slough
50. Hastings Cut
51. Hog Slough
52. Holland Cut
53. Honker Cut
54. Horseshoe Bend
55. Indian Slough
56. Italian Slough
57. Jackson Slough
58. Kellogg Creek
59. Latham Slough
60. Liberty Cut
61. Lindsey Slough
62. Little Connection Slough
63. Little Franks Tract
64. Little Mandeville Cut
65. Little Potato Slough
66. Little Venice Island
67. Livermore Yacht Club
68. Lookout Slough
69. Lost Slough
70. Main Canal (Duck Slough tributary)
71. Main Canal (Italian Slough tributary)
72. Marsh Creek
73. Mayberry Cut
74. Mayberry Slough
75. Middle River
76. Mildred Island
77. Miner Slough
78. Mokelumne River
79. Mormon Slough
80. Morrison Creek
81. Mosher Slough
82. Mountain House Creek
83. North Canal
84. North Fork Mokelumne River
85. North Victoria Canal
86. Old River
87. Paradise Cut
88. Piper Slough
89. Pixley Slough
90. Potato Slough
91. Prospect Slough
92. Red Bridge Slough
93. Rhode Island
94. Rock Slough

Table A.1: Delta and Yolo Bypass Waterways, *Continued*

Map Label # / Waterway Name

95. Sacramento Deep Water Channel
96. Sacramento River
97. Salmon Slough
98. San Joaquin River
99. Sand Creek
100. Sand Mound Slough
101. Santa Fe Cut
102. Sevenmile Slough
103. Shag Slough
104. Sheep Slough
105. Sherman Lake
106. Short Slough
107. Smith Canal
108. Snodgrass Slough
109. South Fork Mokelumne River
110. Steamboat Slough
111. Stockton Deep Water Channel
112. Stone Lakes
113. Sugar Cut
114. Sutter Slough
115. Sweany Creek
116. Sycamore Slough
117. Taylor Slough (Elkhorn Slough tributary)
118. Taylor Slough (near Franks Tract)
119. Telephone Cut
120. The Big Ditch
121. The Meadows Slough
122. Three River Reach
123. Threemile Slough

Map Label # / Waterway Name

124. Toe Drain
125. Tom Paine Slough
126. Tomato Slough
127. Trapper Slough
128. Turner Cut
129. Ulatis Creek
130. Upland Canal (Sycamore Slough tributary)
131. Victoria Canal
132. Walker Slough
133. Walthall Slough
134. Washington Cut
135. Werner Dredger Cut
136. West Canal
137. Whiskey Slough
138. White Slough
139. Winchester Lake
140. Woodward Canal
141. Wright Cut
142. Yosemite Lake
143. Yolo Bypass
144. Deuel Drain
145. Dredger Cut
146. Highline Canal
147. Cache Creek Settling Basin Outflow
148. Knights Landing Ridge Cut
149. Putah Creek
150. Tule Canal

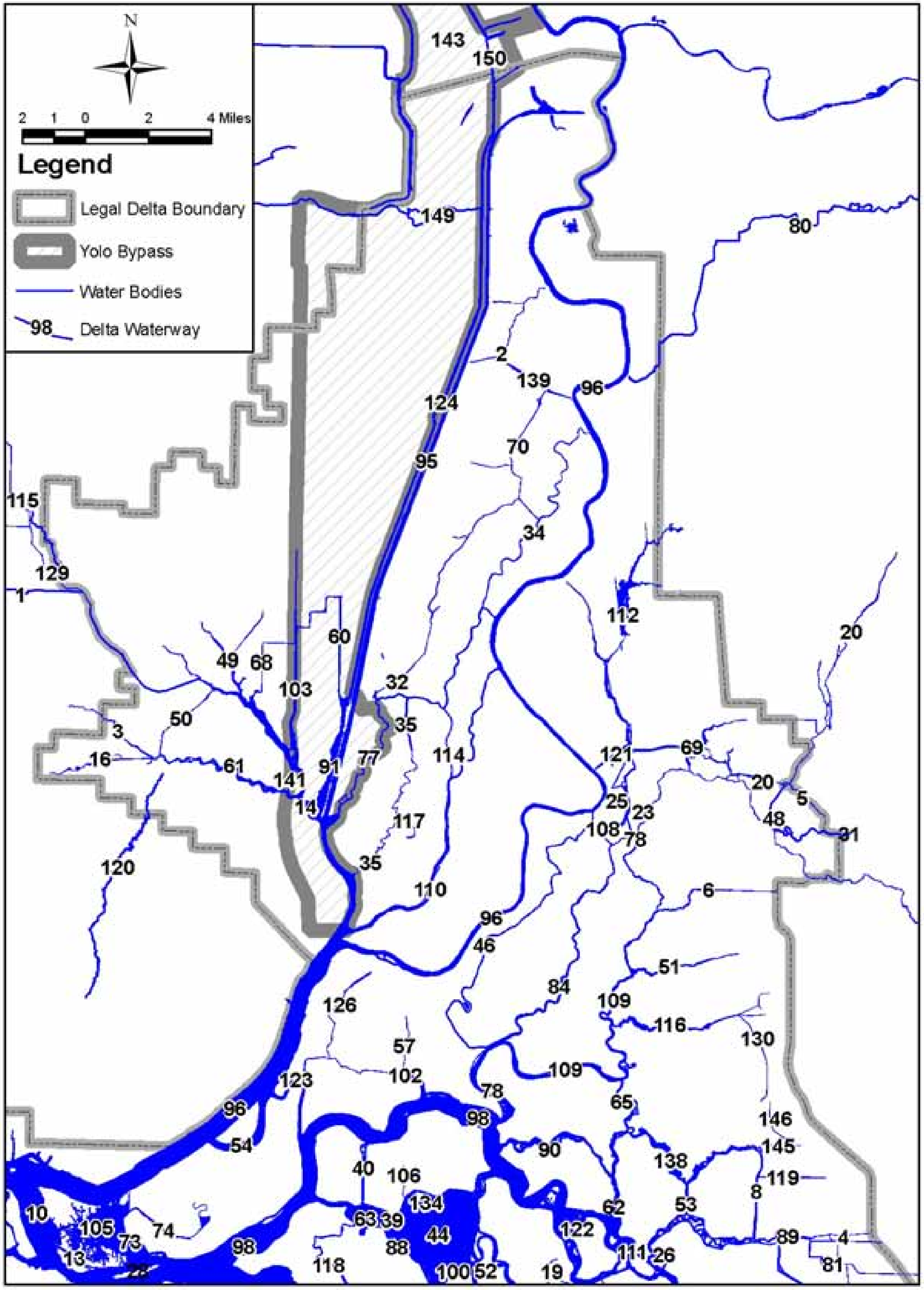

Figure A.1: Delta Waterways (Northern Panel)

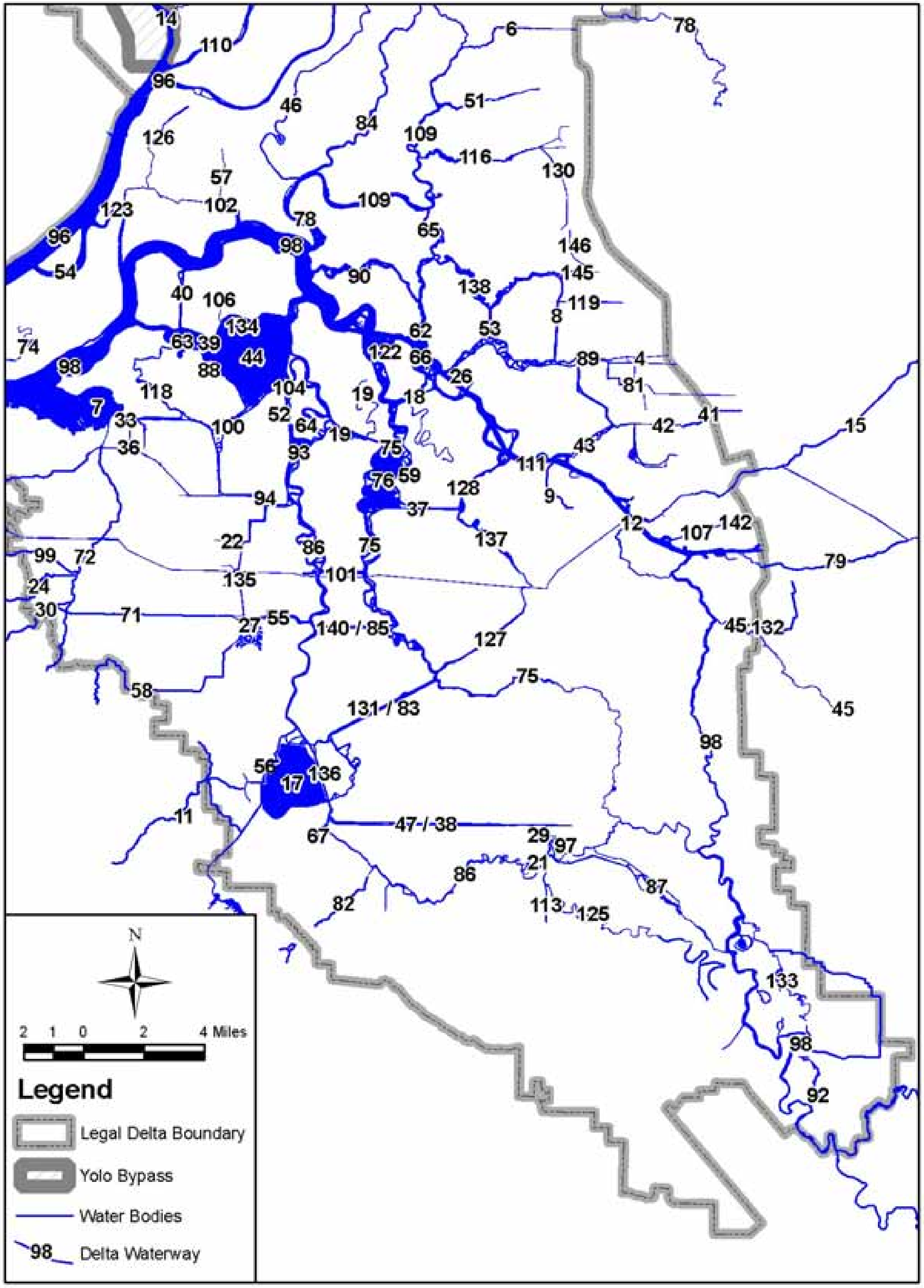

Figure A.2: Delta Waterways (Southern Panel)

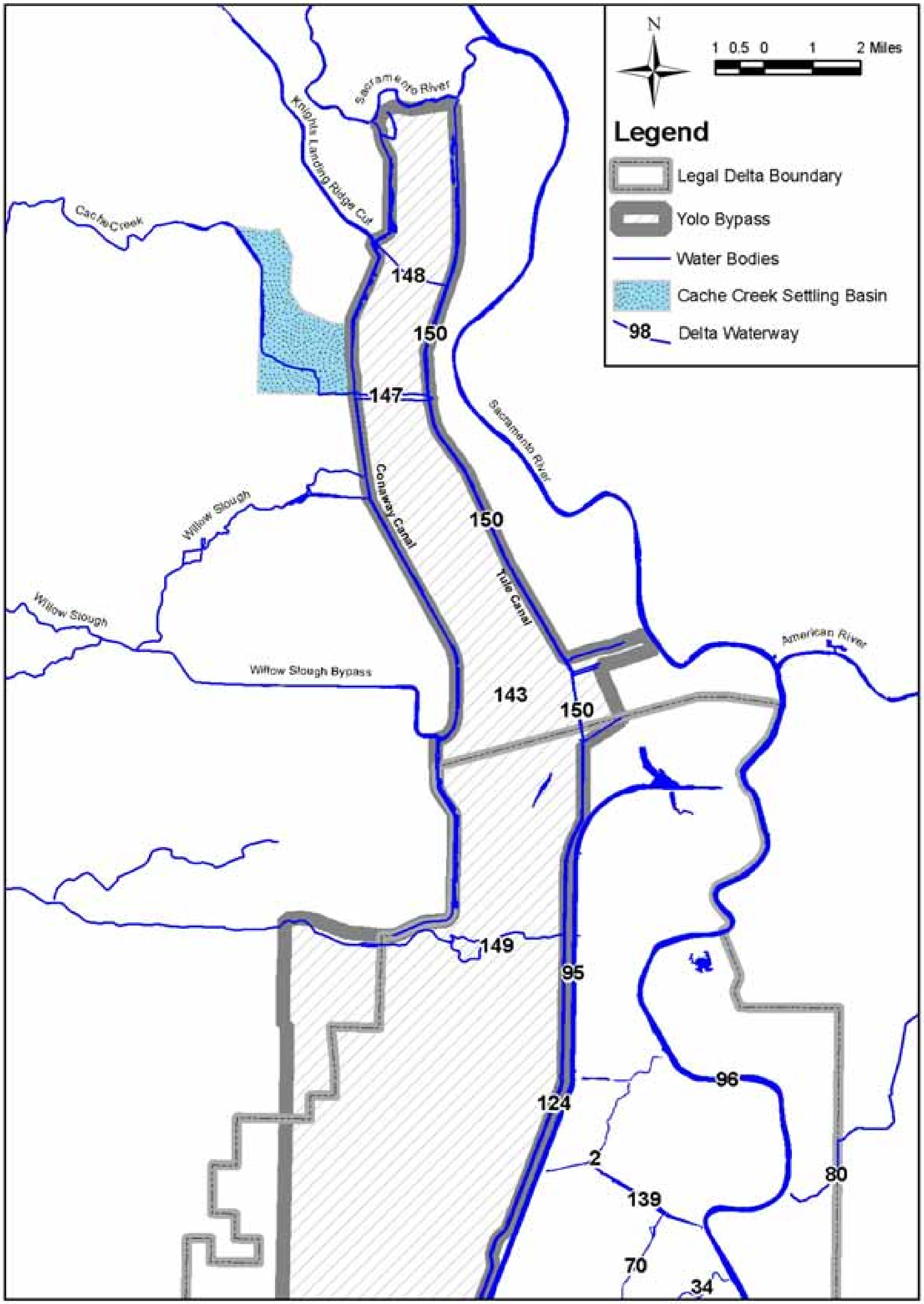

Figure A.3: Northern Yolo Bypass

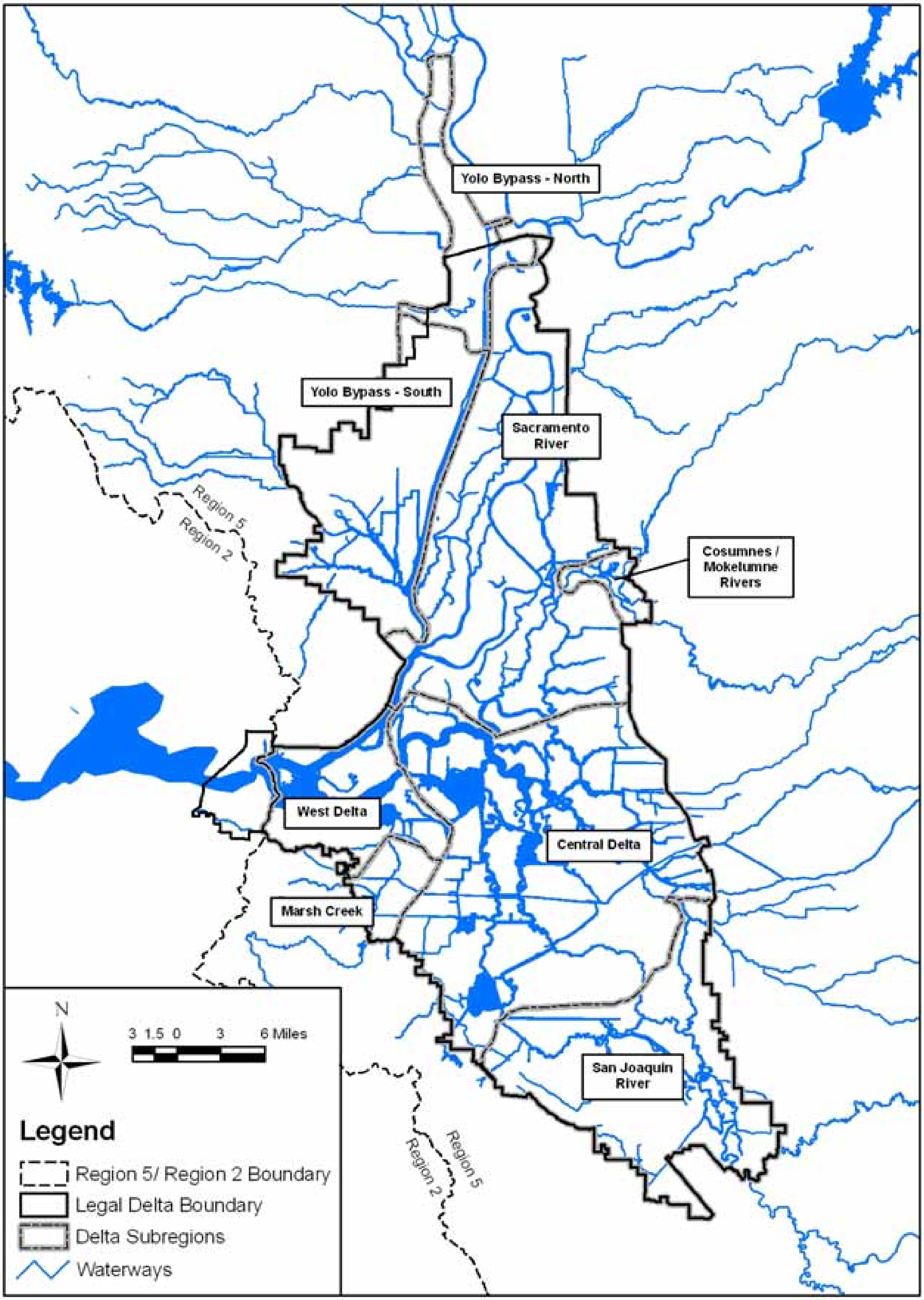

Figure A.4: Subareas for the Delta Methylmercury Control Program

Table A.2: Delta and Yolo Bypass Waterways by Methylmercury Allocation Subarea

Waterway Name [Map Label #]	Waterway Name [Map Label #]	Waterway Name [Map Label #]
CENTRAL DELTA		
Bear Creek [4]	Indian Slough [55]	San Joaquin River [98]
Bishop Cut [8]	Italian Slough [56]	Sand Mound Slough [100]
Black Slough [9]	Jackson Slough [57]	Santa Fe Cut [101]
Brushy Creek [11]	Kellogg Creek [58]	Sevenmile Slough [102]
Burns Cutoff [12]	Latham Slough [59]	Sheep Slough [104]
Calaveras River [15]	Little Connection Slough [62]	Short Slough [106]
Clifton Court Forebay [17]	Little Franks Tract [63]	Smith Canal [107]
Columbia Cut [18]	Little Mandeville Cut [64]	Stockton Deep Water Channel [111]
Connection Slough [19]	Little Potato Slough [65]	Taylor Slough [nr Franks Tract] [118]
Dead Dog Slough [22]	Little Venice Island [66]	Telephone Cut [119]
Disappointment Slough [26]	Livermore Yacht Club [67]	Three River Reach [122]
Discovery Bay [27]	Main Canal [Indian Slough trib.] [71]	Threemile Slough [123]
Dredger Cut [145]	Middle River [75]	Tomato Slough [126]
Empire Cut [37]	Mildred Island [76]	Trapper Slough [127]
Fabian and Bell Canal [39]	Mokelumne River [78]	Turner Cut [128]
False River [39]	Mormon Slough [79]	Upland Canal [Sycamore Slough tributary] [130]
Fisherman's Cut [40]	Mosher Slough [81]	
Fivemile Creek [41]	North Canal [83]	Victoria Canal [131]
Fivemile Slough [42]	North Victoria Canal [85]	Washington Cut [134]
Fourteenmile Slough [43]	Old River [86]	Werner Dredger Cut [135]
Franks Tract [44]	Piper Slough [88]	West Canal [136]
Grant Line Canal [47]	Pixley Slough [89]	Whiskey Slough [137]
Highline Canal [146]	Potato Slough [90]	White Slough [138]
Holland Cut [52]	Rhode Island [93]	Woodward Canal [140]
Honker Cut [53]	Rock Slough [94]	Yosemite Lake [142]
MOKELUMNE/COSUMNES RIVERS		
Bear Slough [5]	Dry Creek [Mokelumne R. trib.] [31]	Lost Slough [69]
Cosumnes River [20]	Grizzly Slough [48]	Mokelumne River [78]
MARSH CREEK		
Deer Creek [24]	Main Canal [Indian Slough trib.] [71]	Rock Slough [94]
Dry Creek [Marsh Creek trib.] [30]	Marsh Creek [72]	Sand Creek [99]
Kellogg Creek [58]		
SACRAMENTO RIVER		
Babel Slough [2]	Little Potato Slough [65]	Stone Lakes [112]
Beaver Slough [6]	Lost Slough [69]	Sutter Slough [114]
Cache Slough [14]	Main Canal [Duck Slough trib.] [70]	Sycamore Slough [116]
Dead Horse Cut [23]	Miner Slough [77]	Taylor Slough [Elkhorn Slough tributary] [117]
Delta Cross Channel [25]	Mokelumne River [78]	
Duck Slough [32]	Morrison Creek [80]	The Meadows Slough [121]
Elk Slough [34]	North Mokelumne River [84]	Tomato Slough [126]
Elkhorn Slough [35]	Sacramento River [96]	Upland Canal [Sycamore Slough tributary] [130]
Georgiana Slough [46]	Snodgrass Slough [108]	
Hog Slough [51]	South Mokelumne River [109]	Winchester Lake [139]
Jackson Slough [57]	Steamboat Slough [110]	

Table A.2: Delta and Yolo Bypass Waterways by Methylmercury Allocation Subarea, *Continued*

Waterway Name [Map Label #]	Waterway Name [Map Label #]	Waterway Name [Map Label #]
SAN JOAQUIN RIVER		
Crocker Cut [21]	Middle River [75]	San Joaquin River [98]
Deuel Drain [144]	Mountain House Creek [82]	Sugar Cut [113]
Doughty Cut [29]	Old River [86]	Tom Paine Slough [125]
Fabian and Bell Canal [38]	Paradise Cut [87]	Walker Slough [132]
French Camp Slough [45]	Red Bridge Slough [92]	Walthall Slough [133]
Grant Line Canal [47]	Salmon Slough [97]	
WEST DELTA		
Big Break [7]	Horseshoe Bend [54]	San Joaquin River [98]
Broad Slough [10]	Marsh Creek [72]	Sand Mound Slough [100]
Cabin Slough [13]	Mayberry Cut [73]	Sherman Lake [105]
Donlon Island [28]	Mayberry Slough [74]	Taylor Slough [near Franks Tract] [118]
Dutch Slough [33]	Rock Slough [94]	
Emerson Slough [36]	Sacramento River [96]	Threemile Slough [123]
False River [39]		
YOLO BYPASS-NORTH (a)		
Cache Creek Settling Basin Outflow [147]	Toe Drain [124]/Tule Canal [150]	Sacramento Deep Water Ship Channel [95]
	Putah Creek [149)]	
Knights Landing Ridge Cut [148]		
YOLO BYPASS-SOUTH (a)		
Alamo Creek [1]	Liberty Cut [60]	Sweany Creek [115]
Babel Slough [2]	Lindsey Slough [61]	Sycamore Slough [116]
Barker Slough [3]	Lookout Slough [68]	The Big Ditch [120]
Cache Slough [14]	Miner Slough [77]	Toe Drain [124]
Calhoun Cut [16]	Prospect Slough [91)]	Ulatis Creek [129]
Duck Slough [32]	Sacramento Deep Water Ship Channel [95]	Wright Cut [141]
Haas Slough [49]		
Hastings Cut [50]	Shag Slough [103]	

(a) Both the “Yolo Bypass-North” and “Yolo Bypass-South” subareas contain portions of the Yolo Bypass flood conveyance channel shown in Figure IV-4. When flooded, the entire Yolo Bypass is a Delta waterway. When the Yolo Bypass is not flooded, the Toe Drain [127] (referred to as Tule Canal [C] for its northern reach), Cache Creek Settling Basin Outflow [A], and Knights Landing Ridge Cut [B] are the only waterways within the Yolo Bypass hydrologically connected to the Sacramento River.

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B. SUMMARY OF FISH MERCURY DATA USED IN TMDL NUMERIC TARGET AND LINKAGE ANALYSIS CALCULATIONS

Section B.1 summarizes the fish mercury data used in the numeric target and linkage analysis chapters. Table B.1 lists the fish species and lengths of fish included in the weighted-average[1] fish mercury concentrations. Tables B.2 through B.5 list the number of samples and fish included in the calculations for each Delta subarea. Data for fish sampled in the Cosumnes River and Mokelumne River and in the northern portion of the Yolo Bypass were included in the numeric target development calculations. However, only data for fish sampled in the Mokelumne River downstream of the Cosumnes River confluence were included in the linkage analysis calculations; these data are summarized in Tables B.4 and B.5. All fish data summarized in these tables are provided in Appendix K. Section B.3 provides figures that illustrate the range of mercury levels in the species within each Delta subarea trophic level food group. Appendix C provides a description of the available mercury data for important commercial and sport fisheries – such as striped bass, salmon, crayfish, clams and blackfish – not included in this data summary because they either do not represent local conditions or do not fit within the trophic level food groups defined by the numeric targets.

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[1] Weighted average mercury concentration is based on the number of fish in the composite samples analyzed, rather than the number of samples.

B.1 Description of Fish Mercury DATA Used in the Numeric Target and Linkage Analysis Chapters

Table B.1: Summary of Fish Species & Lengths Used in the Numeric Target & Linkage Analysis Chapters

Trophic Level 4 Species & Length Ranges Used for Estimation of Human & Bald Eagle Health Risk [150-500 mm, unless CDFG minimum catch limit applies] (a, b) Black crappie (> 150 mm) Channel catfish (> 200 mm) (b) Largemouth bass (> 305 mm) (a) Sacramento pikeminnow (> 150 mm) (b) Smallmouth bass (> 305 mm) (a) White catfish (> 200 mm) (b) White crappie (> 150 mm) (b)	**Trophic Level 4 Species & Length Ranges Used for Estimation of Otter and Osprey Health Risk** (c) Black crappie (150 - 350 mm) Channel catfish (200 - 350 mm) Largemouth bass (150 - 350 mm) Sacramento pikeminnow (150 - 350 mm) Smallmouth bass (150 - 350 mm) White catfish (200 - 350 mm) White crappie (150 - 350 mm)
Trophic Level 3 Species & Length Ranges Used for Estimation of Human Health and Bald Eagle Risk [150-500 mm] (d) Black bullhead Bluegill Carp Channel catfish (150 - 200 mm) Golden shiner Goldfish (e) Redear sunfish Sacramento blackfish Sacramento splittail Sucker Unid goby White catfish (150 - 200 mm) Yellowfin goby	**Trophic Level 3 Species & Length Ranges for Estimation of Osprey, Grebe and Merganser Health Risk.** [All TL3 fish species, 150-350 mm. Small individuals of TL4 species of catfish are included.] (c) Black bullhead Bluegill Carp Channel catfish (150 - 200 mm) Golden shiner Goldfish Redear sunfish Sacramento blackfish Sacramento splittail Sucker Threadfin Shad Unid goby White catfish (150 - 200 mm) Yellowfin goby
Trophic Level 3 Species & Length Ranges for Estimation of Cormorant, Otter, Mink and Kingfisher Health Risk. [All TL3 fish species, 50-150 mm. Small individuals of TL4 species of bass, crappie, and catfish, are included.] (f) Bigscale logperch Bluegill Channel catfish (50 - 150 mm) Golden shiner Inland silverside Largemouth bass (50 - 100 mm) Mosquitofish Prickly sculpin Red shiner Redear sunfish Shimofuri goby Threadfin Shad Unid goby White catfish (50 - 150 mm) White crappie (50 - 120 mm) Yellowfin goby	**Trophic Level 3 for Estimation of Least Tern Health Risk.** [All TL3 and juveniles of TL4 fish species less than 50 mm.] (g) Bluegill Inland silverside Mosquitofish Prickly sculpin Red shiner Shimofuri goby White catfish White crappie

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TABLE B.1 FOOTNOTES:

(a) Size minimum based on CDFG fishing regulations: 12 inch minimum (305 mm) for largemouth and smallmouth bass.

(b) Size minimum based on prey type of the fish species. Example: on average, catfish 200 mm and larger are mainly piscivorous, meaning that a majority of their diet is trophic level three species. Catfish smaller than 200 mm eat mainly prey from trophic level 2. Minimum sizes based on length of fish when they become mostly piscivorous are given for bass, catfish, pikeminnow and crappie (Source: Moyle PB, 2002. Inland Fishes of California, Revised and Expanded, Berkeley, Univ. California Press)

(c) Size minimum based on prey type of the fish species - see note (b). Maximum size of 350 mm is based on largest size generally consumed by osprey or otter. (For bald eagle, use average concentration in TL4 fish grouped for humans to assess risk).

(d) TL3 species for calculating human health risk are those species assumed to be eaten by humans, based on general knowledge of the fishery and size of fish. Staff assumes that most fish eaten are at least 150 mm (6 inches). Small bass are not included in the trophic level 3 species for human consumption because they cannot legally be fished and kept. Crappies are not included because juvenile crappies (TL3) are generally less than 120 mm.

(e) Although goldfish is a TL2 species, large ones may be consumed by humans and are included to estimate human risk. Only one Delta goldfish was analyzed for mercury.

(f) Fish length range of 50-150 mm based on the size of fish typically consumed by kingfisher, cormorant and mink (USFWS, 2004).

(g) Size maximum of 50 mm based on general size limit of prey consumed by California least terns (USFWS, 2003).

Table B.2: Number of Composite Samples and the Total Number of Fish in the Composite Samples Used to Estimate the Weighted Average Trophic Level 3 and 4 Fish Mercury Concentrations for Human and Eagle Health Risk Assessments [(a)]

Trophic Level (Length Range) / Species	Central Delta		Cosumnes River		Mokelumne R. d/s Cosumnes R.		Sacramento River		San Joaquin River		West Delta		Yolo Bypass-North		Yolo Bypass-South		Total # of Samples	Total # of Fish
	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish		
TL4 (150-350 mm)	144	218	16	20	15	21	103	166	95	179	31	39	3	11	52	75	459	729
Channel Catfish	1	4							3	14					1	2	5	20
Crappie	2	9									1	3	2	10	1	5	6	27
Largemouth Bass	102	146	14	18	14	18	52	73	60	92	29	33	1	1	15	24	287	405
Sacramento Pike Minnow					1	3	15	33	1	3	1	3					18	42
Smallmouth Bass							1	5									1	5
White Catfish	39	59	2	2			35	55	31	70					35	44	142	230
TL3 (150-350 mm)	17	80	4	12	5	17	11	47	12	47	2	9	2	10	5	23	58	245
Black Bullhead	2	9					2	10									4	19
Bluegill	6	30			2	10	5	20	4	19							17	79
Carp													2	10	4	18	6	28
Redear Sunfish	9	41	1	5					4	20	1	5					15	71
Sacramento Blackfish									1	5							1	5
Sacramento Splittail							1	4									1	4
Sacramento Sucker			3	7	3	7	3	13			1	4			1	5	11	36
White Catfish									3	3							3	3
TOTAL	161	298	20	32	20	38	114	213	107	226	33	48	5	21	57	98	517	974

(a) Cosumnes River and Yolo Bypass-North fish data were used in the Delta-wide numeric target evaluation (Chapter 3) but not in the linkage analysis because aqueous methylmercury samples were not collected in these subareas. Marsh Creek fish samples collected upstream of any tidal influence, although within the statutory Delta boundary, were not used in any Delta TMDL evaluations because a separate TMDL effort will be conducted for the Marsh Creek watershed. No fish data that met the data use rules described in Section 4.3.1 were available for the Mokelumne River upstream of the Cosumnes River confluence.

Table B.3: Number of Composite Samples and the Total Number of Fish in the Composite Samples Used to Estimate the Weighted Average Trophic Level 3 and 4 Fish Mercury Concentrations for Wildlife Health Risk Assessments (a)

Trophic Level (Length Range) / Species	**Central Delta**		**Cosumnes River**		**Mokelumne R. d/s Cosumnes R.**		**Sacramento River**		**San Joaquin River**		**West Delta**		**Yolo Bypass-North**		**Yolo Bypass-South**		**Total # of Samples**	**Total # of Fish**
	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish		
TL4 (150-350 mm)	**100**	**143**	**17**	**17**	**12**	**18**	**78**	**122**	**59**	**117**	**13**	**17**	**2**	**10**	**43**	**56**	**324**	**500**
Crappie	2	9									1	3	2	10	1	5	6	27
Largemouth Bass	67	83	16	16	11	15	35	47	31	48	11	11			8	8	179	228
Sacramento Pike Minnow					1	3	7	15	1	3	1	3					10	24
Smallmouth Bass							1	5									1	5
White Catfish	31	51	1	1			35	55	27	66					34	43	128	216
TL3 (150-350 mm)	**23**	**82**	**2**	**6**	**3**	**11**	**9**	**32**	**10**	**37**	**1**	**5**					**48**	**173**
Black Bullhead	2	9					2	10									4	19
Bluegill	5	25			1	5	5	20	3	14							14	64
Golden Shiner	1	1															1	1
Redear Sunfish	11	43	1	5					3	15	1	5					16	68
Sacramento Blackfish									1	5							1	5
Sacramento Sucker			1	1	2	6											3	7
Threadfin Shad	3	3															3	3
Unid Goby							2	2									2	2
White Catfish									3	3							3	3
Yellowfin Goby	1	1															1	1
TL3 (50-150 mm)	**193**	**1391**	**45**	**320**	**9**	**71**	**134**	**711**	**47**	**456**	**66**	**281**			**168**	**833**	**662**	**4063**
Bigscale Logperch			1	12			10	30	1	2	1	3			27	122	40	169
Bluegill	23	74	10	18	1	5	4	16	6	68	3	13			1	3	48	197
Golden Shiner	24	210					3	45	5	31							32	286
Largemouth Bass	24	133			1	2	8	81	7	60	5	15					45	291
Mosquitofish															1	1	1	1
Prickly Sculpin	1	1													5	8	6	9
Red Shiner							1	1	2	4					1	4	**4**	**9**
Redear Sunfish	8	8							1	5							9	13
Shimofuri Goby							3	6			1	1			15	53	19	60
Silverside	86	801	32	282	6	62	80	424	18	235	45	189			80	498	347	2491

Table B.3: Number of Composite Samples and the Total Number of Fish in the Composite Samples Used to Estimate the Weighted Average Trophic Level 3 and 4 Fish Mercury Concentrations for Wildlife Health Risk Assessments (a)

Trophic Level (Length Range) / Species	Central Delta		Cosumnes River		Mokelumne R. d/s Cosumnes R.		Sacramento River		San Joaquin River		West Delta		Yolo Bypass-North		Yolo Bypass-South		Total # of Samples	Total # of Fish
	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish	# of Samples	# of Fish		
Threadfin Shad	20	147					12	70	5	45	1	5			16	49	54	316
Unid Goby							3	3									3	3
White Catfish							6	15									6	15
White Crappie	3	11	1	1			1	1	1	3	1	2			6	17	13	35
Yellowfin Goby	4	6	1	7	1	2	3	19	1	3	9	53			16	78	35	168
TL3 (<50 mm)	**37**	**201**	**14**	**222**	**2**	**9**	**24**	**124**	**26**	**384**	**22**	**88**			**62**	**296**	**187**	**1324**
Bluegill	17	136	8	78			8	90	11	276	2	6					46	586
Mosquitofish	4	17	6	144	2	9	2	7	2	13	5	34			11	81	32	305
Prickly Sculpin	1	1															1	1
Red Shiner									11	75					5	27	16	102
Shimofuri Goby							1	3			1	1			3	11	5	15
Silverside	14	43					11	19	2	20	13	37			29	75	69	194
Threadfin Shad	1	4									1	10			13	99	15	113
White Catfish							1	2									1	2
White Crappie							1	3							1	3	2	6
TOTAL	**353**	**1817**	**78**	**565**	**26**	**109**	**245**	**989**	**142**	**994**	**102**	**391**	**2**	**10**	**273**	**1185**	**1221**	**6060**

(a) Cosumnes River and Yolo Bypass-North fish data were used in the Delta-wide numeric target evaluation (Chapter 3) but not in the linkage analysis because aqueous methylmercury samples were not collected in these subareas. Marsh Creek fish samples collected upstream of any tidal influence, although within the statutory Delta boundary, were not used in any Delta TMDL evaluations because a separate TMDL effort will be conducted for the Marsh Creek watershed. No fish data that met the data use rules described in Section 4.3.1 were available for the Mokelumne River upstream of the Cosumnes River confluence.

B.2 Range of Mercury Levels in Species Present in Each Delta Subarea

This section provides graphs that show the range of mercury levels in Delta species by trophic level, species, and Delta subarea evaluated in the numeric target and linkage analyses:

- Figure B.1: TL4 Food Group (150-500 mm) Mercury Levels
- Figure B.2: TL3 Food Group (150-500 mm) Mercury Levels
- Figure B.3: TL4 Food Group (150-350 mm) Mercury Levels
- Figure B.4: TL3 Food Group (150-350 mm) Mercury Levels
- Figure B.5: TL3 Food Group (50-150 mm) Mercury Levels
- Figure B.6: TL3 Food Group (<50 mm) Mercury Levels

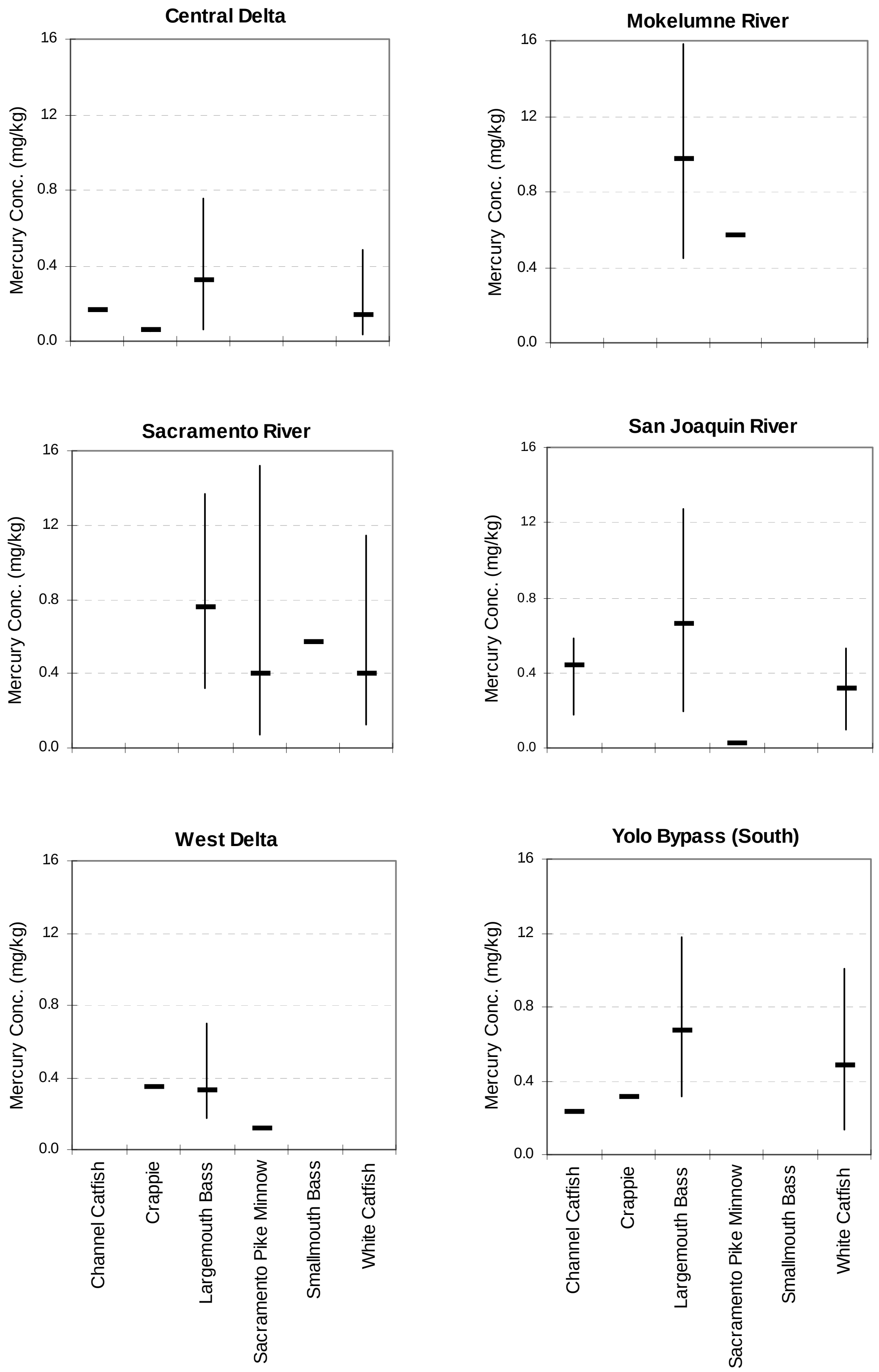


Figure B.1: TL4 Food Group (150-500 mm) Mercury Levels

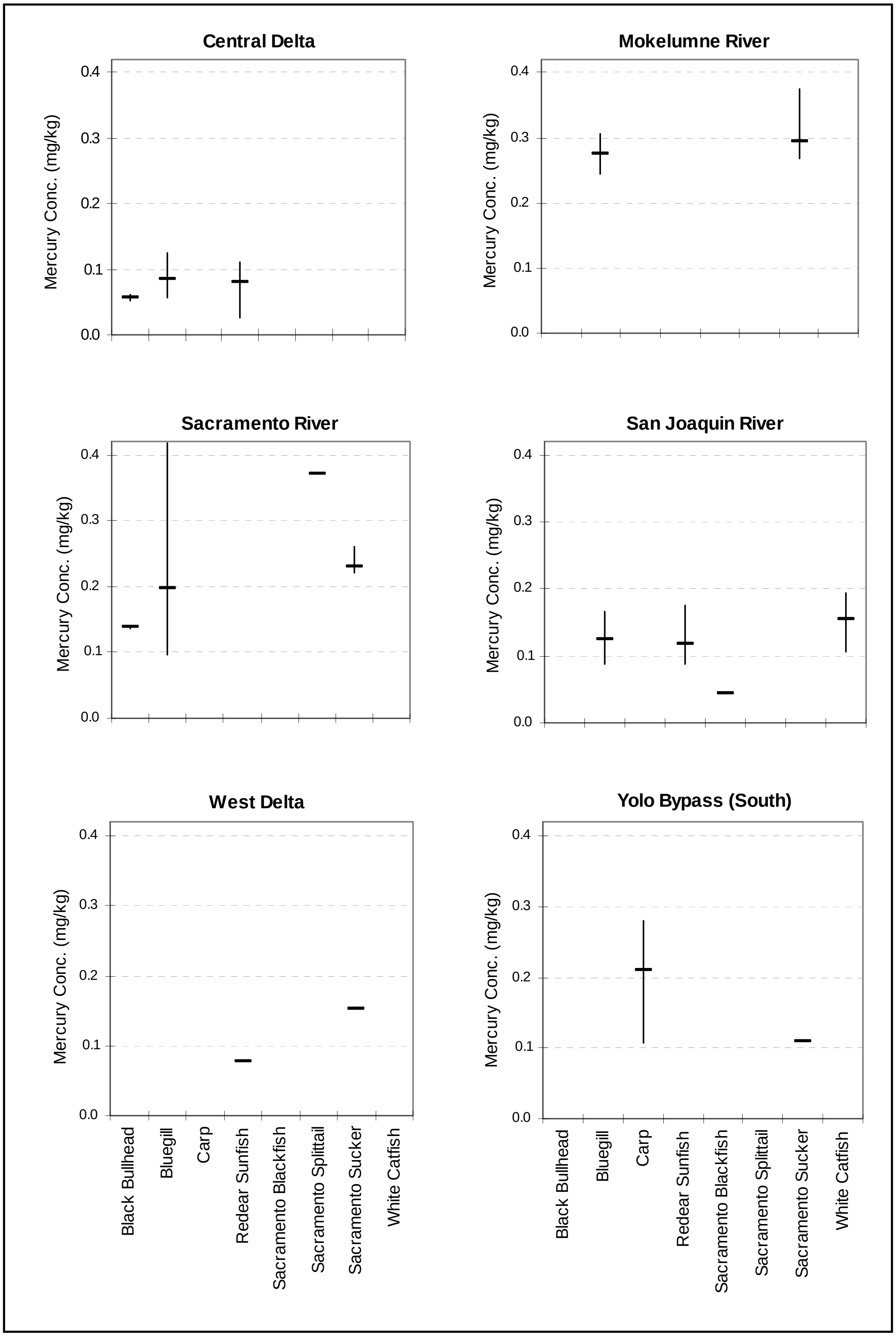


Figure B.2: TL3 Food Group (150-500 mm) Mercury Levels

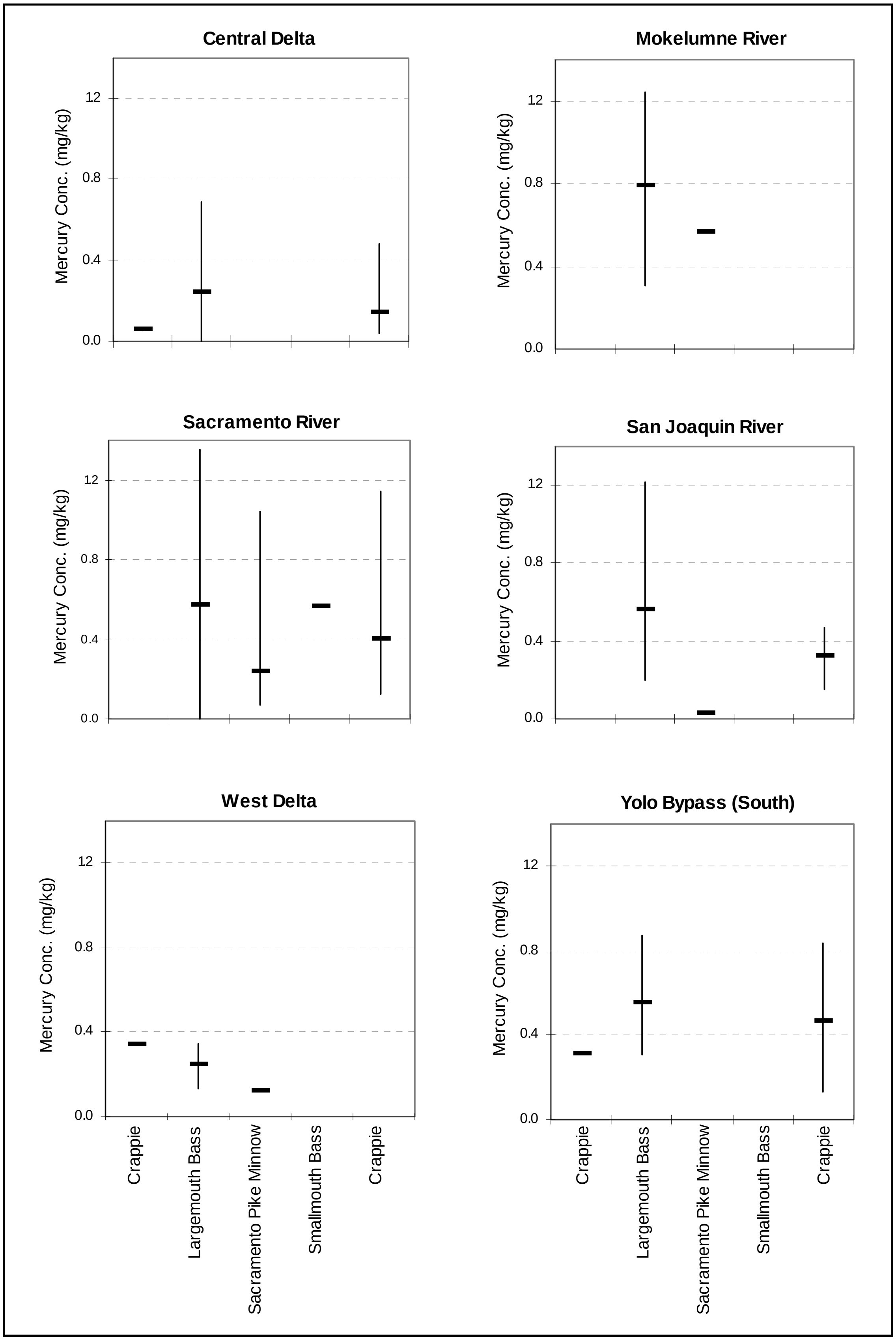
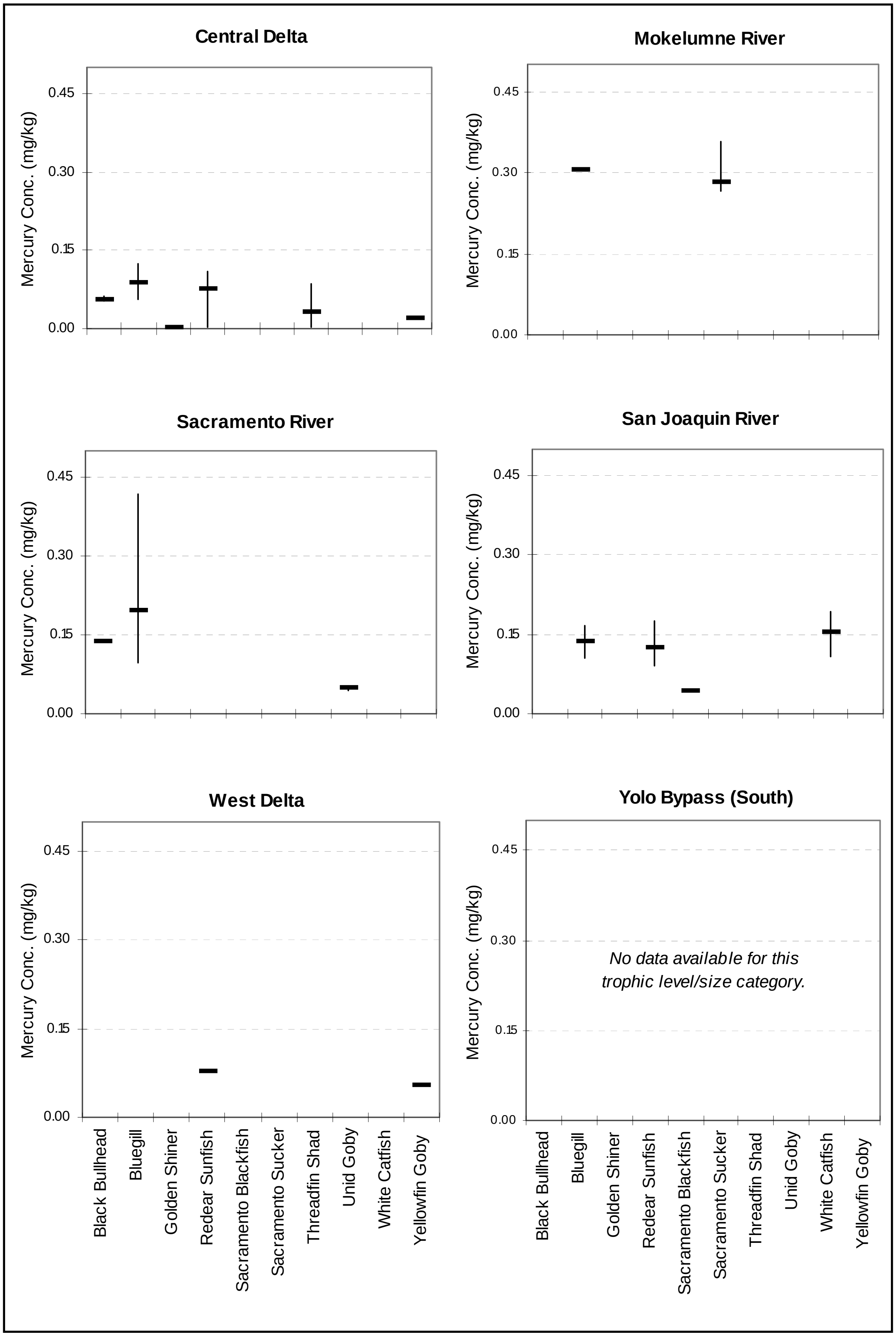


Figure B.3: TL4 Food Group (150-350 mm) Mercury Levels



No data available for this trophic level/size category.

Figure B.4: TL3 Food Group (150-350 mm) Mercury Levels

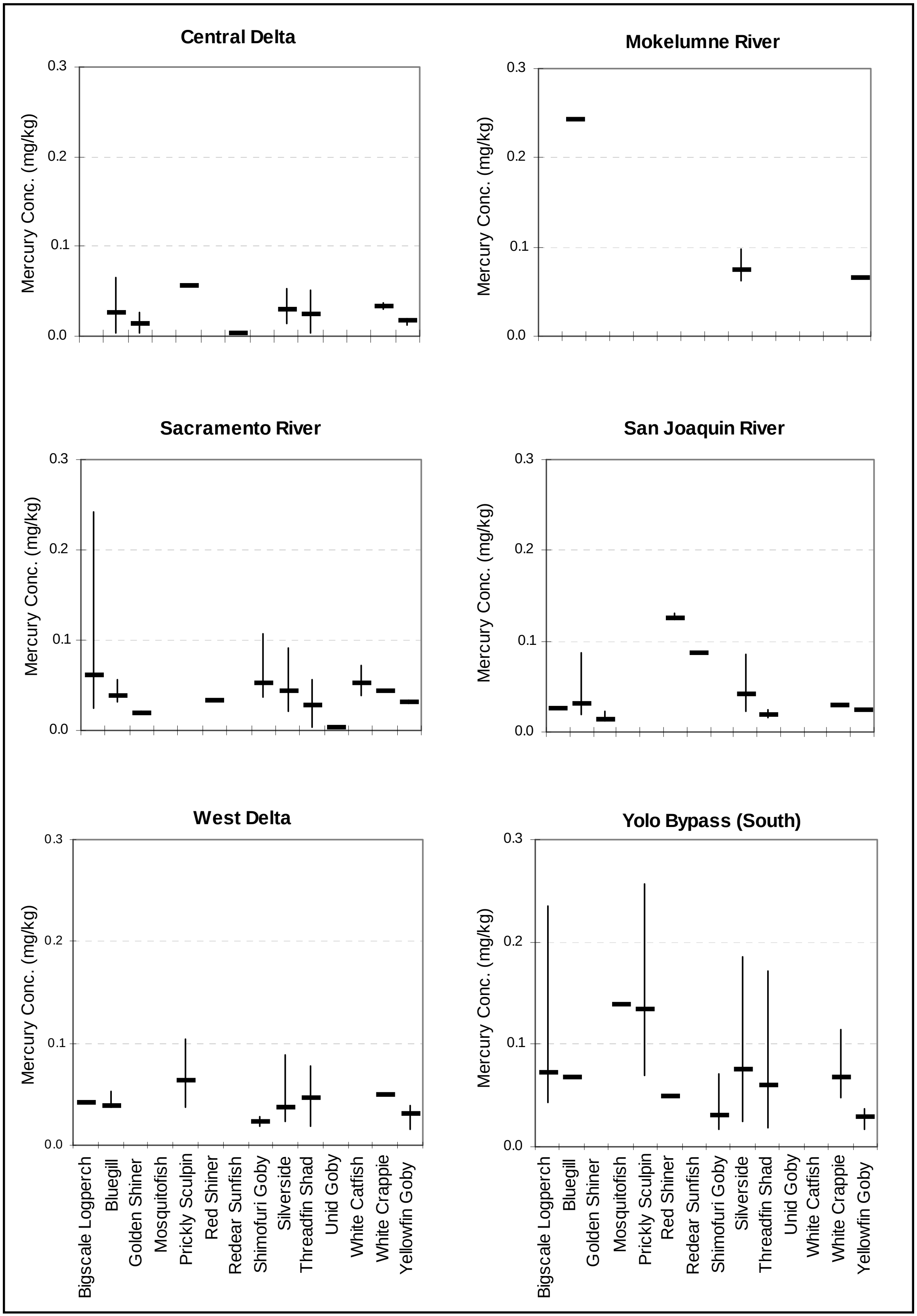
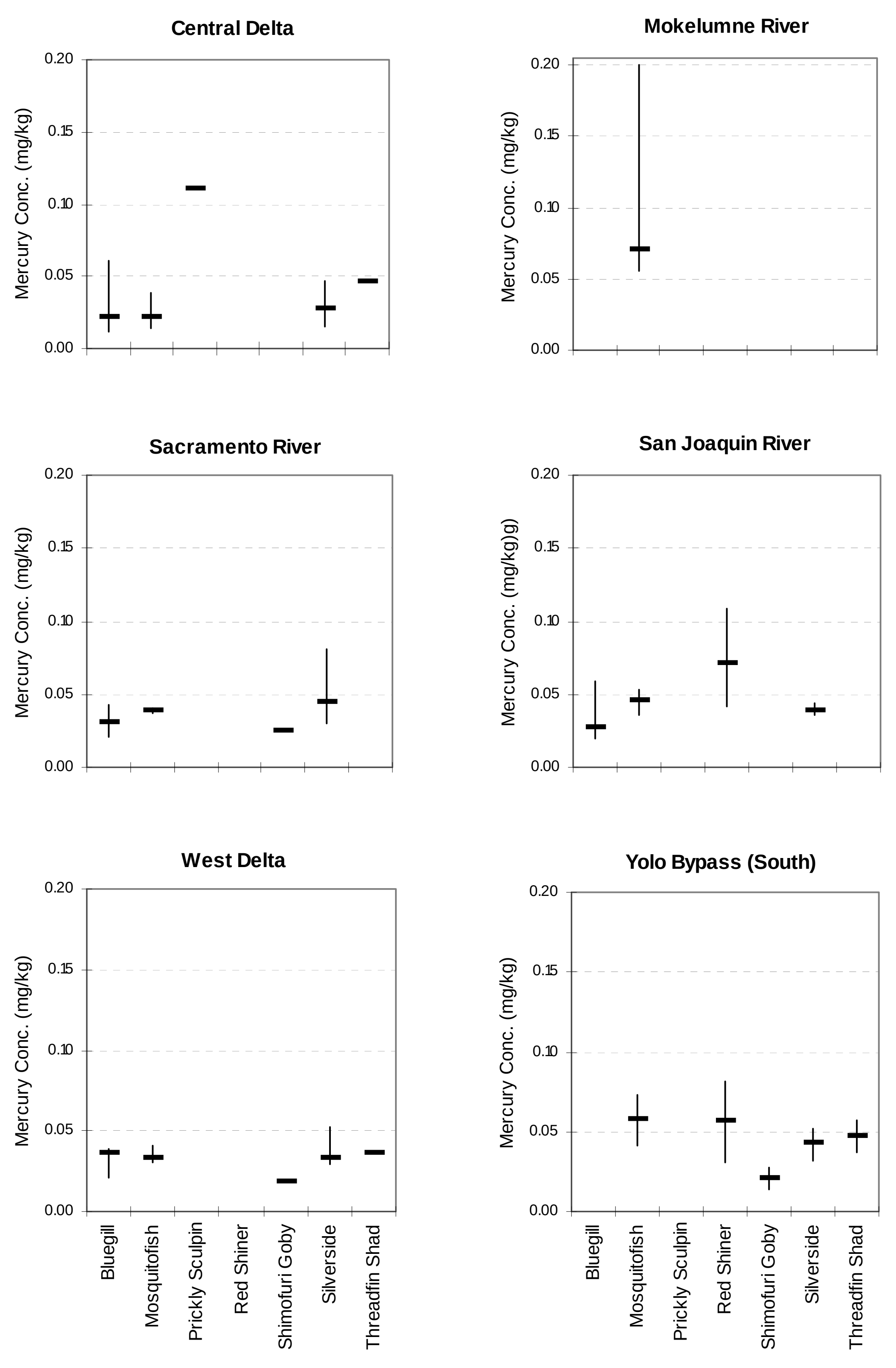


Figure B.5: TL3 Food Group (50-150) Mercury Levels


Central Delta

Mokelumne River

Sacramento River

San Joaquin River

West Delta

Yolo Bypass (South)

Figure B.6: TL3 Food Group (<50 mm) Mercury Levels

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C. COMMERCIAL AND SPORT FISHING IN THE SACRAMENTO-SAN JOAQUIN DELTA

As noted in Chapter 2, the Basin Plan lists the existing and potential beneficial uses of the Delta and Yolo Bypass. The Yolo Bypass is a 73,300-acre floodplain on the west side of the lower Sacramento River. The lower two thirds of the Yolo Bypass are within the legal Delta, and waterways within the entire Delta are included in Clean Water Act 303(d) List as mercury-impaired. However, Table II-1 of the Basin Plan includes separate table rows for the Yolo Bypass and Delta. In this appendix, the term “Delta” includes that portion of the Yolo Bypass that is within the legal Delta boundary.

The Basin Plan provides a standard definition for commercial and sport fishing (COMM). The COMM designation is defined as “uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes” (CVRWQCB, 2009). The current Basin Plan does not include the commercial and sport fishing (COMM) designation for the Sacramento-San Joaquin Delta. However, commercial and sport fishing is a past and present use of the Delta. The proposed Basin Plan Amendment would add COMM for the Delta as a potential beneficial use, as fish in all parts of the Delta are not yet safe to eat in accordance with the proposed fish tissue objectives (a.k.a. numeric targets). The Delta provides habitat for as many as forty freshwater, saltwater and anadromous fishes (Moyle, 2002). Sport fish species that reside in the Delta include striped bass, black bass (e.g., largemouth and smallmouth bass), sturgeon, Chinook salmon, American shad, and catfish.

Fish and other aquatic organisms are collected commercially. CDFG issues commercial fishing licenses in California and reports active commercial fishing in the Delta. Detailed historic commercial fishing data were not available; CDFG’s Marine Resources website provides summary data for commercial landings and associated values for fishing years 2001 and 2002 (Table C.1). The predominant species targeted include bay shrimp, crayfish and threadfin shad. Threadfin shad are used mainly as baitfish for catching striped bass.

Sport and subsistence fishing is common throughout the Delta and takes place year-round. On average, sport fishing license sales in the six Delta counties account for 19% of all licenses issued in the State (Table C.2). Although some of these licenses may have been purchased for use elsewhere, a survey of anglers indicates similar popularity of the Delta for fishing. The Delta Protection Commission and the Department of Parks and Recreation evaluated fishing in the Delta by surveying, via mail, adults who purchased fishing licenses in California in 1996 (DPRec, 1997). Of licensed anglers, 23% reported fishing in the Delta. Delta anglers spent an average of 14 days per year fishing. Authors of the survey multiplied the number of anglers that use the Delta by the average days spent fishing from boat and shore, and in tournaments. In 1996, the total of fishing days in the Delta by licensed anglers was 21.6 million. Fishing from boat was most popular (11.8 million activity days), followed by fishing from shore (9.6 million activity days) and tournament fishing (0.2 million activity days).

Creel surveys and interviews also provide evidence that sport and subsistence anglers actively fish the Delta waterways year-round by boat and from banks. CDFG’s creel surveys indicate that a variety of species are caught and kept (Table C.3, Figure C.1). Fishing derbies for striped bass, black bass and sturgeon take place in the Delta annually. The CDHS Environmental Health Investigations Branch staff conducted interviews of community-based organizations in the Delta region and found that members of many communities regularly eat local fish, especially striped bass, catfish, salmon, sturgeon, crappie, and carp (CDHS, 2004). In addition to the species listed in Tables C.1 and C.3, Sacramento blackfish and shimofuri goby may also be collected from the Delta (Moyle, 2002; anecdotal information). Crayfish are popular with some consumers (CDHS, 2006; Silver *et al.*, 2007). Clams are also collected for human consumption, particularly by some Hispanic/Latino and Southeast Asians groups (CDHS, 2004; 2006). A recent fish consumption and advisory awareness survey of low-income women at a WIC[2] clinic in Stockton indicated that 32% of the 500 survey participants consumed sport fish, 29% consumed a combination of commercial and sport fish that exceeded the USEPA/FDA national advisory limit,[3] and women who demonstrated advisory awareness and knowledge of health-protective behaviors ate less fish overall (Silver *et al*., 2007).

Mercury data from Delta sampling efforts (Table C.4) are available for all of the species listed in Tables C.1 and C.3 (or for similar species) except hitch, longjaw mudsucker, rainbow and steelhead trout, starry flounder, American shad and salmon. Except for American shad and salmon, these species do not appear to be key commercial and sport fish in the Delta. To evaluate American shad and salmon mercury levels for impairment, data from additional Suisun Bay, San Francisco Bay and Delta tributary locations were reviewed. Because salmon are anadromous and spend the majority of their lives in the Pacific Ocean, salmon that are caught in the Delta will most likely have mercury levels similar to those caught upstream in the tributary watersheds. The same is likely true for American shad. Table C.4 includes mercury data for American shad and Chinook salmon collected in the Delta and its upstream tributaries.

Per CDFG fishing regulations, some Delta fish species have size limits:

- Black bass (e.g., largemouth and smallmouth bass) – minimum 12 inches (305 mm);
- Striped bass – minimum 18 inches (457 mm); and
- Sturgeon – between 46 and 72 inches (1,168 to 1,829 mm)

Only samples collected from the tissue (fillet) of fish that met the size limits for these species were included in Table C.4. For other sport fish, only tissue samples collected from fish greater than 100 mm were included. Both fillet and whole fish samples were included for all sizes of threadfin shad, which is used as bait. In addition, all sizes of crayfish and clams were included. Data summarized in Table C.4 were collected between 1970 and 2003.

The Delta-wide weighted average mercury levels in each species were compared to the USEPA criterion for the protection of human health of 0.3 mg/kg and the FDA action level for

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[2] Special Supplemental Nutrition program for Women, Infants, and Children (WIC).

[3] The USEPA and FDA recommend that sensitive populations (i.e., women of childbearing age, pregnant and breastfeeding women and children) completely avoid consuming high-mercury fish (e.g., shark, swordfish, king mackerel, and tilefish) and limited consumption of other commercial fish (12 oz/week, or 48.6 g/day) and sport-caught fish (6 oz/week, or 24.3 g/day). Silver and others attempted to evaluate in their WIC clinic survey whether a woman's combined intake of sport and commercial fish exceeded the USEPA/FDA advisory limits. Because the advisory allows women to eat twice as much commercial fish (12 oz) as sport fish (6 oz) in a week, they halved each woman's commercial intake and added it to her sport intake. If this combined amount exceeded 6 oz/week, or if the woman ate shark, swordfish, tilefish or king mackerel, she was considered to have exceeded the advisory limit.

commercially caught fish of 1.0 mg/kg (Figure C.2). Although many individual samples had mercury levels that exceeded the FDA action level, none of species-specific weighted average mercury concentrations exceeded the action level. In addition, none of the species for which commercial fishing licenses were issued exceeded the USEPA criterion. However, the average mercury concentrations of several sport fish – sturgeon, catfish, crappie, Sacramento splittail, Sacramento pike minnow, largemouth bass, small bass, and striped bass – approached or exceeded the USEPA criterion. The bass had the highest average mercury concentrations of any species. Largemouth bass had mercury levels comparable to striped bass mercury levels.

The linkage analyses described in Chapter 5 and fish data described in Appendix B are based on samples collected between 1998 and 2001 for species that represent local conditions and fit within the trophic level food groups defined by the numeric targets (Chapter 4). All of the species listed in Table C.4 and Figure C.1 were addressed by the numeric target development and linkage analysis (Chapters 4 and 5, Appendix B), except American shad, Asiatic and resident freshwater clams, Chinook salmon, Crangon shrimp, crayfish, striped bass and sturgeon. Of these, only striped bass and sturgeon had average mercury concentrations that exceeded the USEPA criterion of 0.3 mg/kg. As methyl and total mercury reduction efforts take place and the numeric targets are approached throughout the Delta for the species described in Appendix B, striped bass and sturgeon data also will be re-evaluated for compliance with the USEPA criterion and other adopted, Delta-specific water quality objectives.

Table C.1: Commercial Fisheries Landings in the Sacramento-San Joaquin Delta and Associated Value (a)

Species	**Landings (pounds)**		**Value**	
	2001	2002	2001	2002
Bay shrimp	9,509	9,744	$56,954	$63,149
Carp	214		$253	
Crayfish	100,008	108,427	$120,403	$114,712
Hitch	20		$20	
Longjaw mudsucker	29		$0	
Threadfin shad	53,936	49,343	$37,258	$55,028
Yellowfin goby	285		$24	
TOTAL:	**164,001**	**167,514**	**$214,912**	**$232,889**

(a) Source: http://www.dfg.ca.gov/mrd/fishing.html#commercial

Table C.2: Average Number of Sport Fishing Licenses Issued in Six Delta Counties [a, b]

County	Resident Fish Licenses	Striped Bass Tag	Salmon Tag	Steelhead Tag
Alameda	46,240	21,768	429	897
Contra Costa	42,230	26,948	380	1,039
Sacramento	89,617	43,260	1,231	6,306
San Joaquin	43,230	27,906	158	668
Solano	24,338	19,473	161	469
Yolo	9,694	4,567	70	293
Total for Delta Counties:	255,349	143,923	2,427	9,672
Total for California:	1,356,694	342,638	29,293	56,864
% Delta Licences:	19%	42%	8%	17%

(a) Source: http://www.dfg.ca.gov/licensing/statistics/statistics.html

(b) Resident fish licenses and salmon tags are averaged over a 10-year period, striped bass averaged over 7 years, and steelhead averaged over 8 years.

Table C.3: Sum of Fish Kept by Delta Anglers per the CDFG's Central Valley Angler Surveys for 1999 and 2000. [a]

Species [Acronym Used in Figure C.1]	Trophic Level	# of Fish Kept
Catfish [CF]	4	4307
Striped Bass [SB]	4	2496
Chinook Salmon [a.k.a. king salmon, KS]	3	812
American Shad [AS]	3	549
Splittail [SPT]	3	439
Sunfish [SF]	3	344
Black Bass [BB]	4	154
Sturgeon [ST]	3	94
Starry Flounder [STF]	3	27
Sacramento Pikeminnow [SPM]	4	22
Common Carp [CP]	3	20
Steelhead Trout [SH]	3	7
Sacramento Sucker [SKR]	3	6
Rainbow trout [RT]	3	1

(a) Data obtained from Fraser Shilling (University of California, Davis), who requested the query of actual reported number of fish kept and released by species and river mile from the CDFG Creel Database for the 1999 and 2000 Central Valley Angler Surveys 1999 and 2000. A summary of fish kept by Delta subarea is shown in Figure C.1.

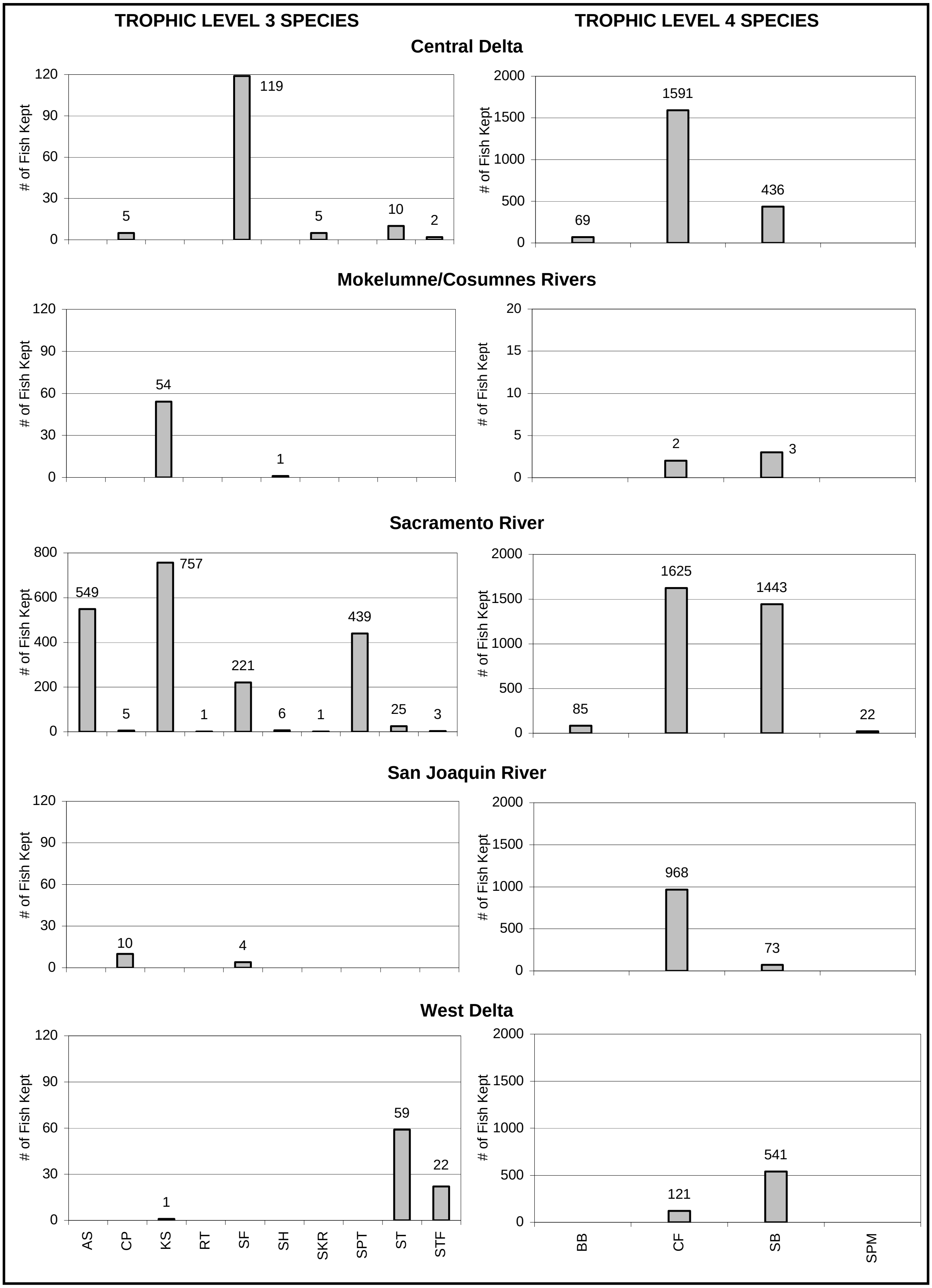

Figure C.1: Sum of Fish Kept by Delta Anglers by Delta Subarea per the CDFG's Central Valley Angler Surveys for 1999 and 2000. (Species acronyms are defined in Table C.3.)

Table C.4: Summary of Available Mercury Concentration Data for Species Targeted by Sport and Commercial Fishing [(a, b, c)]

Common	# of Samples	# of Fish	Min Hg Conc. (mg/kg)	Ave Hg Conc. (mg/kg)	Max Hg Conc. (mg/kg)	Weighted Ave (mg/kg)
American Shad	5	18	0.030	0.047	0.066	0.048
Black Bullhead	4	19	0.053	0.097	0.138	0.099
Black Crappie	1	6	0.130	0.130	0.130	0.130
Bluegill	31	135	0.028	0.147	0.418	0.129
Carp	13	59	0.107	0.235	0.340	0.234
Catfish	28	28	0.060	0.249	1.180	0.249
Channel Catfish	28	82	0.060	0.235	0.600	0.291
Chinook Salmon	10	15	0.040	0.072	0.120	0.062
Clam, Asiatic	275	717	0.007	0.042	0.195	0.039
Clam, Resident Freshwater	3	3	0.016	0.035	0.050	0.035
Crangon Shrimp	10	72	0.006	0.008	0.010	0.008
Crappie	6	27	0.054	0.296	0.591	0.301
Crayfish	383	413	0.003	0.191	1.828	0.182
Largemouth Bass	298	433	0.062	0.585	2.090	0.561
Redear Sunfish	17	88	0.027	0.106	0.329	0.106
Sacramento Blackfish	1	5	0.043	0.043	0.043	0.043
Sacramento Pike Minnow	26	55	0.028	0.572	2.400	0.429
Sacramento Splittail	1	4	0.370	0.370	0.370	0.370
Sacramento Sucker	12	43	0.100	0.271	0.492	0.234
Shimofuri Goby	24	75	0.013	0.034	0.107	0.031
Smallmouth Bass	1	5	0.570	0.570	0.570	0.570
Striped Bass	201	245	0.060	0.572	1.850	0.571
Sturgeon	11	11	0.080	0.271	0.800	0.271
Threadfin Shad	72	432	0.003	0.038	0.171	0.034
White Catfish	190	425	0.031	0.343	1.270	0.365
Yellowfin Goby	2	33	0.040	0.050	0.060	0.048

(a) CDFG's legal limit is 12 inch minimum (305 mm) for largemouth and smallmouth bass, 18 inch minimum (457 mm) for striped bass, and between 46 and 72 inches (1,168 to 1,829 mm) for sturgeon; only data collected from tissue (fillet) samples were included. For other sport fish, only tissue samples collected from fish greater than 100 mm were included. Both fillet and whole fish samples were included for all sizes of threadfin shad, which is typically used as bait. In addition, all sizes of crayfish and clams were included. Results represent total mercury, wet weight concentrations.

(b) Little-to-no mercury data were available for adult salmon and American shad caught in the Delta. To evaluate salmon mercury levels for impairment, data from Suisun Bay and Delta's tributary watersheds were reviewed. Because salmon are anadromous (they spend the majority of their lives in the Pacific Ocean and return to fresh waters only to spawn) adult salmon (typically >750 mm) that are caught in the Delta most likely have mercury levels similar to those caught elsewhere in the Bay-Delta and tributary watersheds. The same is likely true for American shad. American shad samples were collected from the American River, Sacramento River downstream of the Feather River confluence, and Suisun Bay. Chinook salmon samples were collected from the upper Sacramento River near Red Bluff, American River, Sacramento River at River Mile 44 and San Francisco Bay.

(c) Data summarized in this table were collected between 1970 and 2003. In contrast, the numeric target development and linkage analyses are based on data collected between 1998 and 2001.

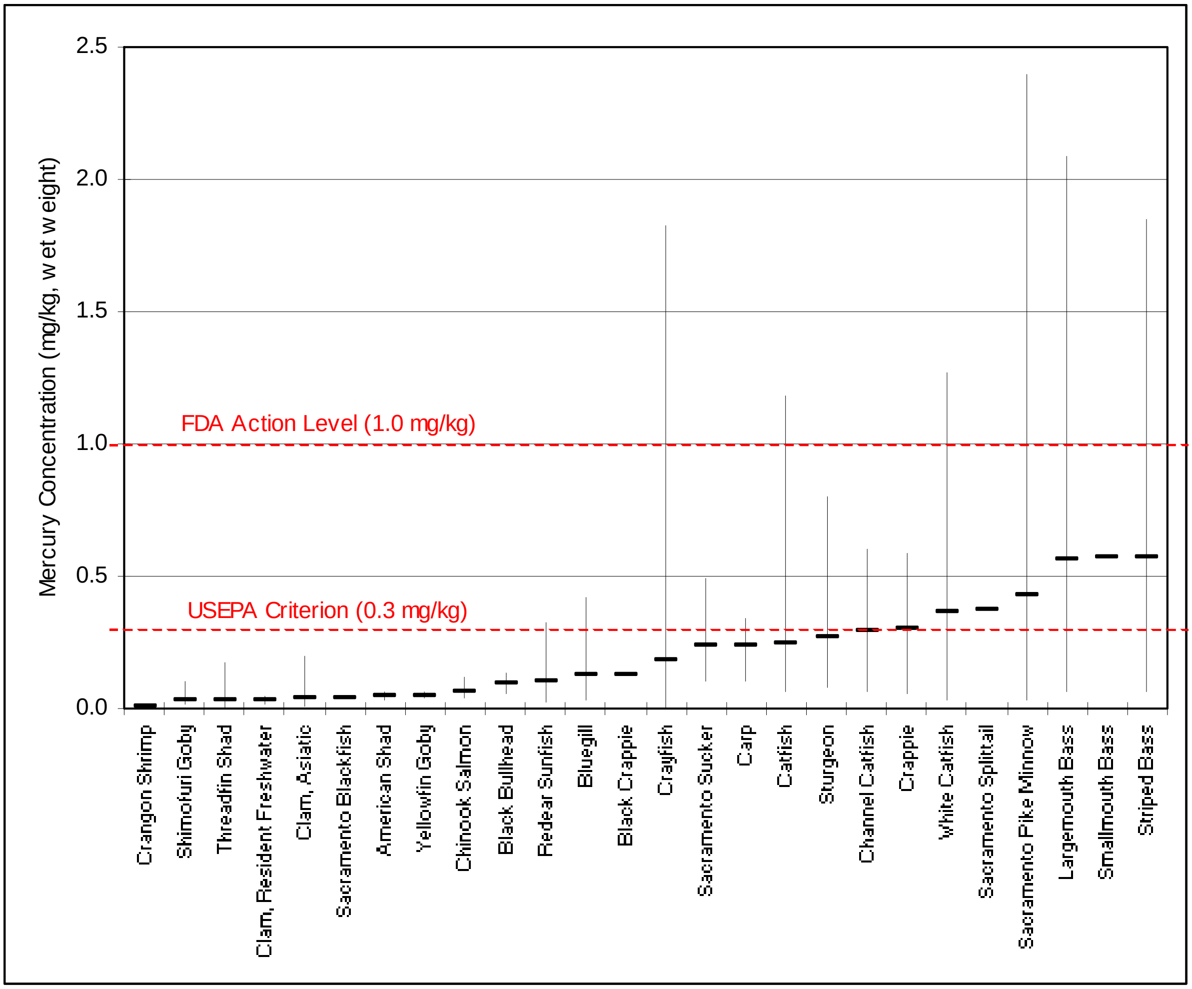

Figure C.2: Minimum, Maximum and Weighted Average Mercury Concentrations in Species Targeted by Sport and Commercial Fishing Based on Available Data

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D. AVAILABLE AQUEOUS METHYLMERCURY DATA AND POOLED VALUES USED IN DELTA LINKAGE & ALTERNATE BAF-BASED LINKAGE APPROACH

Section D.1 provides tables of methylmercury data, statistical summaries and regressions used in the Delta linkage analysis. Section D.2 describes an alternate approach to the linkage analysis using site-specific BAFs.

D. 1 Tables of Methylmercury Data, Statistical Summaries and Regressions Used in the Delta Linkage Analysis

Table D.1: Summary of Available Raw (Unfiltered) Methylmercury Data (ng/l) (a)

Sample Date	Data Source	Delta Mendota Canal	Mokelumne River @ I-5	Sacramento River @ Freeport	Sacramento River @ Greene's Landing	Sacramento River @ RM44	San Joaquin River @ Vernalis	State Water Project	X2
03/28-29/00	A	0.153	0.171		0.148		0.164	0.139	0.204
04/24/00	A	< 0.022	0.28		0.117		0.147	0.0469	0.0819
05/30/00	A	0.171	0.25		0.336		0.134	0.144	0.241
06/26/00	A	0.0737	0.114		0.0716		0.22	< 0.022	0.109
07/18/00	B			0.06					
07/19/00	A	< 0.022	< 0.022		0.052		0.118	< 0.022	< 0.022
07/21/00	C				0.052 [b]				
08/16/00	B			0.078					
08/21/00	A	< 0.022	0.154		0.11		0.14	< 0.022	< 0.022
09/21/00	C				0.063				
09/26/00	A	< 0.022	< 0.022		0.0514		0.0986	0.0581	0.0233
10/19/00	C				0.071				
10/28-29/00	A	< 0.022	0.13		0.08515 (FD: 0.0847 & 0.0856)		0.158	< 0.022	< 0.022
11/07/00	B			0.127		0.136			
11/08/00	C				0.099				
12/18/00	A	0.0628	0.0955		0.08905		0.102	0.0501	0.0595
12/19/00	B			0.108		0.13			
01/17/01	B, C			0.122	0.095	0.119			
01/28-29/01	A	0.144	0.246		0.244 (FD: 0.24 & 0.248)		0.239	0.113	0.0945
02/21/01	B, C			0.118	0.077	0.123			
02/26/01	A		0.32		0.1765		0.18	0.0767	0.165
03/20/01	B			0.168		0.141			
03/21/01	C				0.097				
03/25-26/01	A	0.0924	0.185		0.08405 (FD: 0.0825 & 0.0856)		0.178	0.0551	
04/11/01	D				0.07				
04/17/01	B			0.058		0.077			
04/18/01	C				0.076				
04/26/01	D				0.097				
04/29/01	A	0.024	0.201		0.113		0.0934	0.0584	< 0.014
05/15/01	B, D			0.122	0.116	0.153			
05/16/01	D				0.164				

Table D.1: Summary of Available Raw (Unfiltered) Methylmercury Data (ng/l) (a)

Sample Date	Data Source	Delta Mendota Canal	Mokelumne River @ I-5	Sacramento River @ Freeport	Sacramento River @ Greene's Landing	Sacramento River @ RM44	San Joaquin River @ Vernalis	State Water Project	X2
05/17/01	C				0.141 (FD: 0.136 & 0.146)				
05/27-28/01	A	0.0555	0.178		0.0986		0.122	0.0503	0.0409
05/29/01	D				0.09				
06/06/01	D				< 0.02				
06/14/01	D				0.122				
06/19/01	B			0.089		0.18			
06/25-26/01	A	0.0607	0.208		0.0878		0.256		0.0369
06/28/01	D				0.0878				
07/17/01	B			0.111		0.101			
07/30-31/01	A	0.0645	0.167		0.108		0.147	0.0213	0.0701
08/14/01	B			0.091		0.097			
08/27/01	A	0.0317	0.065		0.0712		0.194	< 0.014	0.0541
09/19/01	B			0.073		0.098			
10/01/01	A	< 0.014	0.184		0.0953		0.163	0.0321	< 0.014
10/17/01	B			0.072		0.069			
11/14/01	B			0.179		0.143			
12/19/01	B			0.154		0.172			
01/16/02	B			0.202		0.196			
02/05/02	B			0.13					
02/06/02	B					0.083			
03/06/02	B			0.05		0.062			
04/03/02	B			0.052		0.067			
05/08/02	B			0.092		0.107			
06/05/02	B			0.064		0.101			
07/10/02	B			0.144		0.135			
08/07/02	B			0.111		0.108			
09/04/02	B			0.068		0.077			
10/02/02	B			0.081		0.095			
11/06/02	B			0.062		0.076			
12/04/02	B			0.103		0.117			
01/08/03	B			0.111		0.14			
02/05/03	B			0.242		0.251			
02/16/03	B			0.094					
03/05/03	B			0.086		0.081			
03/15/03	B			0.066					
03/18/03	E				0.1687 (FD&LR: 0.168, 0.158, & 0.180)				
04/02/03	B			0.089		0.094			
04/15/03	E						0.122 (FD: 0.112 & 0.132)		
04/21/03	E				0.1115 (FD: 0.1 & 0.123)				
04/28/03	E		0.2605 (LR: 0.278 & 0.243)		0.146		0.105		0.093
05/07/03	B			0.12		0.133			

Table D.1: Summary of Available Raw (Unfiltered) Methylmercury Data (ng/l) $^{(a)}$

Sample Date	Data Source	Delta Mendota Canal	Mokelumne River @ I-5	Sacramento River @ Freeport	Sacramento River @ Greene's Landing	Sacramento River @ RM44	San Joaquin River @ Vernalis	State Water Project	X2
05/13/03	E						0.122		
05/20/03	E				0.1002 (LR: 0.0993 & 0.101)				
05/27/03	E	0.0555	0.0925		0.0824		0.133		0.0759
06/10/03	E						0.126 (FD&LR: 0.126, 0.143, & 0.109)		
06/11/03	B			0.1		0.096			
06/18/03	E				0.0366				
06/30/03	E	0.0788					0.178	0.0291 (FD&LR: 0.0345, 0.0272 & 0.0256)	0.0856
07/01/03	E		< 0.0228		0.0233				
07/08/03	E						0.1845 (FD: 0.205 & 0.164)		
07/28/03	E	0.0932	0.076		0.0793 (FD: 0.0661 & 0.0924)		0.212	0.0284	0.0697
09/09/03	E						0.137 (FD: 0.134 & 0.140)		
09/17/03	E				0.0716				
09/29/03	E	0.0883					0.181	0.058	0.098
09/30/03	E		0.103		0.0632				
02/19/04	E				0.242				
02/26/04	E						0.17 (FD: 0.0642 & 0.0723)		
02/29/04	E				0.126 (FD: 0.132 & 0.12)				
03/24/04	E				0.122 (FD: 0.118 & 0.126)				
03/29/04	E						0.165		
04/12/04	E						0.135		
04/28/04	E				0.0956				

(a) FD: Average of field duplicates. LR: Average of laboratory replicates. Data sources: A – Foe, 2003; B – CMP, 2004; C – SRWP, 2004; D – Stephenson *et al*., 2002; E – Data collected by Central Valley Water Board staff to be published in 2008 CALFED report.

(b) Regional Board staff collected a sample at Greene's Landing on 19 September 2000 with a value of 0.052 ng/l. Coincidently, the SRWP program also collected a sample at Greene's Landing on 21 September 2000 with a value of 0.052 ng/l.

Table D.2: Monthly Average Methylmercury Concentrations (ng/l) for March 2000 to October 2000 Period Used to Calculate Average and Median Methylmercury Concentrations for Each Delta Subarea.

Month (a)	**Sacramento River**		**San Joaquin River**		**Mokelumne River**		**Central Delta**		**Western Delta**	
	Average Conc.	# of Samples	Average Conc.	# of Samples	Average Conc.	# of Samples	Average Conc.	# of Samples	Average Conc.	# of Samples
March	0.148	1	0.164	1	0.171	1	0.146	2	0.204	1
April	0.117	1	0.147	1	0.280	1	0.029*	2	0.082	1
May	0.336	1	0.134	1	0.250	1	0.158*	2	0.241	1
June	0.072	1	0.220	1	0.114	1	0.042	2	0.109	1
July	0.055	3	0.118	1	0.011*	1	0.011*	2	0.011*	1
Aug.	0.094	2	0.140	1	0.154	1	0.011*	2	0.011*	1
Sept.	0.057	2	0.099	1	0.011*	1	0.035*	2	0.023	1
Oct.	0.078	2	0.158	1	0.130	1	0.011*	2	0.011*	1
Average	0.120	13	0.147	8	0.140	8	0.055	16	0.087	8
Median	0.086		0.144		0.142		0.032		0.053	

(a) Monthly averages are the mean of all data collected during a given month. The Central Delta subarea includes data collected at the Delta Mendota Canal and State Water Project. The Sacramento subarea includes data collected at Freeport, River Mile 44 and Greene's Landing. The raw data are listed in Table D.1. Values with an asterisk were calculated from a water concentration that was below detection. Half the detection limit was used in the calculations.

Table D.3: Monthly Average Methylmercury Concentrations (ng/l) for March 2000 to April 2004 Period Used to Calculate Annual Average and Median Methylmercury Concentrations for Each Delta Subarea.

Month (a)	**Sacramento River**		**San Joaquin River**		**Mokelumne River**		**Central Delta**		**West Delta**	
	Ave. Conc.	# of Samples	Ave. Conc.	# of Samples	Ave. Conc.	# of Samples	Ave. Conc.	# of Samples	Ave. Conc.	# of Samples
January	0.154	8	0.239	1	0.246	1	0.129	2	0.095	1
February	0.151	11	0.175	2	0.320	1	0.077	1	0.165	1
March	0.106	12	0.169	3	0.178	2	0.110	4	0.204	1
April	0.090	14	0.120	5	0.247	3	0.035*	4	0.061*	3
May	0.133	14	0.128	4	0.174	3	0.095	5	0.119	3
June	0.087*	12	0.195	4	0.161	2	0.051*	5	0.077	3
July	0.087	10	0.165	4	0.066*	4	0.038*	6	0.050*	3
August	0.095	7	0.167	2	0.110	2	0.015*	4	0.033*	2
September	0.073	9	0.145	4	0.099*	3	0.042*	6	0.043*	3
October	0.079	6	0.158	1	0.130	1	0.011*	2	0.011*	1
November	0.117	7								
December	0.125	7	0.102	1	0.096	1	0.056	2	0.060	1
Annual Average	0.108	117	0.160	31	0.166	23	0.060	41	0.083	22
Annual Median	0.101		0.165		0.161		0.051		0.061	

(a) Monthly averages are the mean of all data collected during a given month. The Central Delta subarea includes data collected at the Delta Mendota Canal and State Water Project. The Sacramento subarea includes data collected at Freeport, River Mile 44 and Greene’s Landing. The raw data are listed in Table D.1. Values with an asterisk were calculated using one or more samples with concentrations below detection. Refer to Table D.1 for detections limits associated with each non-detect value.

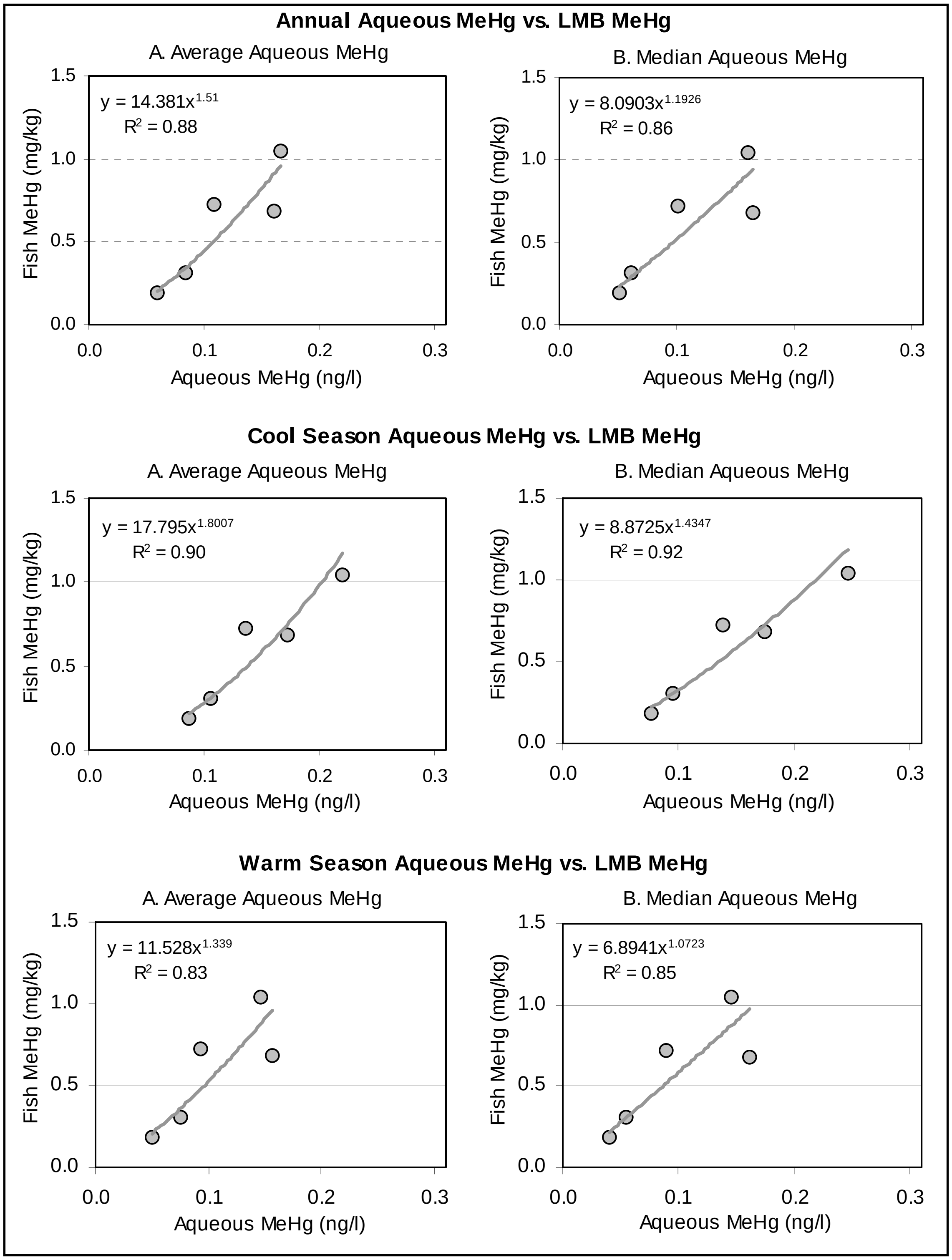

Figure D.1: Relationships between Standardized 350-mm Largemouth Bass Mercury Levels & March 2000 to April 2004 Aqueous Methylmercury.

The warm and cool seasons are defined as March to October and November to February, respectively.

Table D.4: Monthly Average Filtered Methylmercury Concentrations (ng/l) for March 2000 to October 2000 Used to Calculate Annual Average and Median Filtered Methylmercury Concentrations for Each Delta Subarea.

Month (a)	**Sacramento River**		**San Joaquin River**		**Mokelumne River**		**Central Delta**		**Western Delta**	
	Average Conc.	# of Samples	Average Conc.	# of Samples	Average Conc.	# of Samples	Average Conc.	# of Samples	Average Conc.	# of Samples
March	0.039	1	0.051	1	0.074	1	0.077	2	0.058	1
April	0.011*	1	0.036	1	0.165	1	0.016*	2	0.011*	1
May	0.074	1	0.071	1	0.146	1	0.073	2	0.011*	1
June	0.042	1	- - -	0	0.057	1	0.024*	2	0.031	1
July	0.022	1	0.011*	1	0.011*	1	0.011*	2	0.011*	1
August	0.090	1	0.011*	1	0.098	1	0.011*	2	0.011*	1
September	0.039	2	0.033	1	0.011*	1	0.011*	2	0.011*	1
October	0.030*	4	0.042	1	0.063	1	0.011*	2	0.011*	1
Average	**0.043**	**12**	**0.037**	**7**	**0.078**	**8**	**0.029**	**16**	**0.019**	**8**
Median	**0.039**		**0.036**		**0.069**		**0.014**		**0.011**	

(a) Monthly averages are the mean of all data collected during a given month. The Central Delta subarea includes data collected at the Delta Mendota Canal and State Water Project. The Sacramento subarea includes data collected at Freeport, River Mile 44 and Greene’s Landing. The raw data are provided in Appendix L. Values noted with an asterisk were calculated using one or more water concentrations that were below detection. Half the detection limit was used in the calculations.

D.2 Alternate BAF-Based Linkage Approach

The linkage method recommended by Central Valley Water Board staff and described in Chapter 5 is based on the statistically significant relationship between standard 350-mm largemouth bass and average water methylmercury concentrations. A second approach that does not rely on the correlation between largemouth bass and water methylmercury concentrations to derive an implementation goal for water makes use of the total bioaccumulation factor (BAF), an approach used in numerous USEPA-approved TMDLs across the country.[4] A BAF is the ratio of the concentration of a chemical in fish tissue to the concentration of the chemical in the water column. As defined in the Mercury Study Report to Congress (USEPA, 1997a), the BAF is the concentration of the methylmercury in fish divided by the concentration of dissolved methylmercury in water. According to USEPA's 2003 technical support document for the development of national bioaccumulation factors, a total BAF based on the total concentration of a chemical in water also can be used. By definition, BAFs imply a linear relationship between methylmercury in the water column and in fish.

Table D.5 lists the BAFs and safe aqueous methylmercury levels calculated for each Delta subarea and a Delta-wide BAF using standard 350 mm largemouth bass, average unfiltered water methylmercury values, and the following equations. Table D.6 lists BAFs and safe water methylmercury levels based on filtered water data.

Equation 5.1a:

$$\text{BAF} = \text{LMB}_{\text{MeHgconc}} \div \text{Water}_{\text{MeHgconc}}$$

Where: $\text{Water}_{\text{MeHgconc}}$ = Water column concentration of unfiltered MMHg (µg/L)

$\text{LMB}_{\text{MeHgconc}}$ = 350-mm LMB tissue concentration (µg/kg)

Equation 5.b:

$$\text{Safe Level for Water} = \text{LMB}_{\text{MeHg Proposed}}\ \text{Goal} \div \text{BAF}$$

Where: $\text{LMB}_{\text{MeHgconc}}$ = Proposed implementation goal for 350-mm LMB (µg/kg)

Using "Delta-wide" values from Table 5.3 as an example:

$$\text{BAF} = (0.59\ \text{mg/kg} \times 1000) \div (0.110\ \text{ng/l} \div 1000)$$
$$= 5.35 \times 10^{6}$$

$$\text{Safe Level for Water} = (0.180 \div 5.35 \times 10^{6}) \div 10^{6}$$
$$= 0.034\ \text{ng/l}$$

The safe aqueous methylmercury concentrations produced by the BAF method are slightly less than but comparable to the safe levels produced using the regression-based approach. This similarity most likely occurs because both methods used the same data, and because the regressions are nearly linear at low fish and water methylmercury levels. However, the regression-based method is preferred because it does not inherently assume a linear relationship between fish and water methylmercury levels.

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[4] Refer to: http://www.epa.gov/OWOW/tmdl/index.html.

Table D.5: Delta BAFs and Corresponding Safe Methylmercury Levels in Water Calculated Using Unfiltered Water

	Delta Subarea					**Delta-Wide (a)**
	Sacramento River	Mokelumne River	Central Delta	San Joaquin River	West Delta	
Standardized 350-mm Largemouth Bass MeHg (mg/kg)	0.72	1.04	0.19	0.68	0.31	0.59
March-October 2000 Average MeHg in Unfiltered Water (ng/l)	0.120	0.140	0.055	0.147	0.087	0.110
BAF	6.00×10^{6}	7.43×10^{6}	3.45×10^{6}	4.63×10^{6}	3.56×10^{6}	5.35×10^{6}
Safe Methylmercury Concentration in Water (b)	0.030	0.024	0.052	0.039	0.051	0.034

(a) Delta-wide largemouth bass and water methylmercury concentrations were estimated by averaging the subarea values. The Delta-wide BAF and safe water concentration were calculated using the Delta-wide largemouth bass and water values.

(b) Safe levels in water correspond to the proposed implementation goal of 0.18 mg/kg methylmercury in standard 350-mm largemouth bass.

Table D.6: Delta BAFs and Corresponding Safe Methylmercury Levels in Water Calculated Using Filtered Water Data

	Delta Subarea					**Delta-Wide (a)**
	Sacramento River	Mokelumne River	Central Delta	San Joaquin River	West Delta	
Standardized 350-mm Largemouth Bass MeHg (mg/kg)	0.72	1.04	0.19	0.68	0.31	0.59
March-October 2000 Average MeHg in Filtered Water (ng/l)	0.043	0.078	0.029	0.037	0.019	0.041
BAF	1.67×10^{7}	1.33×10^{7}	6.55×10^{7}	1.84×10^{7}	1.63×10^{7}	1.43×10^{7}
Safe Methylmercury Concentration in Water (b)	0.011	0.014	0.027	0.010	0.011	0.013

(a) Delta-wide largemouth bass and water methylmercury concentrations were estimated by averaging the subarea values. The Delta-wide BAF and safe water concentration were calculated using the Delta-wide largemouth bass and water values.

(b) Safe levels in water correspond to the proposed implementation goal of 0.18 mg/kg methylmercury in standard 350-mm largemouth bass.

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E. METHODS USED TO ESTIMATE WATER VOLUMES FOR DELTA AND SACRAMENTO BASIN INPUTS AND EXPORTS

Average annual water volume is a critical component of the source assessments described in Chapters 6 and 7 because water volume is multiplied by the concentration of each constituent to determine loads. Also, a balanced water budget indicates that all major water imports and exports have been identified. This appendix contains a hydrologic evaluation of wet and dry years during the methyl and total mercury source assessment study periods (Section E.1) and a description of methods used to estimate water volumes used in the source assessments (Section E.2). All figures and tables referenced in the text are provided at the end of Appendix E.

E.1 Hydrologic Evaluation of Source Assessment Study Periods

Water volumes entering the Delta vary from season to season and year to year. A “water year” (WY) is the period between October and September that encompasses the entire wet season; for example, WY2001 is the period between 1 October 2000 and 30 September 2001. The methylmercury load analyses (Chapter 6) focused on the four-year WY2000-2003 period, which encompasses the available methylmercury concentration data at the time the TMDL was developed. The total mercury and sediment load analyses (Chapter 7) focused on two periods, WY2000-2003 and WY1984-2003. The WY2000-2003 period was selected for comparison to the methylmercury load estimates. Enough information was available to evaluate the twenty-year WY1984-2003 period for the Sacramento Basin tributaries, which input the most total mercury to the Delta of any source. This period was evaluated because it includes a fairly even mix of wet and dry years and better describes long-term average conditions.

Water year types in California are classified according to the natural water production of the major basins. The California Department of Water Resources (DWR) Hydrologic Classification Index (HCI) was used to evaluate the distribution of wet and dry years in the Central Valley. Figure E.1 graphs the Sacramento Valley and San Joaquin Valley indices for the period of record (1901 to 2003). The DWR HCI classifies water years as “wet”, “above normal”, “below normal”, “dry”, or “critical dry” (DWR, 2003). For the Sacramento Valley, normal hydrologic conditions equate to an index value of 7.8, wet is ≥9.2, dry is 5.4 to 6.5, and critical dry is ≤5.4. For the San Joaquin Valley, normal hydrologic conditions equate to an index value of 3.1, wet is ≥3.8, dry is 2.1 to 2.5, and critical dry is ≤2.1. The WY2000-2003 period has average indices of 7.3 and 2.7 for the Sacramento and San Joaquin watersheds, respectively, and appears to be a relatively dry period compared to the period of record. In comparison, the WY1984-2003 period appears to encompass a fairly even mix of wet and dry years. The Sacramento River HCI indicates that during the WY1984-2003 period, ten water years were “wet” or “above normal”, and ten years were “below normal,” “dry,” or “critical dry”. The San Joaquin River HCI indicates that nine water years were “wet” or “above normal”, and eleven years were “below normal,” “dry,” or “critical dry.”

The distribution of wet/dry years in the twenty-year study period was compared to the distribution of wet/dry years during the past century in the Sacramento and San Joaquin River watersheds. The Sacramento River index includes water years 1906 to 2003 and the San Joaquin River index includes water years 1901 to 2003. Using the Chi-square test, it was determined that the distribution of water year classifications between the WY1984-2003 period and the entire record was not statistically different (a=0.05) from the distributions for both the Sacramento and San Joaquin River watersheds. Therefore, it was concluded that the WY1984-2003 period is representative of long-term conditions.

E.2 Water Volume Estimation Methods

Average annual water volumes were estimated for the following Delta inputs and exports:

1. Tributary inputs to the Delta;
2. Wastewater treatment plants;
3. Atmospheric deposition;
4. Urban runoff;
5. Delta outflows to San Francisco Bay and diversions to southern California (Delta Mendota Canal and State Water Project);
6. Agricultural diversions;
7. Evaporation; and
8. Dredging.

The WY2000-2003 period is a relatively dry four-year period, while the WY1984-2003 period reflects an even mix of wet and dry years, conditions typical for the last 100 years. As illustrated by Table 6.1 in Chapter 6, the WY2000-2003 water budget balances within 5% and the WY1984-2003 water budget balances within 1%. This indicates that the major water inputs and exports have been identified.

Water volume information was obtained from a variety of sources (Table E.1). A DWR model, Dayflow, provided daily flow estimates for several of the major Delta exports, including outflow to San Francisco Bay, the Delta Mendota Canal (DMC), State Water Project (SWP), and agricultural withdrawals. Four-year and 20-year precipitation amounts and land use acreages were used to estimate wet weather inputs from urban areas, atmospheric deposition, and tributaries with no flow gages, whenever that duration of data was available for a given monitoring station. Project files were reviewed to determine recent average annual discharges from NPDDES-permitted facilities in the Delta and annual average volumes removed by dredging projects. The following sections describe how each water volume was derived.

E.2.1 Flow-Gage Based Water Volumes

Average annual water volumes were estimated for tributary inputs to the Delta using a variety of methods determined by available data (Table E.1). Flow gages provided daily flows for the major tributaries. If there was no nearby flow gage, Staff used precipitation-based runoff estimates to calculate loads (Section E.2.3).

Table E.2 lists the flow gages used to calculate average annual water volume. The use of multiple flow gages was required to estimate water volumes corresponding to the following monitoring locations: Feather River near Nicolaus, Mokelumne River downstream of I-5, and Yolo Bypass. Because of the complexities of the Yolo bypass hydrology, it is discussed in its own section (Section E.2.2).

Staff estimated flows for the Feather River at Nicolaus using the formula: 1.11 x [Bear at Wheatland + Yuba at Marysville + Feather at Gridley]. The coefficient of 1.11 was determined by fitting a regression of historical flow data at Nicolaus when flows were rated (1942 to 1983) and historical flow data for the same time period paired by date of the sum of Feather River at Gridley, Yuba River at Marysville and the Bear River at Wheatland. The coefficient of 1.11 compensates for inputs not included by the Gridley, Marysville, and Wheatland gages.

The flow of the Mokelumne River near I-5 was estimated by summing the gaged flows of the Mokelumne at Woodbridge and Cosumnes River at Michigan Bar. If Mokelumne at Woodbridge flows were missing for particular days, the sum of Camanche Dam outflow and Cosumnes River at Michigan Bar was used. If both the Mokelumne at Woodbridge flow and Camanche Dam outflow were missing, then those particular days were considered missing values. Flow records for Mokelumne at Woodbridge flow and Camanche Dam outflow for water years 1995 and 1996 were missing more than 20% of their values; all other water years during the study period had either Mokelumne at Woodbridge flow and/or Camanche Dam outflow records available. Therefore, the 20-year flow average was estimated by normalizing the total flows for the WY1984-2003 period. To estimate the missing values, first the number of days in the 20-year period (7305) was divided by the number of days with a recorded value in the flow record (6517). Then the resulting quotient was multiplied by the calculated sum of loads divided by 20 to obtain the average annual load. Normalization was not needed for the WY2000-2003 period.

E.2.2 Yolo Bypass Inflows & Outflows to the Delta & Hydrologic Conditions in January 1995

Yolo Bypass Boundary Definition & Hydrologic Features

The Yolo Bypass is a 73,300-acre floodplain on the west side of the lower Sacramento River in Yolo and Solano Counties (Figure E.2) within the levees of the Sacramento River Flood Control Project. The Fremont and Sacramento Weirs route floodwaters to the Yolo Bypass from the Sacramento and Feather Rivers, Sutter Bypass and their associated tributary watersheds. Cache and Putah Creeks, Willow Slough, and the Knights Landing Ridge Cut from the Colusa Basin all drain directly to the Yolo Bypass.

The Interstate 80 (I-80) causeway bisects the Yolo Bypass east to west. The bypass north of I-80 is bounded on the east by the Tule Canal (the upper extension of the Toe Drain) and the East Bypass Levee and bounded on the west by the West Bypass Levee. For the purpose of this TMDL, staff used the boundaries defined by 2001 Yolo Basin Foundation report, *A Framework for the Future: Yolo Bypass Management Strategy* (Jones & Stokes, 2001[5]) to delineate the bypass south of I-80. South of I-80 the bypass is bounded on the east by the Toe Drain and the East Bypass Levee (also considered the west levee of the Sacramento River Deep Water Ship Channel), downstream to the northwest corner of Prospect Island. At this location, the bypass extends east to include Prospect Island, although the East Bypass Levee remains intact along the west edge of the island. South of Prospect Island, the east side of the Bypass extends downstream of the confluence of Cache and Lindsey Sloughs to the downstream boundary of Egbert Tract. This eastern downstream limit of the bypass is roughly co-located with the confluence of Steamboat and Cache Sloughs. The west side of the bypass is bounded by the West Bypass Levee to just south of Putah Creek and the Putah Creek Sink downstream of Putah Creek. The southern bypass is unleveed on the west side for approximately eight miles, allowing floodwaters to flow unimpeded as far west as Yolo County Road (CR) 104. Farther downstream (approximately 1 mile north of Yolo CR 155), the West Bypass Levee resumes and extends south and west of Liberty Island. The west side of the bypass extends farther south, downstream of Liberty Island, and along the western boundary of Egbert Tract.

The southern portion of the Yolo Bypass (about 52,600 acres) lies within the statutory Delta boundary and has some tidally influenced areas. Tidal conditions are observed as far upstream in the Toe Drain as the I-80 causeway (Jones & Stokes, 2001). The Toe Drain, which drains to Prospect Slough, is the primary drainage in the Yolo Bypass. The water elevation in the Toe Drain typically fluctuates tidally between three and seven feet at the Yolo Bypass at Lisbon gage (operated by DWR, gage ID “LIS”) (Figure E.2). A few hundred feet north of this gage, the Lisbon Weir limits the range of tidal fluctuation upstream of the weir. The main part of the weir consists of a sheet piling-reinforced rock mound with three “slap gates” (like trap doors) that allow water to flow northward with incoming tides, but not southward with outgoing tides (Jones & Stokes, 2001; Kirkland, personal communication). The weir impounds upstream inflow and tidal water at an elevation equal to the weir crest elevation (2.5 feet above sea level) (Jones & Stokes, 2001). This provides higher and more stable water levels for upstream agricultural diversion pumps.

When tributary inputs upstream of Lisbon Weir are greater than approximately 800 cfs, water flows southward over the weir (Kirkland, personal communication). During the summer season, the water stage is typically greater to the south of the weir, so that there is a net upstream flow on Toe Drain. However, even during the summer, very high tides cause the pool upstream of the weir to fill and then drain southward across the top of the weir when the tide turns (Kirkland, personal communication). Until recently, the Lisbon gage provided only stage information; it was rated for velocity in winter 2004. Preliminary calculations by DWR and Central Valley Water Board staff indicate that there was a monthly net downstream flow from the Yolo Bypass at Lisbon ranging between 56,00 and 152,000 acre-feet per month for the months of March, April and May 2004. However, there was a net upstream flow of 700 to 3,000 acre-feet per month in June and July 2004. That is, there was no net outflow from the Yolo Bypass to the Delta during these summer months. Observations during summer months in 2005 and 2006

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[5] Jones & Stokes. 2001. *A Framework for the Future: Yolo Bypass Management Strategy.* Final report (J&S 99079) prepared for the CALFED Bay-Delta Program by the Yolo Bypass Working Group, Yolo Basin Foundation, and Jones & Stokes. August 2001.

indicate there is net outflow from the Yolo Bypass during wetter years (Foe, personal communication).

Yolo Bypass Inflow and Outflow Calculations

Aqueous methyl and total mercury sampling took place on Prospect Slough at the Toe Drain to estimate mercury concentrations in outflows from the Yolo Bypass to the central Delta. However, no flow gage is available at that location. Several gages are available upstream that can be used to estimate Yolo Bypass outflows. The “Yolo Bypass near Woodland” flow gage (USGS gage 11453000) represents the sum of inflow from Fremont Weir, Knights Landing Ridge Cut, and Cache Creek Settling Basin (Figure E.2); the USGS Woodland gage record includes only daily mean flows greater than 1,000 cfs. Flow gages are also active on Cache Creek at Yolo (USGS gage 11452500), Sacramento Weir (USGS gage 11426000), Putah Creek near Winters (USGS gage 11454000), and the Putah South Canal (USGS gage 11454210, available after 10/1/94), which diverts water from Putah Creek downstream of the Winters gage. No flow gages are active on Knights Landing Ridge Cut or Willow Slough Bypass and, as noted above, the gage on Toe Drain near Lisbon was only recently rated for velocity. Inflows from Knights Landing Ridge Cut, Putah Creek and Willow Slough to the Yolo Bypass were estimated using hydrologic models developed by Jones and Stokes (Jones & Stokes, 2001).

Knights Landing Ridge Cut. The Knights Landing Ridge Cut (KLRC) is an artificial overflow channel that connects the lower end of the Colusa Basin Drain (CBD) to the Yolo Bypass. Under low-flow conditions, the CBD discharges to the Sacramento River through a set of gates, and little to no water flows from the KLRC to the Yolo Bypass (Jones & Stokes, 2001). The daily discharge of the CBD to the Sacramento River is measured by a gage operated by DWR (Colusa Basin Drain at Knights Landing). However, when the Sacramento River stage exceeds 25 feet, the gates close and flow in the CBD is shunted through the KLRC to the Yolo Bypass (Jones & Stokes, 2001). These flows are not gaged; however, staff was able to estimate the KLRC inflows to the Yolo Bypass using a hydrologic model developed by the consulting firm, Jones and Stokes.

The daily discharge velocity of the CBD is measured by a gage operated by DWR at a location near Highway 20. The CBD near Highway 20 gage is about 20 miles upstream of the confluence between the CBD and the KLRC. Therefore, the gage flows do not include the runoff from 22 square miles of tributary watershed area to the CBD between the Highway 20 gage and the CBD-KLRC confluence (Jones & Stokes, 2001). According to the Jones & Stokes hydrologic model, during significant rainfall events (days with greater than 0.3 inches of rain at Colusa), the total flow arriving at the lower end of the CBD was estimated by multiplying the gaged daily flow at CBD near Highway 20 by the drainage area ratio of 1.21. Daily precipitation data at Colusa was obtained from a gage operated by the California Irrigation Management Information System. During days with no significant rainfall (less than 0.3 inches/day of rain at Colusa), the total flow at the lower end of the CBD was estimated to be equal to the CBD near Highway 20 gaged daily flow.

Greater than 0.3 inches of rain at Colusa:

$$Q_{CBD} = 1.21Q_{CBD20}$$

Less than 0.3 inches of rain at Colusa:

$Q_{CBD} = Q_{CBD20}$

Where: Q_{CBD20} = Gaged flow of the Colusa Basin Drain at Highway 20
Q_{CBD} = Estimated total flow arriving at the lower end of the Colusa Basin Drain

Because the majority of the water from the CBD arriving at the Knights Landing Ridge Cut is discharged to the Sacramento River, the estimated KLRC inflow to the Yolo Bypass was then calculated by subtracting the gaged outflow to the Sacramento River (the CBD at Knights Landing DWR gage) from the estimated total flow arriving at the lower end of the drain (Jones & Stokes, 2001):

$Q_{YB} = Q_{CBD} - Q_{KNL}$

Where: Q_{YB} = Knights Landing Ridge Cut inflow to the Yolo Bypass
Q_{KNL} = Gaged outflow to the Sacramento River from the Knights Landing Ridge Cut

<u>Putah Creek</u>. Upstream of the Yolo Bypass, Putah Creek is impounded by the Monticello Dam, a large dam that creates Lake Berryessa, and the Putah Diversion Dam, a small rediversion dam that creates Lake Solano. The Putah Diversion Dam is about 7 miles downstream of the Monticello Dam. Much of the water trapped behind the Putah Diversion Dam is pumped southward through the Putah South Canal for agricultural uses. However, some of the water in Lake Solano is released to the lower Putah Creek channel. These releases to Putah Creek are gaged by USBR. However, the Putah Diversion Dam is located about 22 miles upstream of the West Bypass Levee of the Yolo Bypass. Flows between the Putah Diversion Dam and the Yolo Bypass are affected by seepage losses, tributary inflows, evapotranspiration, and channel storage (Jones & Stokes, 2001).

Staff estimated the Putah Creek inflows to the Yolo Bypass using the hydrologic model developed by Jones and Stokes (Jones & Stokes, 2001). The calculations were divided into three hydrologic conditions: scheduled Berryessa and Putah Diversion Dam water-rights releases only, active rainfall runoff, and Lake Berryessa spills. During periods when flows at Putah Diversion Dam consisted entirely of scheduled water-rights releases, inflow to the Yolo Bypass equals the Diversion Dam releases minus the net flow losses along the channel. During periods when there was active rainfall runoff but no spill from Lake Berryessa, inflow to the Yolo Bypass equals two times the gaged flow at Putah Diversion Dam minus net flow losses. When Lake Berryessa was spilling, inflow to the Yolo Bypass equals the gaged flow at Putah Diversion Dam minus net flow losses. The net flow losses along the 22 miles downstream of the Diversion Dam were estimated to be a constant 30 cfs in the Jones & Stokes model. The equations for the flow model are as follows:

Conditions 1 (scheduled releases only) and 3 (Lake Berryessa spill):

$Q_{YB} = Q_{PDD} - 30$

Condition 2 (active rainfall runoff):

If: 1. $Q_{PDD} > 60$ cfs (to eliminate scheduled release-only condition)
2. $Q_{BER} < 900$ cfs (to eliminate Lake Berryessa spill periods)
3. $Q_{INT} > 100$ cfs (to eliminate noise in the interdam runoff estimates)

Then: $Q_{YB} = Q_{PDD}(2) - 30$

Where: Q_{PDD} = Putah Creek flow at Putah Diversion Dam
Q_{BER} = Outflow from Lake Berryessa (releases plus spills from USBR gage)
Q_{INT} = Rainfall runoff from the reach between Lake Berryessa and Putah Diversion Dam
$Q_{INT} = Q_{INF} - Q_{BER}$ (Q_{INF} = estimated inflow to Lake Solano calculated by USBR)
Q_{YB} = Putah Creek outflow to Bypass

<u>Willow Slough</u>. Flows in Willow Slough were not gaged at any time during the study period. Staff estimated the Willow Slough inflows to the Yolo Bypass using a hydrologic model developed by Jones and Stokes (Jones & Stokes, 2001). This model estimated Willow Slough daily inflows to the Yolo Bypass by correlation with gaged runoff in the interdam reach of Putah Creek, adjusted for drainage area size. Runoff in the interdam reach of Putah Creek was calculated by subtracting gaged Lake Berryessa outflow (USBR gage BER) from the Lake Solano inflow (calculated by USBR from a daily water balance). The following equation was used to calculate the estimated Willow Slough inflow to the Yolo Bypass:

$$Q_{WS} = -0.000423(Q_{INT})^2 + 3.19Q_{INT}$$

Where: Q_{WS} = Willow Slough outflow to the Bypass
Q_{INT} = Rainfall runoff from the interdam reach between Lake Berryessa and Putah Diversion Dam

<u>Yolo Bypass Inflows</u>. To estimate total inflows to the Yolo Bypass upstream of Prospect Slough at Toe Drain on the days that average daily flows were greater than 1,000 cfs at Yolo Bypass near Woodland, the following equation was used:

$$\text{Yolo Bypass Inputs} = \text{Yolo Bypass near Woodland} + \text{Putah Creek} + \text{Sacramento Weir Spill} + \text{Willow Slough}$$

To estimate total inflows to the Yolo Bypass on the days that average daily flows were less than 1,000 cfs at Yolo Bypass near Woodland, the following equation was used:

$$\text{Yolo Bypass Inputs} = \text{Cache Creek @ Yolo} + \text{Knights Landing Ridge Cut} + \text{Fremont Weir} + \text{Putah Creek} + \text{Sacramento Weir Spill} + \text{Willow Slough}$$

Total outflow from the Yolo Bypass was estimated by subtracting 800 cfs from the total inflow to account flow trapped behind Lisbon Weir. If the estimated total inflow was less than 800 cfs, it was assumed that there was zero net flow past Lisbon Weir. As Figure E.3 illustrates, the average daily outflow estimates indicate that there is generally no net outflow between July and October, which is comparable with the preliminary outflow estimates described earlier that were developed by DWR and Regional Board staff using March-July 2004 flow data for the gage downstream of the Lisbon Weir.

Concentration/Flow Regressions & Hydrologic Conditions in January 1995

Total mercury and TSS samples were collected from Prospect Slough near Toe Drain typically during outgoing tides. As described in Section 7.1.1.1, total mercury and TSS concentrations observed were regressed against estimated daily Yolo Bypass outflows at Lisbon Weir to determine if statistically significant correlations might exist (Appendix I, Figure I.1). There is generally no net outflow from the Yolo Bypass's Toe Drain downstream of Lisbon Weir between July and October. Therefore, although sampling of Prospect Slough took place during outgoing tides with the intent of sampling outflows from the Yolo Bypass, during the summer months this sampling most likely represents waters tidally-pumped northward from Cache Slough, rather than outflows from the Yolo Bypass north of Lisbon Weir.

Extremely high total mercury and TSS concentrations were measured in Prospect Slough on 10 and 11 January 1995 (Figure I.1). Cache Creek Settling Basin (CCSB) and Fremont Weir spills were evaluated to determine whether these concentrations were likely to have occurred regularly during the 20-year study period. Flows from the CCSB are controlled by the following factors: (1) the CCSB can release up to 400 cfs through its low flow outlet; (2) above 400 cfs, the CCSB begins to fill at a rate of inflow (measured by the gage at Yolo) minus 400 cfs; and (3) when the basin fills beyond its capacity of approximately 43,200 acre-feet (weir height of 12 feet multiplied by 3,600 acres, the area of the CCSB), water begins spilling over the weir. Weir spill continues until inflow to the CCSB decreases to 400 cfs (CDM, 2004). Cache Creek Settling Basin daily outflows were estimated based on these factors and compared to the timing of Fremont Weir spills (Figure E.4). The high concentrations observed in Prospect Slough on 10 and 11 January 1995 may have resulted from the high releases from the Cache Creek Settling Basin that occurred on 9 January without any dilution flow from Fremont Weir. Although the CCSB has had such high releases several times throughout the 20-year record, all occurred concurrently with spills from Fremont Weir. Because the magnitude of CCSB release without any dilution that occurred on 9 January appears to have happened only once in the 20-year period, the 10 and 11 January 1995 total mercury and TSS concentration values were not included in the concentration/flow regressions used to predict average annual loads exported by the Yolo Bypass to the Delta.

E.2.3 Precipitation-Based Water Volumes

Atmospheric wet deposition, tributary inputs from ungaged watersheds, and storm runoff from urban areas were estimated using the rational method:

$$Q_e = Rf \times A \times RC$$

Where: Q_e = Estimated volumetric runoff rate (acre-feet per year)
Rf = Annual precipitation amount in the watershed (feet per year)
A = Watershed area (acres)
RC = Runoff coefficient

Precipitation data for seventeen gages located throughout the Delta source region (Table E.3) were compiled with a focus on gages that appeared to represent the general precipitation pattern of each region and had records at least 20 years in length. All but one of the gages used in this analysis had records that exceeded 20 years in length. The average annual precipitation amount for WY2000-2003 and WY1984-2003 were calculated for each gage. Land use information was obtained from the California Department of Water Resources Land Use Survey Data and USGS/USEPA National Land Cover Data (DWR, 1993-2002[6], USGS/USEPA, 1993[7]) to determine acreages for each land use in the Delta and its ungaged tributary watersheds. The Delta and its ungaged tributary subwatersheds were divided into areas defined by (1) proximity to a precipitation gage, and (2) land use category. Because of their size, tables of the land use acreages divided by land use type and precipitation area are not included in this appendix but can be provided electronically upon request. Table E.4 provides just the urban acreage in the Delta. Then runoff coefficients were assigned to each land use type (Table E.5). Using a combination of software programs (Microsoft Excel and ESRI ArcView), 4-year and 20-year average annual stormwater runoff amounts were calculated for each subarea using Equation E.1.

Dry weather urban runoff was estimated by adapting the daily dry season runoff values developed by Larry Walker Associates (LWA, 1996) for the Sacramento region. Larry Walker Associates determined average dry season runoff to be 49 mgd and inter-storm runoff to be 58 mgd in the greater Sacramento region. LWA estimated that there were 302 square miles (193,280 acres) of urban area in the Sacramento region. The daily dry season runoff value was divided by the acreage to obtain dry season runoff volume per acre:

$$\begin{aligned}\text{Dry Season Runoff} &= 49 \times 10^6 \text{ gallons/day} \div 193{,}280 \text{ acres} \\ &= 254 \text{ gallons/acre/day}\end{aligned}$$

It was assumed that the dry season runoff amounts in the greater Sacramento region are representative of all urban areas within the statutory Delta boundary and its ungaged tributary watersheds. LWA's dry season runoff estimates were used for dry days in both the dry season and wet season to estimate the annual average non-storm urban runoff in the Delta. The average number of non-rain days per year for the WY1984-2003 period (305 days) was multiplied by 254 gallons/acre/day and the Delta urban acreage (about 55,000 acres), to obtain an average annual runoff volume of 4,300 million gallons per year (13,000 acre-feet/year).

E.2.4 Dayflow Model

Output from the Dayflow Model was used to estimate the average annual water volume of outflows to San Francisco Bay and diversions south of the Delta *via* the Delta Mendota Canal (Central Valley Project pumping at Tracy) and State Water Project (Clifton Court Intake). Dayflow is a computer program maintained by the California Department of Water Resources Interagency Ecological Program (http://www.iep.ca.gov/dayflow/index.html). It was developed in 1978 as an accounting tool for determining historical Delta boundary hydrology (mean daily flows). In 2000, the software used to perform Dayflow calculations was rewritten in Java. The input data include the principal Delta stream inflows, Delta precipitation, Delta exports, and Delta gross channel depletions. These data include both monitored and estimated values.

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[6] DWR. 1993-2003. Land Use Data. California Department of Water Resources. Available at: http://www.landwateruse.water.ca.gov/basicdata/landuse/digitalsurveys.cfm.

[7] USEPA/USGS Multi-Resolution Land Characterization Program National Land Cover Data available at: http://www.epa.gov/mrlc/nlcd.html.

Input data is stored in a HEC-DSS file, and output is written to an ASCII file. Dayflow output is used extensively in studies initiated by the Department of Water Resources, the Department of Fish and Game, and by other State and Federal agencies and private consultants. Dayflow output files can be downloaded from the IEP Dayflow website: http://www.iep.ca.gov/dayflow/output/index.html.

E.2.6 Evaporation

The amount of water lost through evaporation from Delta water surfaces was estimated by multiplying the average evaporation rate for the region by the water surface acreage. Mean evaporation at Brannan Island and Grizzly Island near Rio Vista is approximately 73.4 inches per year. Mean evaporation at the Oakdale Woodward Dam Station south of Stockton is approximately 78.43 inches per year. Staff used an evaporation rate of 73.4 inches per year and a water surface acreage of approximately 48,600 acres (1.97×10^8 square meters) (see Section 4.4.3) to estimate an evaporation water loss of about 300,000 acre/feet per year.

E.2.7 Dredging

Sediment is dredged at various locations in the Delta to maintain ship channels and marinas. Table 6.17 in Chapter 6 provides details on recent dredge projects within the Delta and Figure 6.9 shows their approximate locations. Approximately 533,400 cubic yards per year (cy/yr) of sediment are dredged on average. The amount of water removed by dredge projects was estimated using weight-volume relationships for saturated soils described by Das (1990)[8], specific gravity values of 1 and 2.65 for water and solids, respectively, and the assumption that the water content of the dredged material is 100% (50% water and 50% sediment by weight[9]):

Water Volume =
= (dredged material [cy/yr]) x $(1 + (1 \div 2.65))$ x (cy to acre-feet conversion factors)
= 533,400 cy x $(1 \div 1.3774)$ x $(27 \div 43{,}560)$
= 240 acre-feet/yr

This estimate does not account for how much water is removed by dredging activities that incorporate river water with the dredge sediment to form a slurry that can then be pumped and delivered via pipeline to dredge material disposal sites for settling and disposal. Nor does the estimate account for return water discharged by disposal sites to adjacent receiving waters.

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[8] Das, B.M. 1990. Principles of Geotechnical Engineering. Second Edition. PWS-Kent Publishing Company, Boston, 665 pp.

[9] This is a common assumption for dredging operations. (U.S. Army Corps of Engineers. 2002. “Moisture Content,” personal communication from L. Fade to G. Collins, San Francisco Bay Regional Water Quality Control Board, October.)

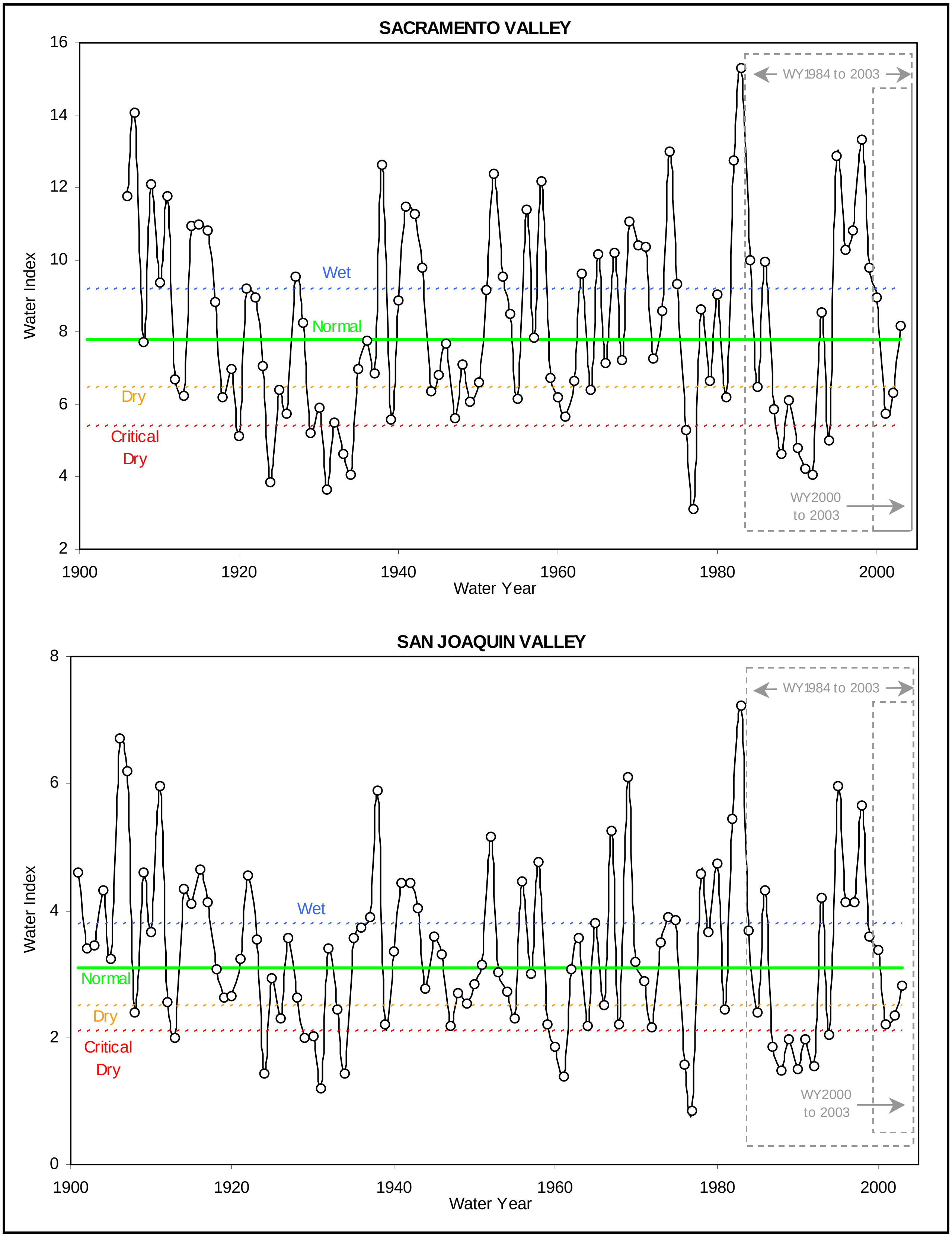


Figure E.1: California Dept. Water Resources Chronological Reconstructed Sacramento Valley & San Joaquin Valley Water Year Hydrologic Classification Indices (DWR, 2005)

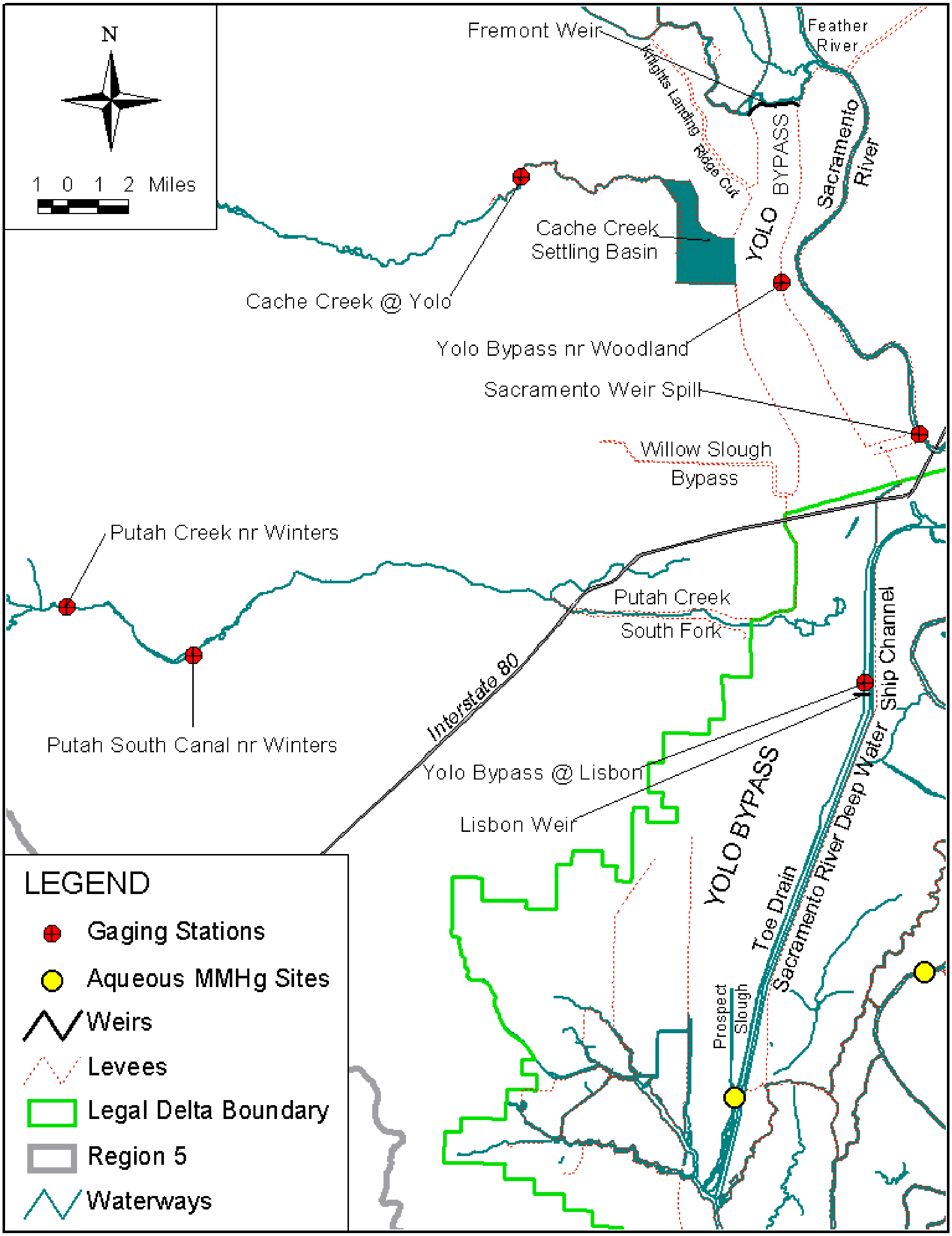


Figure E.2: Hydrologic Features of the Yolo Bypass.

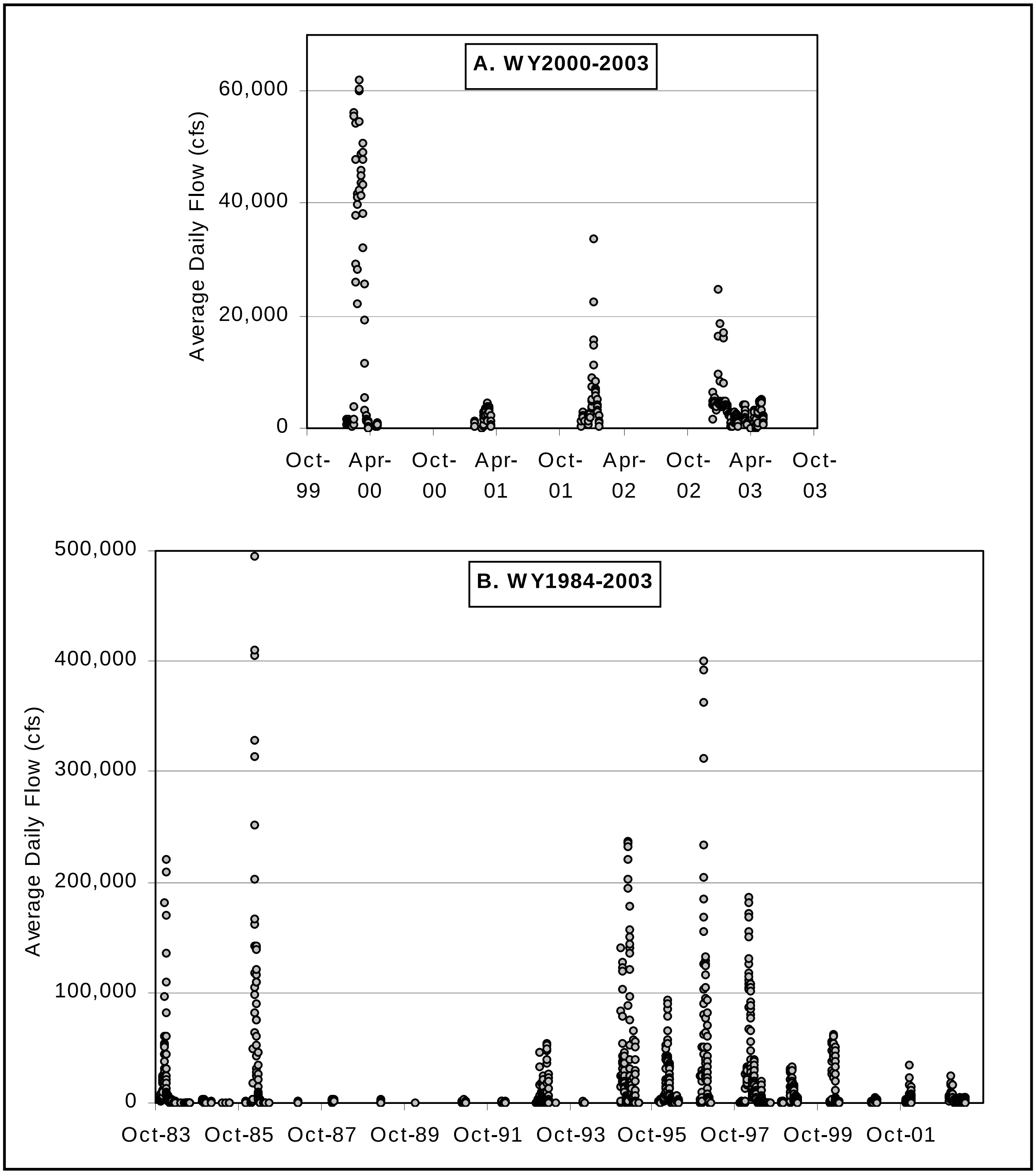


Figure E.3: Estimated Average Daily Outflows from the Yolo Bypass below Lisbon Weir during [A] WY2000-2003 and [B] WY1984-2003

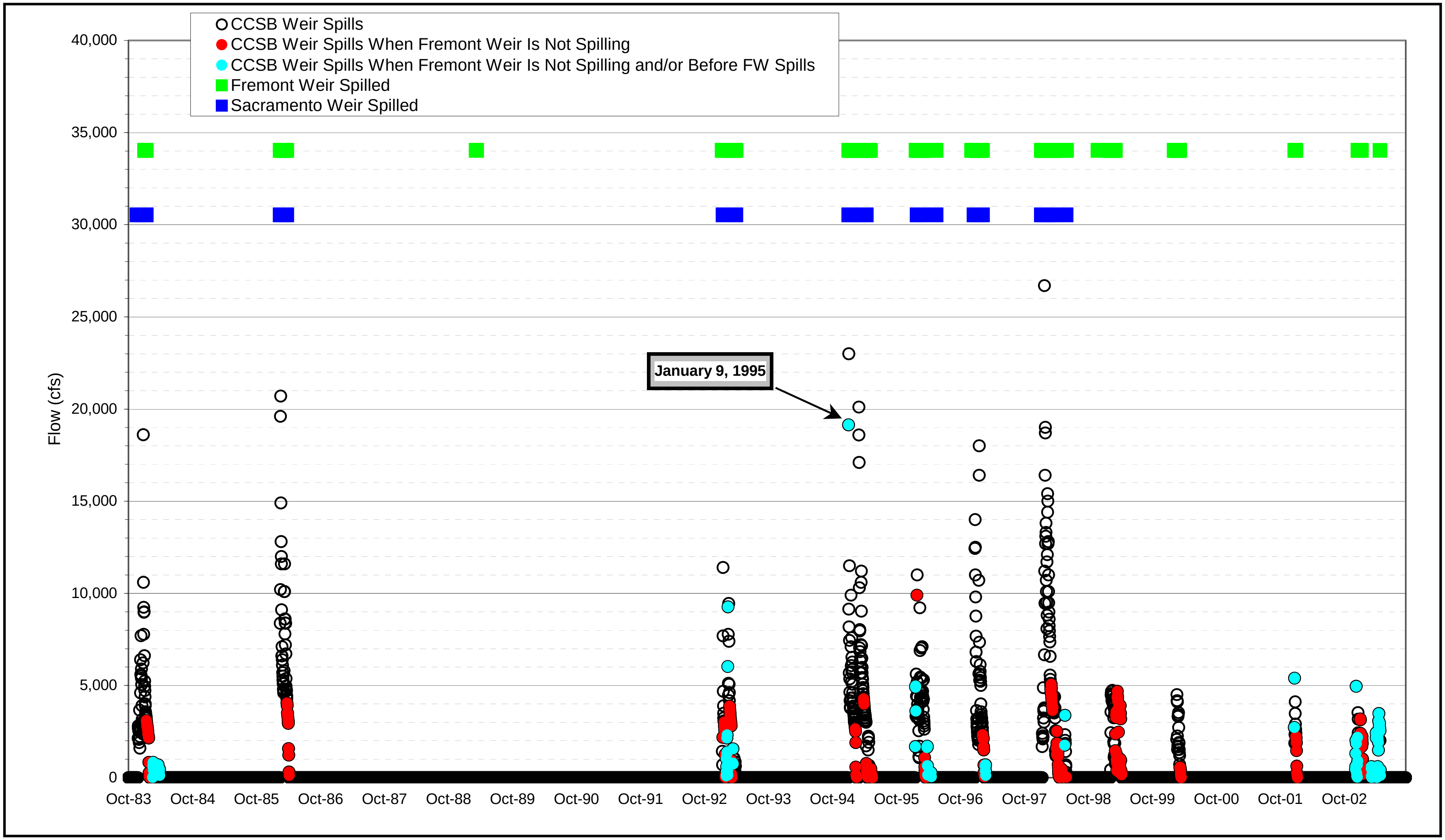


Figure E.4: Comparison of Estimated Cache Creek Settling Basin (CCSB) Outflows Compared to Fremont Weir Spills

Table E.1: Methods Used to Estimate Average Annual Water Volumes for Delta and Sacramento Basin Inputs and Exports

Type	Method	Location of Method Description
Tributary Inputs		
American River @ Discovery Park Cache Creek Settling Basin Colusa Basin Drain Feather River nr Nicolaus Fremont Weir Marsh Creek Mokelumne River d/s I-5 Sacramento River above Colusa Sacramento River @ Freeport San Joaquin River @ Vernalis Sutter Bypass	Flow -Gage Based Method	Section E.2.1
Yolo Bypass Outflows Knights Landing Ridge Cut Putah Creek @ Mace Blvd. Willow Slough	Flow-Gage + Hydrologic Model	Section E.2.2
Bear/Mosher Creek Calaveras River/Mormon Slough Coon Creek/Cross Canal French Camp Slough / Lone Tree Creek Morrison Creek Natomas East Main Drain Ulatis Creek Other Small Drainages to the Delta	Precipitation-Based Method	Section E.2.3
Other Inputs		
Wastewater Discharges	Project Files	Tables G.1 and G.2 (Appendix G)
Atmospheric deposition	Precipitation-Based Method	Section E.2.3
Urban runoff	Precipitation-Based Method + Dry Weather Estimate	Section E.2.3
Exports		
Delta Mendota Canal State Water Project Outflows to San Francisco Bay	Dayflow Model	Section E.2.4
Agricultural Diversion	Delta Island Consumptive Use Model	Section 6.2.4 (Chapter 6)
Evaporation	Evaporation Rate x Water Acreage	Section E.2.5
Dredging	Project Files	Section E.2.6

Table E.2: Gage Records Used to Calculate Average Annual Water Volumes for Delta and Sacramento Basin Tributaries.

Gage Name	Gage Operator	Gage ID [(a)]	Period of Record	Data Type
American River @ Fair Oaks	USGS and DWR	11446500	10/1/1904 - present	Daily
Bear River near Wheatland	USGS and DWR	BRW	1/24/97 - present	Event
Butte Slough near Meridian (Sutter Bypass)	DWR	BSL	10/1/1975 - present	Daily
Cache Creek @ Yolo	USGS and DWR	11452500	4/1/1903 - present	Daily
Colusa Basin Drain near Hwy 20	DWR	CDR, A02976	3/12/97 - present (CDR), 5/1/41 - present (A02976)	Event (CDR), Daily (A02976)
Colusa Basin Drain @ Knights Landing	DWR	A02945	10/1/1975 - present	Daily
Feather River @ Gridley	DWR	GRL	1/1/93 - present	Daily
Feather River near Nicolaus	USGS	11425000	4/1/42 - 9/30/83	Daily
Fremont Weir	DWR	FRE	10/1/1983 - present	Daily
Cosumnes River @ Michigan Bar	USGS and DWR	MHB	1/1/93 - present	Daily
Marsh Creek @ Brentwood	USGS	11337600	8/26/2000 - present	Daily
Mokelumne River @ Woodbridge	East Bay Municipal Utility District & USGS	WBR, 11325500	6/1/24 - 9/30/01	Daily
Putah Creek Outflow at Putah Diversion Dam	USBR		1/1/98 - present	Daily
Lake Solano Calculated Inflow	USBR		1/1/98 - present	Daily
Lake Berryessa Outflow	USBR	BER	10/4/93 - present	Daily
Sacramento River @ Colusa	USGS & DWR	COL	1/1/92 -present	Daily
Sacramento River @ Freeport	USGS	FPT	10/1/48 - present	Daily
San Joaquin near Vernalis	USGS & DWR	11303500, VNS	10/1/23 - present (11303500), 1/1/93 - present	Daily
Yolo Bypass near Woodland	USGS & DWR	11453000, YBY	6/29/98 - 7/13/98 (YBY), 10/1/39 - 3/17/03 (11453000)	Daily
Yuba River near Marysville	USGS	11421000	10/1/43 - present	Daily

(a) Letter-based “Gage ID” records were accessed through the California Data Exchange Center (CDEC) website, http://cdec.water.ca.gov. Alphanumeric “Gage ID” records were accessed through the DWR’s Water Data Library website, http://wdl.water.ca.gov/hydstra/index.cfm. Numeric “Gage ID” records were accessed through the U.S. Geological Survey Surface-Water Data for the Nation website, http://waterdata.usgs.gov/nwis/sw. Putah Creek outflow at the Putah Diversion Dam and Lake Solano Calculated Inflow were accessed through the U.S. Bureau of Reclamation Reservoir Operations Reports website, http://www.usbr.gov/mp/cvo/reports.html.

Table E.3: Summary of Precipitation Data Used to Estimate Runoff

Station [(a)]	Code	Latitude	Longitude	Beginning of Record [(b)]	Data Type	WY2000-2003 Average	WY1984-2003 Average
Adin RS	ADN	41.194	-120.944	10/01/1943	MA [(c)]	11.5	15.1
Calaveras Big Trees	CVT	38.283	-120.317	10/01/1929	MA	48.6	53.1
Capay	CPY	38.730	-122.130	01/01/1905	MA	20.4	22.5
Englebright (USACE)	ENG	39.239	-121.267	03/01/1989	MA	33.0	34.5
Fiddletown	FDD	38.533	-120.700	12/01/1937	MA	33.2	35.5
Folsom Dam	FLD	38.700	-121.167	10/01/1955	MA	22.2	24.2
Foresthill R S	FRH	39.017	-120.850	10/01/1936	MA	46.1	50.4
Los Banos	LSB	37.050	-120.867	01/01/1905	MA	7.8	9.5
New Exchequer-Lk McClure	EXC	37.585	-120.270	10/01/1935	MA	18.8	19.4
North Fork R S	NFR	37.233	-119.500	01/01/1905	MA	30.1	33.0
Orland	ORL	39.750	-122.200	01/01/1905	MA	18.7	21.6
Quincy RS (USFS)	QNC	39.960	-120.950	01/01/1905	MA	36.9	36.4
Sacramento WB City	SCR	38.583	-121.500	01/01/1905	MA	18.7	19.5
Shasta Dam (USBR)	SHA	40.718	-122.420	10/01/1957	DA [(c)]	63.6	61.4
Stockton Fire Station 4	STK	38.001	-121.317	01/01/1905	MA	16.6	17.2
Stony Gorge Reservoir	STG	39.583	-122.533	10/01/1926	MA	20.2	20.9
Yosemite Headquarters	YSV	37.740	-119.583	01/01/1905	MA	32.3	36.3

(a) All precipitation records were obtained from CDEC, http://cdec.water.ca.gov.
(b) All records continue through WY2003.
(c) MA: monthly accumulated; DA: daily accumulated.

Table E.4: Urban Acreage within the Legal Delta Boundary and Yolo Bypass North of the Delta

Delta Subarea (a)	**Precipitation Gage Region / Land Use Code** [(a)]															**Grand Total**
	Los Banos				**Sacramento WB City**						**Stockton Fire Station 4**					
	U	UI	UR	T	T	U	UC	UI	UR	UT	T	U	UI	UR	UT	
Central Delta					11	50	121	30	42		1276	12955	983	317		**15,785**
Marsh Creek											67	2891	88	381		**3,427**
Mokelumne River					26						57	44	39			**166**
Sacramento River					728	6286	225	206	921	198	258	176	107	38		**9,143**
San Joaquin River	9	1	0.3	21							2372	6802	2232	2125		**13,562**
West Delta					3	21	11	2	27	136	446	8423	323	335	23	**9,750**
Yolo Bypass-North					505	1407	40	1080	48	32						**3,112**
Yolo Bypass-South					437	168	7	3	43							**658**

(a) Acreages rounded after water volume and load calculations were made. Land use codes are defined in Table E.5. Acreages by subarea obtained using DWR land use GIS coverages (1993-2003) and ArcGIS [GIS software], Version 9.2, Redlands, CA: Environmental Systems Research Institute, Inc., 1999-2006. As described in Section 6.2.5, urban acreages corresponding to each MS4 permittee within each subarea were determined using available MS4 service area delineations (e.g., paper and electronic maps provided by the MS4 Permittees and 1990 city and county boundaries). Because of their size, these more detailed delineations are not included in this appendix but are available upon request.

Table E.5: Land Uses and Runoff Coefficients

Code Definition [(a)]	Runoff Coefficient
Agriculture - Other, mixed, or uncategorized	0.175
Barren	0.300
Commercial [UC]	0.71
Crop & Pasture - uncategorized	0.175
Entry Denied	0.175
Industrial [UI]	0.70
Landscaped (irrigated lawns, cemeteries, parks)	0.22
Native Vegetation - uncategorized	0.150
Open Recreation	0.175
Orchard	0.200
Orchard & Vineyard - uncategorized	0.200
Pasture	0.175
Rangeland	0.150
Residential [UR]	0.50
Rice Fields	0.175
Row and Field Crops	0.175
Strip Mine or Quarry	0.3
Transitional [UT]	0.70
Transportation, Communication, Utilities [T]	0.700
Urban unclassified (includes mixed use) [U]	0.56
Vineyard	0.200
Water	1.000
Wetland and Marsh	0.150

(a) Staff adapted runoff coefficients provided by: Lindeburg, M.R. 1992. Civil Engineering Reference Manual. Sixth Edition. Professional Publications, Inc.: Belmont, CA. Appendix A: Rational Method Runoff Coefficients. Urban land use codes used in Table E.4 are noted in brackets.

F. SUMMARY OF METHYLMERCURY CONCENTRATION DATA FOR MAJOR DELTA TRIBUTARY INPUT AND EXPORT LOADS

The monthly average methylmercury concentrations and water volumes used to estimate the WY2000-2003 annual average methylmercury loads for tributary inputs and exports are presented in Tables F.1 and F.2, respectively. Methylmercury concentration data for these and other major Sacramento Basin tributaries are included in Appendix L. Figures F.1a, F.1b, and F.2 present the plots of methylmercury concentration versus daily flow for each tributary input and export monitoring station with daily flow data available.

Table F.1: Monthly Average Methylmercury Concentrations (ng/l) for March 2000 to April 2004 Period Used to Estimate Annual Average Loads. (a)

Month	Cache Creek Settling Basin Outflow (b)	Delta Mendota Canal	Feather River near Nicolaus	Fremont Weir (Sacramento River @ Colusa) (c)	Knights Landing Ridge Cut (Colusa Basin Drain @ Road 99E)	Mokelumne River @ I-5	Outflow to San Francisco Bay (X2)	Putah Creek @ Mace Blvd	Sacramento River @ Freeport	San Joaquin River @ Vernalis	State Water Project
January		0.144	0.079	0.067	0.434	0.246	0.095	0.078	0.145	0.239	0.113
February	0.328	**0.133***	0.104	0.100	0.181	0.320	0.165	0.29	0.146	0.175	0.077
March	0.324	0.123	0.118	0.186	0.251	0.178	0.204	0.168	0.093	0.169	0.097
April	0.155	0.018	0.109	0.069*	0.096	0.247	0.061	0.12	0.066	0.120	0.053
May	0.532	0.094	0.172	0.103	0.086	0.174	0.119	0.456	0.111	0.128	0.097
June	0.421	0.071	0.106	0.155*	0.090	0.161	0.077	0.193	0.084	0.195	0.020
July	0.960	0.056	0.035	0.048*	0.088	0.066	0.050	0.189	0.105	0.165	0.020
August		0.021	***0.052****	0.071*	***0.086****	0.110	0.033	0.181	0.093	0.167	0.009
September	0.991	0.035	0.069	0.094*	0.084	0.099	0.043	0.139	0.071	0.145	0.049
October		0.011	0.088	0.124*	0.183	0.130	0.011	0.114	0.077	0.158	0.011
November		***0.037****	0.113	0.097*	0.421	***0.113****	***0.035****	***0.083****	0.123	***0.130****	***0.031****
December		0.063	***0.096****	0.054	***0.428****	0.096	0.060	0.053	0.122	0.102	0.050
Average of All Data	0.504	0.062	0.103	0.105	0.214	0.153	0.075	0.197	0.105	0.156	0.051
Median of All Data	0.432	0.061	0.096	0.089	0.125	0.167	0.070	0.126	0.097	0.147	0.049
Annual Average (d)	**0.504**	**0.064**	**0.099**	**0.102**	**0.191**	**0.166**	**0.083**	**0.180**	**0.103**	**0.160**	**0.054**

(a) No methylmercury concentration data were available for the month of February at the Delta Mendota Canal monitoring station, the months of August and December at the Feather River and Colusa Basin Drain monitoring stations, or for the month of November at the Delta Mendota Canal, Mokelumne River, Putah Creek, San Joaquin River, State Water Project, and X2 monitoring stations. Monthly average methylmercury concentrations were estimated for the months with no data by averaging the concentrations for months before and after the month with no data; these estimated values are shown in ***bold, italicized text*** with an asterisk.

(b) Sampling at the Cache Creek Settling Basin Outflow did not take place monthly; therefore all available methylmercury concentration data were averaged to estimate the annual average methylmercury concentration.

(c) Fremont Weir did not spill during months that are highlighted in gray and noted with an asterisk. The annual average methylmercury concentration for Fremont Weir was estimated by averaging the monthly averages of the months when a spill occurred.

(d) The annual average concentration was estimated by averaging the monthly averages (not including months during which no samples were collected), except for the Cache Creek Settling Basin and Fremont Weir. The methods used for these two locations are described in footnotes (b) and (c), respectively.

Table F.2: Monthly Average Water Volumes (acre-ft/month) for WY2000-2003 Used to Estimate Annual Average Loads.

Month	Cache Creek Settling Basin Outflow	Delta Mendota Canal	Fremont Weir	Knights Landing Ridge Cut Inflow to Yolo Bypass	Mokelumne River @ I-5	Outflow to San Francisco Bay (X2)	Putah Creek @ Mace Blvd	Sacramento River @ Freeport	San Joaquin River @ Vernalis	State Water Project
January	61,650	220,976	110,745	86,228	42,065	1,954,767	489	2,028,832	140,952	348,372
February	28,463	217,720	467,038	40,250	83,824	2,207,169	5,041	1,943,680	204,443	330,373
March	46,893	212,535	479,532	33,301	81,111	2,217,055	15,743	1,963,652	305,780	331,844
April	23,334	125,614	0	6,518	53,898	1,092,635	4,594	1,117,939	198,024	141,047
May	14,559	68,390	56	11,575	51,465	1,340,314	7,837	1,278,515	211,065	61,101
June	1,621	193,597	0	2,344	30,773	526,409	774	963,395	115,685	191,995
July	989	261,949	0	5,041	17,305	447,565	799	1,187,600	90,040	346,303
August	957	264,294	0	3,901	9,269	305,230	268	1,039,802	90,825	372,866
September	704	251,515	0	179	5,873	242,934	11	841,082	92,246	314,355
October	2,224	249,026	0	5,804	10,175	283,774	0	651,856	139,616	196,722
November	1,782	233,733	0	10,852	18,901	403,620	460	747,823	126,600	251,665
December	38,739	207,372	3,081	46,981	25,680	1,079,304	5,360	1,335,662	122,874	290,356
Average Annual Water Volume (M Acre-ft/yr)	**0.22**	**2.5**	**1.1**	**0.25**	**0.43**	**12.1**	**0.041**	**15.1**	**1.8**	**3.2**

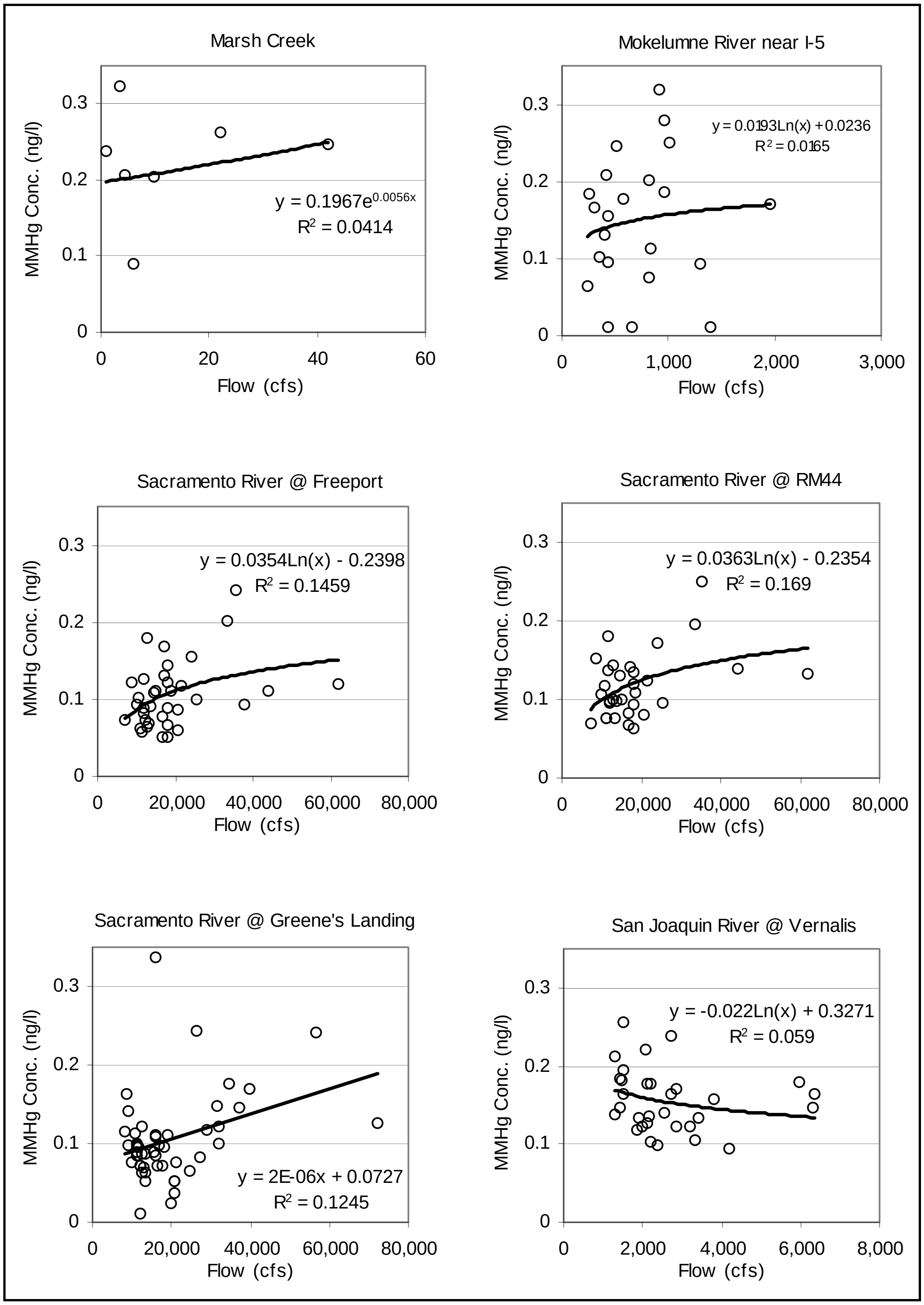


Figure F.1a: Methylmercury Concentration versus Daily Flow for Tributary Inputs with Daily Flow Data Available.

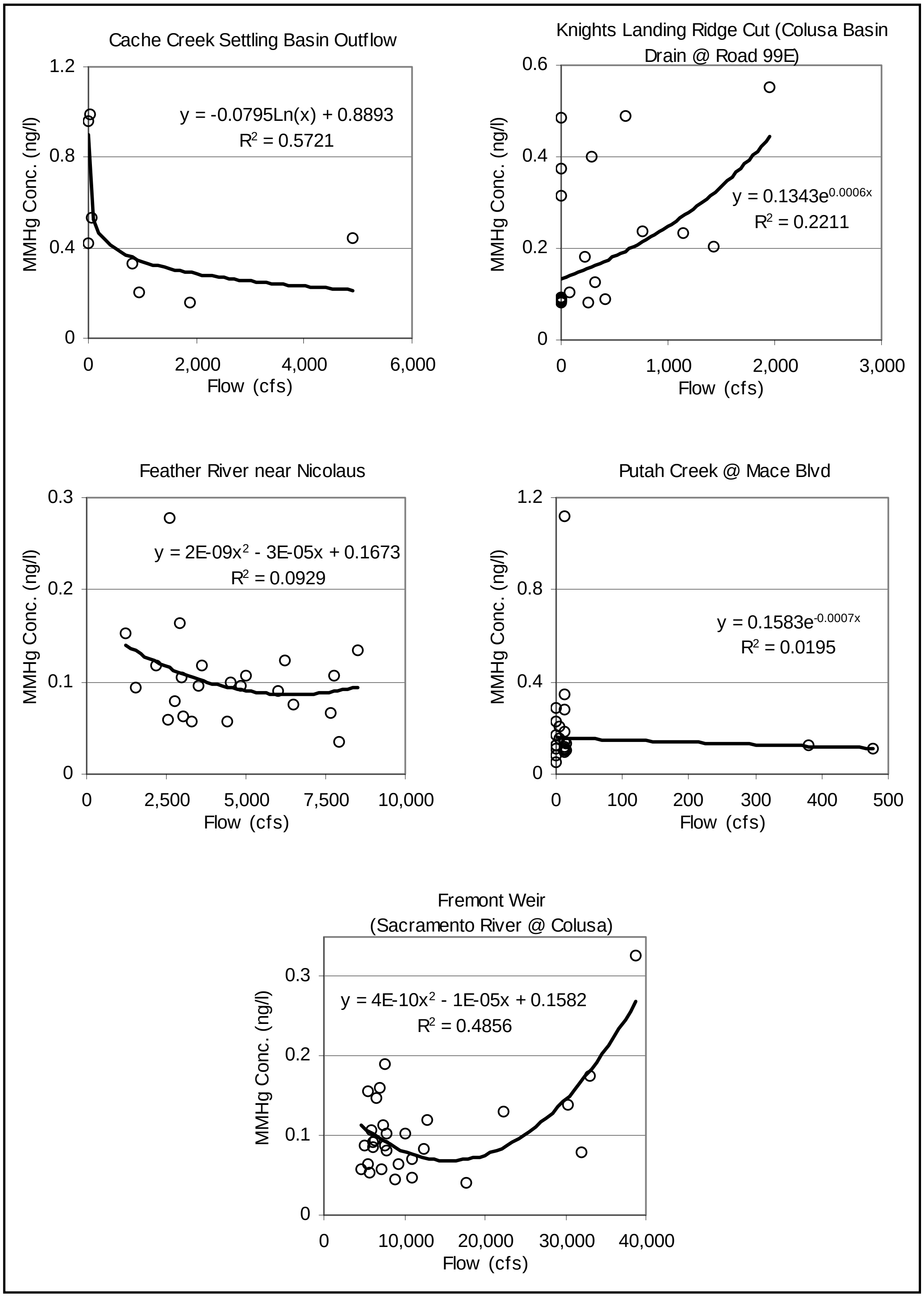
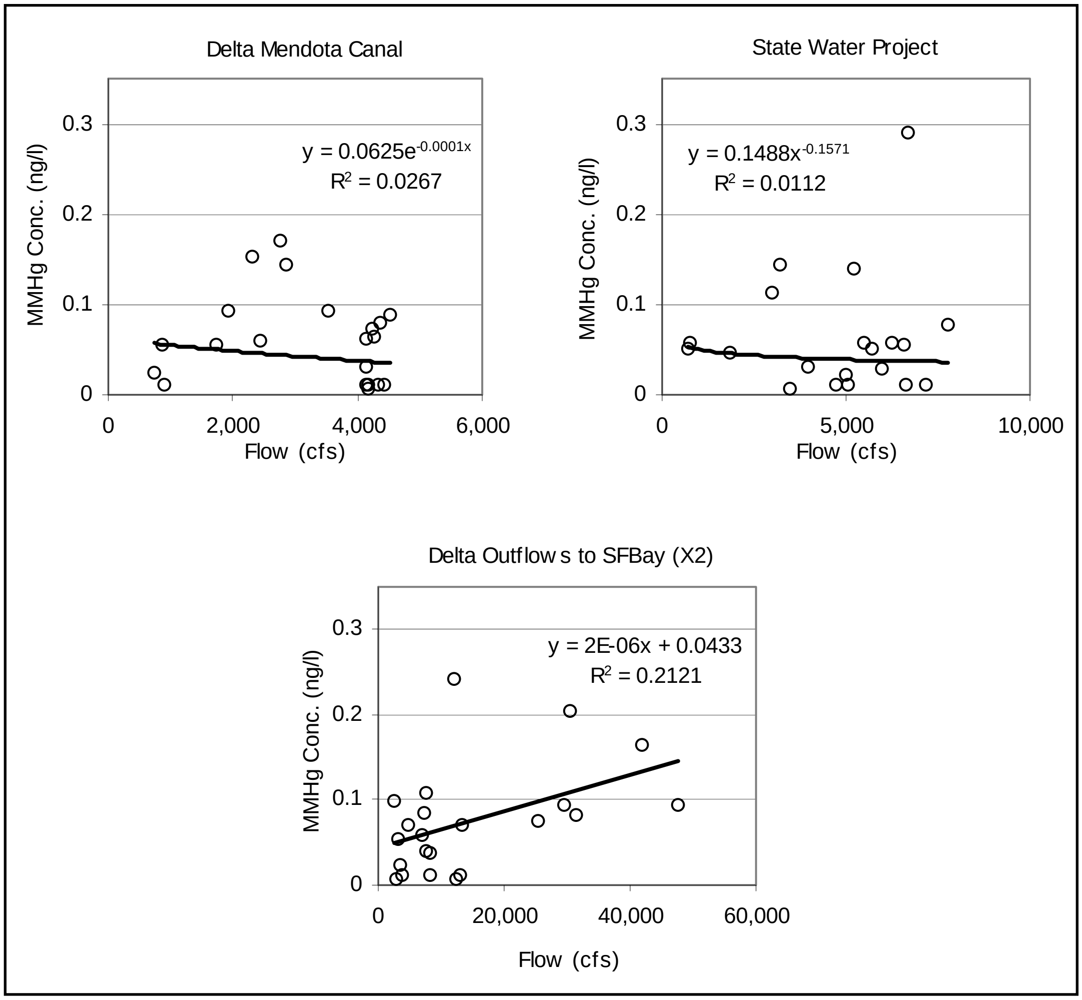


Figure F.1b: Methylmercury Concentration versus Daily Flow for Tributary Inputs with Daily Flow Data Available.



Figures F.2: Methylmercury Concentration versus Daily Flow for Exports with Daily Flow Data Available.

G. INFORMATION ABOUT NPDES-PERMITTED FACILITIES IN THE DELTA AND ITS TRIBUTARY WATERSHEDS

Table G.1: Summary of Unfiltered Total Mercury Concentrations in Discharges from Facilities within the Delta and Yolo Bypass (a)

Facility Name (NPDES #) (a)	**Facility Type**	**Delta Subarea**	**Average Daily Discharge** (mgd)	**TotHg Sampling Period**	**Ave. Conc.** (ng/l)	**Conc. Range** (ng/l)	**# of Samples**	**Standard Deviation**	**t Value** (p = 0.975, conf 95%, df = n-1)	**95% Conf. Interval (ng/l)**	**Annual TotHg Load** ± 95% Conf. Interval (g/yr)
Brentwood WWTP (CA0082660)	Mun. WWTP	Marsh Ck	3.1	8/04-10/05	1.3	0.6- 2.2	15	0.54	2.145	0.30	5.5 ±1.3
Davis WWTP (CA0079049) Discharge 001 (e)	Mun. WWTP	Yolo Bypass	2.8	8/04-1/05, 7/05	7.4	2.0-10.8	7	2.84	2.447	2.63	16.8 ±6.0
Davis WWTP (CA0079049) Discharge 002 (e)	Mun. WWTP	Yolo Bypass	2.4	2/05-6/05	6.9	4.8-10.5	5	2.43	2.776	3.02	9.4 ±4.1
Deuel Voc.Inst. WWTP (CA0078093)	Mun. WWTP	San Joaquin	0.47	3/02-12/02	3.3	2.5-4.6	4	0.90	3.182	1.44	2.1 ±0.9
Discovery Bay WWTP (CA0078590)	Mun. WWTP	Central	1.5	8/04-10/05	5.0	1.8- 11.0	10	2.76	2.262	1.97	10.4 ±4.1
GWF Power Systems (CA0082309)	Power	West	0.05	4/01-10/05	4.3	0.6- 25.7	42	3.74	2.021	1.17	0.27 ±0.07
Lincoln Center Groundwater Treatment Facility	Groundwater Treatment	Central	0.25	11/05-06/07	0.57	<0.2-1.6	20	0.38	2.093	0.18	0.20 ±0.06
Lodi White Slough WWTP (CA0079243)	Mun. WWTP	Central	4.5	8/04-10/05	3.3	1.6-7.2	15	1.38	2.145	0.77	20.8 ±4.8
Manteca WWTP (CA0081558)	Mun. WWTP	San Joaquin	4.63	9/04-10/05	10.7	2.0-20.3	14	5.91	2.16	3.41	68.1 ±21.7
Mirant Delta LLC Contra Costa Power Plant, Outfall 1 & 2 (CA0004863)	Power	West	2.90	2/04-5/05	6.1	1.6-10.1	4	4.14	3.182	6.58	(b)
			121.03	2/04-5/05	7.1	4.1-11.8	4	3.64	3.182	5.79	(b)
Oakwood Lake Subdivision Mining Reclamation (CA0082783) (c)	Lake Dewatering	San Joaquin	9.15	1/02-11/02	2.9	2.1-3.9	4	0.97	3.182	1.54	36.8 ±19.5
Rio Vista Trilogy WWTP (CA0083771) (d)	Mun. WWTP	Sacramento	0.10	1/03	3.7	3.7	1	--	--	--	0.52
Rio Vista WWTP (CA0079588)	Mun. WWTP	Sacramento	0.47	12/01-12/03	9.5	1.7-19	20	4.69	2.086	2.19	6.2 ±1.4
San Joaquin Co DPW CSA 31 Flag City WWTP (CA0082848)	Mun. WWTP	Central	0.06	1/05-10/05	3.2	0.6-17	8	5.57	2.365	4.66	0.27 ±0.39
SRCSD Sacramento River WWTP (CA0077682)	Mun. WWTP	Sacramento	162	10/99-9/03	7.59	2.9-16.2	195	2.23	1.972	0.31	1,699 ±70
SRCSD Walnut Grove WWTP (CA0078794)	Mun. WWTP	Sacramento	0.08	12/00-1/04	21.5	11-29.4	9	5.24	2.306	4.03	2.4 ±0.45
State of California Central Heating/Cooling Plant (CA0078581)	Heating /Cooling	Sacramento	5.26	3/02-12/02	2.8	1.1-3.7	4	1.19	3.182	1.9	(b)
Stockton WWTP (CA0079138)	Mun. WWTP	San Joaquin	28	8/04-7/05	5.2	3.0-11	12	3.00	2.201	1.91	201 ±74
Tracy WWTP (CA0079154)	Mun. WWTP	San Joaquin	9.49	8/04-8/05	11.0	2.1-18.6	13	4.43	2.179	2.68	145 ±35
West Sacramento WWTP (CA0079171)	Mun. WWTP	Sacramento	5.60	8/04-7/05	3.3	1.6-5	11	1.08	2.228	0.72	25.7 ±5.6
Woodland WWTP (CA0077950)	Mun. WWTP	Yolo Bypass	6.05	8/04-7/05	6.1	0.91-53	12	1.08	2.201	0.68	50.7 ±5.7

Table G.1 Footnotes:

(a) The sum of annual facility effluent total mercury discharge loads is 2,284 g/yr. No mercury data are yet available for Metropolitan Stevedore (CA0084174), a marine bulk commodity terminal in the Central Delta subarea. Mercury and flow data for the Sacramento Combined WWTP (CA0079111) in the Sacramento River subarea are summarized in Table G.2. If the estimated loading from the Combined WWTP is included (151 g/yr, see Table G.2b), the **total mercury loading to the Delta from NPDES facilities is approximately 2,435 g/yr or 2.4 kg/yr**.

(b) Based on the comparison of the available intake and outfall mercury data for the Mirant Delta facility and other similar facilities that discharged to the Delta in years past (Table G.5 in Appendix G), such facilities may not act as measurable sources of mercury to the Delta. According to its NPDES permit, the Central Heating/Cooling Plant adds no chemicals to its supply water; however, the permits for Mirant Delta and other similar facilities in the tributary watersheds indicate that mercury-containing chemicals may be added to their cooling water and other low-volume waste streams may be included in their discharges (see Tables G.6 and G.7). Staff recommends that the assumption that power and heating/cooling plants do not contribute mercury to Delta and upstream surface waters be re-evaluated as additional information becomes available.

(c) The Oakwood Lake Subdivision Mining Reclamation was formerly known as the Manteca Aggregate Sand Plant.

(d) The City of Rio Vista's Trilogy WWTP was replaced by the Northwest WWTP, which began discharging to the Sacramento River subarea in 2007 under the same NPDES permit (CA0083771). The Northwest WWTP has a startup dry weather discharge of 1 mgd and peak discharge of 3 mgd. No effluent methylmercury concentration data were available for either the Trilogy or Northwest WWTPs, and no effluent total mercury concentration data were available for the Northwest WWTP, at the time the Delta methylmercury TMDL was developed. The above total mercury load is based on effluent total mercury concentration data available for the Trilogy WWTP and may not be characteristic of Northwest WWTP discharges. The Northwest WWTP effluent total mercury loads will be determined once it completes one year of monthly monitoring of its discharge.

(e) The City of Davis WWTP (CA0079049) has two seasonal discharge locations; wastewater is discharged from Discharge 001 to the Willow Slough Bypass upstream of the Yolo Bypass and from Discharge 002 to the Conaway Ranch Toe Drain in the Yolo Bypass. The Discharge 001 total mercury load is based on effluent volumes for October 2004 through January 2005 plus July 2005 through September 2005. The Discharge 002 total mercury load is based on effluent volumes for February 2005 through June 2005. Because the discharge to Willow Slough is outside of the Delta/Yolo Bypass, it is not included in the sum of facility loads.

Table G.2a: Summary of City of Sacramento Combined Sewer System Total Mercury Concentration Data (a, b)

DATE	**CWTP** (ng/l)	**SUMP-2** (ng/l)	**PIONEER** (ng/l)
12/03/1994	58	82	32
01/08/1995	47	120	
01/10/1995			220
03/02/1995	90		98
03/09/1995			85
03/21/1995	68		83
Average	**66**	**101**	**104**
# of Samples	4	2	5
Standard Deviation	18.30	26.87	69.78
t value (p=0.975, conf 95%, df =n-1)	3.182	12.706	2.776
Confidence Interval	29	241	87

(a) The City of Sacramento owns and operates a combined sewer system (CSS) that serves 7,510 acres in the downtown, East Sacramento, and Land Park areas. An additional 3,690 acres with separate sewers contributes sanitary sewage to the combined system. The CSS conveys domestic and industrial wastewater and storm runoff to Sump 2, where up to 60 mgd is pumped to the Sacramento Regional County Sanitation District's regional wastewater treatment plant (SRCSD) for secondary treatment prior to discharge to the Sacramento River. This discharge is designated as point 001 and is governed by NPDES No. CA0077682. When flow to Sump 2 exceeds 60 mgd, the City operates its Combined Wastewater Treatment Plant (CWTP), where an additional 130 mgd of combined wastewater receives primary treatment with disinfection and discharge to the Sacramento River at points 002 and 003. The CWTP basins may also be used for storage of flows and diversion of flows back to the SRCSD. Flows to Sump 2 greater than 190 mgd are diverted to the 28 million gallon Pioneer Interceptor and Reservoir for storage. During major storms, Sump 1/1A also pumps up to 120 mgd to Pioneer Reservoir. The stored combined wastewater is diverted back to the SRCSD or the CWTP for treatment as treatment capacity allows, or is discharged to the Sacramento River if storm flows exceed total treatment and storage capacity. The discharge from Pioneer Reservoir occurs at point 006 and receives partial settleable solids and floatables removal, in a flow-through process, without disinfection. During extreme high flow conditions, discharges of untreated combined wastewater may occur at Sump 2 bypass points 004 and 005 and at Sump 1 bypass point 007. Collected screenings are hauled to a landfill, and sludges and other solids removed from liquid wastes are pumped through the collection system to the SRCSD.

(b) Total mercury concentration data were obtained from a City of Sacramento monitoring report to the Regional Board (City of Sacramento, 1996). Only data collected using clean hands techniques (MDL of 0.1 ng/l) were used for TMDL calculations.

Table G.2b: City of Sacramento Combined Stormwater/Sewer System Annual Water Volumes & Total Mercury Load Estimates

Water Year	**Water Volume**(a) (MG/year)				**Total Mercury Load** (b) (kg/year)			
	CWTP	PIONEER	SUMP 2	**TOTAL**	CWTP	PIONEER	SUMP 2	**TOTAL**
1993	459.6	42.5	243.9	**746.0**	0.114 ±0.051	0.017 ±0.038	0.093 ±0.082	**0.224** ±0.171
1994	190.5		18.6	**209.0**	0.047 ±0.021		0.007 ±0.006	**0.054** ±0.027
1995	399.7	189.7	435.9	**1025.3**	0.099 ±0.044	0.074 ±0.171	0.167 ±0.147	**0.341** ±0.363
1996	433.7	259.8	89.3	**782.8**	0.108 ±0.048	0.102 ±0.235	0.034 ±0.030	**0.244** ±0.313
1997	354.3	139.0	210.9	**704.2**	0.088 ±0.039	0.055 ±0.126	0.081 ±0.071	**0.223** ±0.236
1998	440.2	515.1		**955.3**	0.110 ±0.049	0.202 ±0.46		**0.312** ±0.514
1999	8.3	65.4		**73.7**	0.002 ±0.001	0.026 ±0.059		**0.028** ±0.060
2000	90.8	291.3	82.9	**465.0**	0.023 ±0.01	0.114 ±0.263	0.032 ±0.028	**0.169** ±0.301
2001		32.6		**32.6**		0.013 ±0.029		**0.013** ±0.029
2002		53.7		**53.7**		0.021 ±0.049		**0.021** ±0.049
2003		90.6		**90.6**		0.036 ±0.082		**0.036** ±0.082
Average Annual Water Volume (MG/year):				**467**	**Average Annual TotHg Load** (kg/year):			**0.151** ±0.195

(a) Annual water volumes discharged to the Sacramento River obtained from City of Sacramento annual monitoring reports.

(b) Total mercury load estimates are based on average total mercury concentrations and confidence intervals shown in Table G.2a.

Table G.3a: Summary of Effluent 1 and Effluent 2 Methylmercury Concentrations

FACILITY	Foot-notes	EFF1 # of Samples	EFF1 # of non-detects	Ave EFF1 MeHg Conc (ng/l) (p)	Min EFF1 MeHg Conc (ng/l)	Max EFF1 MeHg Conc (ng/l)	EFF2 # of Samples	EFF2 # of non-detects	Ave EFF2 MeHg Conc (ng/l)	Min EFF2 MeHg Conc (ng/l)	Max EFF2 MeHg Conc (ng/l)
Aggregate											
Crystal Creek Aggregate	a	1	1	0.010	0.01	0.01					
J.F. Shea CO Fawndale Rock and Asphalt	a	1	1	0.010	0.01	0.01	1	1	0.010	0.01	0.01
Lehigh Southwest Cement Co.	a, b	1	1	0.010	0.01	0.01	1	1	0.010	0.01	0.01
Oakwood Lake Subdivision Mining Reclamation	a	2	1	0.027	0.01	0.043					
Aquaculture											
Calaveras Trout Farm (Rearing Facility)		2		0.060	0.027	0.092					
DFG Darrah Springs Fish Hatchery	a, c	4	1	0.024	0.01	0.031	4	1	0.028	0.01	0.043
DFG Merced River Fish Hatchery		1		0.037	0.037	0.037					
DFG Moccasin Creek Fish Hatchery	a	1	1	0.010	0.01	0.01					
DFG Mokelumne River Fish Hatchery	a	4	1	0.041	0.01	0.059					
DFG Nimbus Fish Hatchery		4		0.081	0.053	0.129					
DFG San Joaquin Fish Hatchery		2		0.060	0.047	0.073					
Pacific Coast Sprout Farms (Sacramento Facility)	a	1	1	0.010	0.01	0.01					
UC Davis Center for Aquatic Biology & Aquaculture	a, d	4	2	0.030	0.01	0.067	4	1	0.082	0.01	0.243
USDI BR Winter Run Rearing Facility	a	4	4	0.010	0.01	0.01					
USDI FWS Coleman Fish Hatchery		3		0.030	0.023	0.043					
Food											
Bell Carter Olive Company Inc.	a	4	2	0.017	0.01	0.027					
CA Dairies, Inc. Los Banos Foods	a	4	3	0.016	0.013	0.026					
Hershey Chocolate USA, Oakdale	a	4	4	0.010	0.01	0.01					
Heating/Cooling											
CA State of, Central Heating/Cooling Facility	a	4	3	0.015	0.01	0.029					
CALAMCO - Stockton Terminal		4		0.293	0.03	0.919					
Gaylord Container Corp. Antioch Pulp and Paper Mill		3		0.055	0.048	0.061					
Sacramento International Airport		2		0.035	0.023	0.046					
UA Local 38 Trust Fund Konocti Harbor Resort		1		0.079	0.079	0.079					
Manufacturing											
Formica Corporation Sierra Plant		1		0.050	0.05	0.05					
Proctor & Gamble Co. WWTP	a, e	3	3	0.010	0.01	0.01	1		0.033	0.033	0.033
Mines											
Sliger Mine	a	4		0.064	0.025	0.0909					

Table G.3a: Summary of Effluent 1 and Effluent 2 Methylmercury Concentrations

FACILITY	Foot-notes	EFF1 # of Samples	EFF1 # of non-detects	Ave EFF1 MeHg Conc (ng/l) (p)	Min EFF1 MeHg Conc (ng/l)	Max EFF1 MeHg Conc (ng/l)	EFF2 # of Samples	EFF2 # of non-detects	Ave EFF2 MeHg Conc (ng/l)	Min EFF2 MeHg Conc (ng/l)	Max EFF2 MeHg Conc (ng/l)
Misc											
DGS Office of State Publishing	a, k	4 [3]	4 [3]	0.010	0.01	0.01					
South Feather Water & Power	a, k	2 [1]	2 [1]	0.013	0.013	0.013					
UC Davis Hydraulics Laboratory		3		0.057	0.038	0.082					
Paper Mill											
Pactiv Molded Pulp Mill	a	12	5	0.039	0.01	0.085					
SPI Anderson Division		4		0.106	0.036	0.14	2		0.154	0.13	0.177
SPI Shasta Lake (Effluent 1 & 2)		1		0.023	0.023	0.023	1		1.190	1.19	1.19
Stimpel Wiebelhaus Assoc. SWA at Mountain Gate		1		0.081	0.081	0.081					
POTW											
Aerojet Sacramento Facility	f, k	1 (0)		(k)	(k)	(k)					
Anderson WWTP	a	12	2	0.090	0.01	0.271					
Atwater WWTP	a	12	3	0.034	0.01	0.084					
Auburn WWTP	a	12	6	0.028	0.01	0.072					
Bella Vista Water District		1		0.027	0.027	0.027					
Biggs WWTP		2		1.605	0.15	3.06					
Brentwood WWTP	a	13	13	0.010	0.01	0.01					
Canada Cove LP French Camp Golf & RV Park		4		0.147	0.029	0.291					
Chico Regional WWTP		12		0.157	0.057	0.527					
Clear Creek CSD WWTP		2		0.036	0.028	0.043	1		0.041	0.041	0.041
Colfax WWTP		3		0.197	0.115	0.35					
Colusa WWTP		4		2.863	1.97	4.02					
Corning Industries/ Domestic WWTP	k	3 [2]		0.044	0.034	0.053					
Cottonwood WWTP		5		0.096	0.045	0.245					
Davis WWTP	o	7		0.546	0.305	1.04	5		0.613	0.247	1.44
Deer Creek WWTP	a	13	11	0.015	0.013	0.032					
Deuel Vocational Institute WWTP	a, k	4 [3]	4 [3]	0.010	0.01	0.01					
Discovery Bay WWTP	a	12	7	0.191	0.013	2.03					
El Dorado Hills WWTP	l	5	5	0.013	0.013	0.013	2	2	0.013	0.013	0.0125
Galt WWTP		6		0.139	0.027	0.22					
Grass Valley WWTP	a	16	2	0.160	0.01	0.938					
Jackson WWTP		4		0.108	0.061	0.161					
Lincoln WWTP	a, k	8 [7]	6	0.018	0.01	0.068					
Live Oak WWTP		4		0.591	0.427	0.785					

Table G.3a: Summary of Effluent 1 and Effluent 2 Methylmercury Concentrations

FACILITY	Foot-notes	EFF1 # of Samples	EFF1 # of non-detects	Ave EFF1 MeHg Conc (ng/l) (p)	Min EFF1 MeHg Conc (ng/l)	Max EFF1 MeHg Conc (ng/l)	EFF2 # of Samples	EFF2 # of non-detects	Ave EFF2 MeHg Conc (ng/l)	Min EFF2 MeHg Conc (ng/l)	Max EFF2 MeHg Conc (ng/l)
Lodi White Slough WWTP	a, n	12 [10]	4 [3]	0.147	0.01	1.24					
Manteca WWTP		11		0.216	0.037	0.356					
Mariposa PUD WWTP		4		0.393	0.04	0.912					
Maxwell PUD WWTP		4		0.993	0.044	1.72					
Merced WWTP		12		0.386	0.13	0.672					
Modesto ID Regional WWTP	k	3 [2]		0.056	0.045	0.066					
Modesto WWTP		4		0.125	0.109	0.161	1		0.140	0.14	0.14
Nevada City WWTP	a	4	2	0.048	0.01	0.146					
Nevada Co SD #1 Cascade Shores WWTP	a	3	1	0.142	0.01	0.286					
Nevada Co SD #1 Lake Wildwood WWTP	a	12	1	0.109	0.01	0.32					
Nevada Co SD #2 Lake of the Pines WWTP		2		1.409	0.708	2.11					
Olivehurst PUD WWTP	a	13	1	0.144	0.013	0.268					
Oroville WWTP		12		0.147	0.061	0.28					
Paradise Irrigation District	a	1	1	0.013	0.013	0.013					
Placer Co. SA #28 Zone #6 WWTP		2		0.668	0.474	0.862					
Placer Co. SMD #1 WWTP		12		0.141	0.042	0.35					
Placer Co. SMD #3 WWTP		12		0.100	0.037	0.381					
Placerville Hangtown Creek WWTP	a	12	1	0.058	0.013	0.17					
Planada Comm. Service Dist. WWTP		4		1.168	0.374	2.04					
Red Bluff WWTP	a	12	6	0.030	0.01	0.057					
Redding Clear Creek WWTP	a	12	3	0.042	0.013	0.084					
Redding Stillwater WWTP	a	13	13	0.013	0.013	0.013					
Rio Alto WD- Lake CA WWTP		3		1.219	0.141	3.35					
Rio Vista Main WWTP		4		0.164	0.035	0.522					
Roseville Dry Creek WWTP	a	12	4	0.023	0.01	0.055					
Roseville Pleasant Grove WWTP	a	12	10	0.017	0.01	0.07					
San Andreas SD WWTP		4		0.249	0.178	0.293					
San Joaquin Co DPW - Flag City WWTP	a	3	1	0.081	0.013	0.152					
Shasta Lake WTP	a	2	1	0.025	0.01	0.04					
Shasta Lake WWTP	a	2	1	0.022	0.01	0.034					
SRCSD Sacramento River WWTP		60		0.718	0.144	1.640					
SRCSD Walnut Grove WWTP (CSD1)	k	3 [2]		2.155	0.949	3.36					
Stockton WWTP	a	12	1	0.935	0.01	2.09					
Tracy WWTP	a	13	1	0.145	0.013	0.422					

Table G.3a: Summary of Effluent 1 and Effluent 2 Methylmercury Concentrations

FACILITY	Foot-notes	EFF1 # of Samples	EFF1 # of non-detects	Ave EFF1 MeHg Conc (ng/l) (p)	Min EFF1 MeHg Conc (ng/l)	Max EFF1 MeHg Conc (ng/l)	EFF2 # of Samples	EFF2 # of non-detects	Ave EFF2 MeHg Conc (ng/l)	Min EFF2 MeHg Conc (ng/l)	Max EFF2 MeHg Conc (ng/l)
Tuolumne UD Sonora RWTP/ Jamestown SDWTP		3		0.182	0.071	0.262					
Turlock WWTP	a, g	12	1	0.060	0.02	0.079					
UC Davis WWTP	a	13	4	0.038	0.010	0.078					
United Auburn Indian Community Casino WWTP	a	2	2	0.010	0.010	0.010					
Vacaville Easterly WWTP	a	12	4	0.024	0.010	0.057					
West Sacramento WWTP	a	12	1	0.050	0.010	0.085					
Williams WWTP		4		1.553	0.560	2.100					
Woodland WWTP	a	12	2	0.031	0.013	0.059					
Yuba City WWTP		12		0.295	0.106	0.625					
Power											
Calpine Corp. Greenleaf Unit One Cogen Plant		4		0.064	0.02	0.117					
Camanche Dam Powerhouse	a	4	3	0.020	0.01	0.039					
GWF Power Systems	a	4	4	0.013	0.013	0.013					
Mirant Delta CCPP	h	12		0.075	0.020	0.121	10		0.086	0.042	0.15
Sacramento Cogen Authority Procter & Gamble Plant	a	4	1	0.052	0.013	0.070					
SMUD Rancho Seco Nuclear Generating Station	a	12	4	0.040	0.013	0.104					
Stockton Congeneration Co.	a	4	3	0.017	0.013	0.029					
Wheelabrator Shasta Energy Co.		4		0.104	0.055	0.178					
WTP (GW)											
Aerojet Interim GW WTP	a, k	2 [1]	2 [1]	0.013	0.013	0.013	2 [1]	2 [1]	0.013	0.013	0.013
Boeing Company, Interim Treatment System	a	1	1	0.010	0.01	0.01					
Defense Logistics Agency Sharpe GW Cleanup	a, i	3	2	0.018	0.01	0.033	1	1	0.010	0.01	0.01
General Electric Co. GWCS	a, j, m	3	3	0.010	0.01	0.01	3	3	0.010	0.01	0.01

Table G.3a Footnotes:

a. Sample MeHg concentration <MDL; half the detection limit was used for calculations.
b. Lehigh Southwest Cement Co. Effluent 1: Outfall #1, Shale Quarry Tunnel Road. Effluent 2: Lehigh Southwest Cement Co., 002B: Shale Quarry
c. Darrah Springs Fish Hatchery Effluent 1: Upper Springs. Effluent 2: Darrah Springs Fish Hatchery - Lower Springs
d. UCD Center for Aquatic Biology & Aquaculture, Effluent 1: CABA Aquatic Center. Effluent 2: CABA Putah Creek Facility
e. Proctor & Gamble, Pond Effluent 2: Effluent PTI-660
f. Aerojet Sacramento facility, Effluent 1 sample collected from West Detention Pond because there was no discharge to the American River during the rainy season.
g. City of Turlock WWTP, Effluent 1: (R5)
h. Mirant Delta CCPP EFF 1:Outfall 001, Effluent 2: Outfall 002
i. Defense logistics agency, Sharp GW Cleanup; Effluent 1: CBCGWTPEFF = Central area B/C Aquifer zone, Effluent 2: NBGWTPEFF = North GWTP effluent
j. General Electric Co., GWCS: Effluent 1: Air Stripper Effluent, Effluent 2: 100-foot Zone Effluent
k. Results for the following facilities and sample dates were not incorporated in the calculations due to sample preservation hold times exceeding EPA recommendations: Aerojet Interim GW WTP (18 November 2005, EFF 1 and EFF 2 were both <MDL); Aerojet Sacramento Facility (18 March 2005, 0.057 ng/l); Corning Industries/ Domestic WWTP (22 September 2004, 0.041 ng/l); Deuel Vocational Institute WWTP (26 October 2004, <MDL); DGS Office of State Publishing (8 July 2005, <MDL); Lincoln WWTP (25 August 2005, 0.034 ng/l); Miners Ranch WTP (9 September 2004, <MLD);Modesto ID Regional WWTP (8 October 2004, 0.038 ng/l); and SRCSD Walnut Grove WWTP (CSD1) (29 December 2004, 0.759 ng/l).
l. El Dorado Hills WWTP sampled effluent when discharging to land and to surface water. Only samples collected when the plant discharged to surface water (December 2004 through April 2005) were used in the summary. Effluent that was reclaimed during the seven warm season months ranged from nondetect to 0.055 ng/l, with one sample (9 August 2005, 0.057 ng/l) excluded due to sample preservation hold time exceeding EPA recommendations.
m. General Electric Co. GWCS conducted four sampling events. However, results for General Electric Co. GWCS samples collected on 8 October 2004 were not incorporated in the calculations due to sample contamination with mercury in the laboratory.
n. Lodi White Slough WWTP sampled effluent when discharging to land and to surface water. Only samples collected when the plant discharged to surface water (September 2004 through June 2005) were used in the summary. Effluent that was reclaimed in August 2004 and July 2005 had methylmercury concentrations of 0.054 ng/l and <MDL, respectively.
o. Davis WWTP: Effluent 1: Willow Slough, Effluent 2: Conaway Ranch Toe Drain in the Yolo Bypass.
p. Tables 6.5 and 8.4 in the main text of the TMDL Report and Tables B and C in the draft Basin Plan amendment provide average concentration values rounded to two decimal places using un-rounded Excel calculations, while this table provides values rounded to three decimal places. For example, the Tracy WWTP had an average methylmercury concentration of 0.014465 ng/l per the Excel calculations, which rounds to 0.0145 ng/l in this table, and 0.14 ng/l (not 0.15 ng/l) in Table 6.5.

Table G.3b: Summary of Effluent 3 and Effluent 4 Methylmercury Concentrations

FACILITY	**Foot-notes**	**EFF 3 # of Samples**	**EFF 3 # of non-detects**	**Ave EFF 3 MeHg Conc** (ng/l)	**Min EFF 3 MeHg Conc** (ng/l)	**Max EFF 3 MeHg Conc** (ng/l)	**EFF 4 # of Samples**	**EFF 4 # of non-detects**	**Ave EFF 4 MeHg Conc** (ng/l)	**Min EFF 4 MeHg Conc** (ng/l)	**Max EFF 4 MeHg Conc** (ng/l)
Aggregate											
Lehigh Southwest Cement Co.	a, b	1	1	0.010	0.010	0.010	1		0.062	0.062	0.062
Paper Mill											
SPI Shasta Lake (Effluent 1 & 2)		1		0.485	0.485	0.485					
WTP (GW)											
Aerojet Interim GW WTP	a, e	2 [1]	2 [1]	0.013	0.013	0.013	2 [1]	2 [1]	0.013	0.013	0.013
Defense Logistics Agency Sharpe GW Cleanup	a, c	2	2	0.010	0.010	0.010	3	1	0.047	0.010	0.108
General Electric Co. GWCS	a, d	3	3	0.010	0.010	0.010					

a. Sample MeHg concentration <MDL; half the detection limit was used for calculations.

b. Lehigh Southwest Cement Co., EFF 3: 001A: Limestone Quarry, EFF 4: 00X: Cement Plant

c. Defense logistics agency, Sharp GW Cleanup, EFF 3: SBGWTPEFF= South GWTP effluent, EFF 4: SSJCUPST = South San Joaquin Irrigation District Canal (upstream sample).

d. General Electric Co. EFF 3: GWCS: Multizone Effluent

e. Aerojet Interim GW WTP results for samples collected on 18 November 2005 (both <MDL) were not incorporated in the calculations due to sample preservation hold time exceeding EPA recommendations.

f. General Electric Co. GWCS conducted four sampling events. However, results for General Electric Co. GWCS samples collected on 8 October 2004 were not incorporated in the calculations due to sample contamination with mercury in the laboratory.

Table G.4: Available Intake and Outfall Methylmercury Concentration Data for Aquaculture, Power and Heating/Cooling Facilities in the Delta and Its Upstream Tributary Watersheds $^{(a)}$

Facility [NPDES #, Type]	Sample Date	Outfall 1 MeHg Conc (ng/l) $^{(b)}$	Outfall 1 MeHg Qual. $^{(b)}$	Outfall 2 MeHg Conc (ng/l)	Outfall 2 MeHg Qual. $^{(b)}$	Outfall 2 Field Dup MeHg Conc (ng/l)	Outfall 2 Field Dup MeHg Qual. $^{(b)}$	Intake 1 MeHg Conc (ng/l) $^{(a)}$	Intake 1 MeHg Qual. $^{(b)}$	Intake 1 Dup. MeHg Conc (ng/l)	Intake 1 Dup. MeHg Qual. $^{(b)}$	Intake 2 MeHg Conc. (ng/l)	Intake 2 MeHg Qual. $^{(b)}$
CALAMCO - Stockton Terminal [CA0083968, Heating /Cooling]	8/26/04	0.030	B					0.026	B				
Calaveras Trout Farm (Rearing Facility) [CA0081752, Aquaculture]	9/30/04	0.027	B					0.067					
Camanche Dam Powerhouse [CA0082040, Power]	1/19/2005	ND	<MDL					0.095	(ba)				
DFG Darrah Springs Fish Hatchery [CA0004561, Aquaculture]	9/15/04	0.029	B, (nn)	0.043	B, X, (mm)			ND	<MDL, (nn)			0.020	<MDL, (nn)
DFG Mokelumne River Fish Hatchery [CA0004791, Aquaculture]	11/16/04	0.048	A					ND	<MDL, A	0.020	<MDL, A		
DFG Nimbus Fish Hatchery [CA0004774, Aquaculture]	11/16/04			0.129	A			0.051	A				
	2/17/05	0.053										0.031	
	6/20/05	0.085						0.052					
DFG San Joaquin Fish Hatchery [CA0004812, Aquaculture]	9/28/04	0.073						0.021	B				
GWF Power Systems [CA0082309, Power]	8/11/04	ND	<MDL					ND	<MDL				
	11/4/04	ND	<MDL					ND	<MDL				
	2/3/05	ND	<MDL					0.263					
	5/5/05	ND	<MDL					ND	<MDL				

Table G.4: Available Intake and Outfall Methylmercury Concentration Data for Aquaculture, Power and Heating/Cooling Facilities in the Delta and Its Upstream Tributary Watersheds, *continued*

Facility [NPDES #, Type]	Sample Date	Outfall 1 MeHg Conc (ng/l) (a)	Outfall 1 MeHg Qual. (b)	Outfall 2 MeHg Conc (ng/l)	Outfall 2 MeHg Qual. (b)	Outfall 2 Field Dup MeHg Conc (ng/l)	Outfall 2 Field Dup MeHg Qual. (b)	Intake 1 MeHg Conc (ng/l) (a)	Intake 1 MeHg Qual. (b)	Intake 1 Dup. MeHg Conc (ng/l)	Intake 1 Dup. MeHg Qual. (b)	Intake 2 MeHg Conc. (ng/l)	Intake 2 MeHg Qual. (b)
Mirant Delta CCPP [CA0004863, Power]	2/4/04	0.081		0.0835		0.0799	(k)	0.296	(l)				
	3/3/04	0.116		0.127				0.12	(l)	0.122	(l)		
	8/3/04	0.020	J	0.070				ND	<MDL				
	9/1/04	0.080		0.060				0.080	(l)				
	10/5/04	0.049	B	0.060				0.038	(l), B				
	11/2/04	0.047	B	0.042	B			0.040	(l), B				
	12/2/04	0.030	B	0.063				0.070	(l)				
	1/11/05	0.083		0.081				0.102	(l)				
	2/8/05	0.097		0.120				0.098	(l)				
	3/8/05	0.121		0.150				0.15	(l)				
	4/26/05	0.083			Y			0.069	(l)				
	5/25/05	0.091			Y			0.077	(l)				
Sacramento Cogen Authority Procter & Gamble Plant [CA0083569, Power]	8/11/04	0.056						ND	<MDL				
	10/6/04	0.069						ND	<MDL				
	1/5/05	0.070						0.080					
	5/4/05	ND	<MDL					ND	<MDL				

(a) ND: nondetect (below method detection limit). Analytical method detection limits were 0.025 ng/l or less.

(b) < MDL: below method detection limit; detection limits ranged between 0.020 and 0.025 ng/l.

A:	Samples were received out of optimal temperature range.
B:	Sample results above the MDL and below the ML; should be considered an estimate.
J:	Detected but below the reporting limit; result is an estimated concentration.
X:	Collected 9/14/04.
Y:	No discharge.
(l):	Mirant Delta CCPP Intake 002.
(mm):	Darrah Springs Fish Hatchery - Lower Springs.
(nn):	Darrah Springs Fish Hatchery - Upper Springs.
(ba):	Camache Dam Powerhouse receiving water received 200 feet upstream of discharge.

Table G.5a: Available Intake and Outfall Total Mercury Concentration Data for Power and Heating/Cooling Facilities in the Delta Region

Facility [NPDES #, Type]	Proximity to Delta	Sample Date	Outfall 1 TotHg Conc. (ng/l)	Outfall 2 TotHg Conc. (ng/l)	Intake 1 TotHg Conc. (ng/l)	Intake 2 TotHg Conc. (ng/l)
CALAMCO – Stockton Terminal (a) [CA0083968, Heating/Cooling]	Delta / Yolo Bypass	1/15/02	6.60		6.70	
Gaylord Container Corp. Antioch Pulp and Paper Mill (a) [CA0004847, Heating/Cooling]	Delta / Yolo Bypass	5/27/04	6.40		6.70	
		6/17/04	7.00		7.60	
		7/19/04	9.10		10.00	
		8/26/04	3.50		3.80	
		9/23/04	3.80		2.60	
		10/14/04	5.00		7.50	
Mirant Delta CCPP [CA0004863, Power]	Delta / Yolo Bypass	3/28/2000	6.17	9.23	5.6	9.23
		12/11/2001	4.6	3.6		4.9
		7/9/2002	6.54	6.38		6.77
		5/6/2003		6.29		5.45
		7/15/2003	7.88	8.42		4.97
		2/4/2004	3.69	4.21 (b)		4.3
		2/9/2004	3.68	2.60		5.58
		3/3/2004	9.15	8.19		8.06
		8/3/2004	10.1	11.8		8.40
		2/8/2005	1.6	4.25		3.90

(a) The CALAMCO and Gaylord facilities no longer discharge to surface water. The Gaylord facility discharged non-contact cooling water from operation of its power plant. It obtained its water from wells.

(b) Average of field duplicates, 4.14 and 4.27 ng/l.

Table G.5b: Mirant Delta CCPP Evaluation of Total Mercury Concentrations (ng/l) in Inputs to Its Discharge.

Sample Date	Demineralizer-Regeneration Wastewater (Discharge to Outfall 1)	Oil-Water Separator (Discharge to Outfall 1)	Reverse Osmosis Reject Water (Discharge to Outfall 1)	Boiler Blowdown (Discharge to Outfall 2)	E-011-1M Firewater System Testing (Discharge to Outfall 2)
3/28/2000					11.1
7/24/2002		1.75	21.8	1.01	
7/30/2002	69.0				
10/9/2002	4.62	4.02	13.8	1.78	
1/14/2003	6.73	6.09	5.65	5.19	

Table G.6: Description of Discharges from Power and Heating/Cooling Plants in the Delta Region.

Agency (NPDES No.)	Proximity to Delta	Discharge Volume (mgd)	Discharge Description	Added Chemicals That May Contain Mercury above Detectable Levels (see Table G.7 (a))
Aerojet Sacramento Facility (CA0004111)	Downstream of Dam	0.02	The discharge contains stormwater, cooling tower overflow, boiler blowdown and some wastewater. The facility has 53 treated boilers, 12 non-treated boilers, 69 non-treated cooling towers, 13 treated cooling towers, 56 evaporation condensers, and numerous other similar systems. Water is used to cool rocket exhaust deflector plates during test firings. Wastewater may include water used to operate propellant vapor scrubbers when tanks are vented, and to draw a vacuum on propellant-contaminated components prior to disassembly. The Discharger states that this wastewater contains hydrazines, oxides of nitrogen, and N-nitrosodimethylamine. The wastewater is collected in a batch process, analyzed for compliance with effluent specifications and discharged to the sanitary sewer or Buffalo Creek, or if not meeting effluent limits, is either treated (neutralization and chemical oxidation) for discharge or is hauled to a Class I disposal site. Maximum concentrations of treatment chemical in the boiler discharges (10 gallons per day [gpd]) are 40 ppm potassium hydroxide, 40 ppm dipotassium sulfite. Chemicals added to boilers and cooling towers: Betz Entec Opti-guard ACS or Betz Entec Optisperse 24; Betz Entrec 552 or Betz Entrec 367.	potassium hydroxide
California (State of) Central Heating/ Cooling facility	Delta / Yolo Bypass	5.26	Facility discharges closed-system cooling water. The heating of downtown State buildings is achieved through the use of boilers that do not discharge waste to surface waters. The Central Heating/Cooling Plant adds no chemicals to its cooling water.	
Calpine Corp. Greenleaf Unit One Cogen Plant (CA0081566)	Downstream of Dam	0.11	The discharger owns and operates a natural gas cogeneration plant that uses water for steam generation and cooling. The discharge consists of cooling water blowdown, which consists of reverse osmosis reject water, boiler blowdown, and condensed steam. The permit did not identify the water supply source for cooling water. Chemicals added to Cooling Water: Chlorine, Nalco 8305 Plus, Nalco 8300 dispersant, Nalco Stabrex ST40, sodium bisulfite solution, sodium hypochlorite solution, sulfuric acid, Nalco 1742, Nalco Elimin-Ox Oxygen Scavenger, Nalco Tri-act 1820 Inhibitor.	chlorine / chloride, potassium hydroxide, sodium bisulfite, sodium hypochlorite, sulfuric acid
East Bay Municipal Utility District Camache Dam Powerhouse (CA0082040)	Downstream of Dam	0.04	The discharger owns and operates an industrial wastewater collection, treatment, and disposal system at the Camanche Dam Power House. The facility obtains process water from the Mokelumne River. Within the powerhouse, drainage, washdown, and leakage waters that contain lubricating oil and other petroleum products are collected in a sump, treated with a belt skimmer, pumped to a separation/retention pond where additional oil is removed with a rope skimmer and a series of separation baffles, and then discharged to the Mokelumne River.	lubricating oil
GWF Power Systems (CA0082309)	Delta / Yolo Bypass	0.05	The facility generates electrical power from the burning of petroleum coke as its primary fuel. Its discharge contains process wastewater from cooling tower blowdown, boiler blowdown, gland steam condensate, plant drains, reverse osmosis reject water and storm water. Water for cooling purposes and steam production is obtained from the City of Antioch. Chemicals added: Sulfuric acid, Stabrex ST40 (microbiocide), dispersant, Phosperse-Plus 8309 Inhibitor (corrosion inhibitor), and water conditioners.	sulfuric acid, sodium hydroxide

Table G.6: Description of Discharges from Power and Heating/Cooling Plants in the Delta Region.

Agency (NPDES No.)	**Proximity to Delta**	**Discharge Volume (mgd)**	**Discharge Description**	**Added Chemicals That May Contain Mercury above Detectable Levels (see Table G.7 [(a)])**
Mirant CCPP (CA0004863)	Delta / Yolo Bypass	123.93	Discharge consists of non-cooling water and other low-volume waste streams resulting from the operation of the CCPP. Cooling water is drawn from the San Joaquin River. Waste streams to Outfall 1 include oil/water separator effluent [0.156 mgd], demineralization regeneration wastewater [0.0033 mgd], and reverse osmosis reject water [0.047 mgd]. Waste streams to Outfall 2 include boiler blowdown [0.030 mgd], boiler wastewater management system effluent [0.00165 mgd], cooling tower blowdown [3.63 mgd], HRSG blowdown [0.032 mgd], evaporative cooler blowdown [0.0324 mgd], and treatment chemicals [volume not available]. Chemicals added: Chlorine, sodium hypochlorite, sodium bromide, polyacrylate, sodium bisulfate, and terbuthlazine.	chlorine / chloride, sodium hypochlorite, sodium bisulfate
SMUD Rancho Seco Nuclear Generating Station (CA0004758)	Downstream of Dam	0.09	Discharge contains stormwater, irrigation runoff, treated liquid radioactive wastewater, fire protection water, treated municipal wastewater, and dilution water from the Folsom South Canal. The facility plans to decrease the domestic wastewater effluent volume as the decommissioning process of the nuclear plant continues. Chemicals added: Sodium hypochlorite may be added to the retention basins for algae control.	sodium hypochlorite *[discharge should be classified as predominantly domestic wastewater]*
Wheelabrator Shasta Energy Co. (CA0081957)	Downstream of Dam	0.02	The Shasta facility is a wood-burning power plant and the Lassen facility is a natural gas fired plant. The combined discharges from these plants contain cooling water, plant maintenance water, storm water runoff, groundwater from the "internal under drain" system, boiler blowdown, reject water from a reverse osmosis system, demineralization system backwash, fuel storage pile leachate and seepage, fly ash, bottom ash, waste petroleum products, and domestic waste. Firewater system, cooling, blowdown, maintenance, and drinking water are obtained from groundwater wells. Chemicals added: Sodium hydroxide (50%), sulphuric acid (93%), Drew Phos 2600, Amercor 8750, Mekor 70, Cortrol OS7700, Vitec 3000, Conntect 5000 (engine cleaner detergent), ammonia, sodium hypochlorite solution, caustic soda liquid (25%), Drew 2215, DrewSperse, and Hypersperse MSI 300.	sodium hydroxide, sulfuric acid, ammonia, sodium hypochlorite, caustic soda

(a) Mercury data were not available for many of the added chemicals, especially the proprietary formulations for which lists of all product-specific ingredients are not publicly available. Potassium hydroxide and sodium hydroxide may be active ingredients in several of the formulations; see Table G.7.

Table G.7: Mercury Concentrations in Chemicals Commonly Used at Power and Heating/Cooling Facilities.

Chemicals	Hg Concentration [(a)]	Comment
ammonia (NH_3)	0.00243 ppb, 0.001 mg/l.	The MASCO Mercury Database had two compound test results for ammonium hydroxide, a common commercial form of ammonia.
bleach (not defined)	0.000568 ppb, 0.001 ppm	
caustic soda (50% membrane grade)	1 ppb	
caustic soda (50% solution)	1 ppb	
caustic soda (flake)	50 ppb	
caustic soda (water care grade)	0.5 ppm	
caustic soda liquid (25%)	0.5 ppm	
chlorine	535 ppm	Chlorine is extracted from chlorides through oxidation and electrolysis. Per a compound test result in the MASCO Mercury Database, chloride had a concentration of 535 ppm.
hydrogen peroxide (H_2O_2, a.k.a. bleach)	0.0012 mg/L	
Oil (lubricating)	239-578 ng/l (LDGV), 4.2 ng/l (HDDV)	4 samples collected from three light-duty gasoline vehicles (LDGVs), 1 sample collected from one heavy-duty diesel vehicle (HDDV).
phosphoric acid	0.0002 ppb	
potassium hydroxide	0.000212 ppb	Potassium hydroxide may be an active ingredient in Nalco 8305 Plus and Betz Entec products. [(b)]
sodium bisulfate	0.010 ppm, 0.000208 ppb	
sodium bisulfite (solution)	0.001 mg/L	
sodium chloride (sodium salt)	0.001 mg/l (saline)	
sodium hydroxide	0.000624 ppb	Sodium hydroxide may be an active ingredient in Nalco Stabrex ST40. [(b)]
sodium hypochlorite (12.5% solution, a.k.a. bleach)	<1 ppb to 20 ppb	
sulfuric acid (25% solution)	5 ppb	
sulfuric acid (50% solution)	2 to 10 ppb	
sulfuric acid (ACS Reagent)	5 ppb	
sulfuric acid (industrial)	0.05 mg/L	
sulfuric acid/sulphuric acid (% not defined)	0.0002 ppb, 0.3 ppb	

(a) All mercury concentration data were obtained from the MASCO Mercury Database (MASCO, 2008) except for the data for oil (Hoyer *et al*., 2002). Units of measure provided in this table are cited precisely as stated in these references.

(b) Many of the products that facilities reported using are proprietary formulations for which lists of all product-specific ingredients are not publicly available; publicly available Material Safety Data Sheets were available for some formulations.

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H. URBAN RUNOFF CONSTITUENT CONCENTRATION DATA

Figure H.1 Site Codes:

1. Arcade Creek
2. City of Sacramento Strong Ranch Slough
3. City of Sacramento Sump 104
4. City of Sacramento Sump 111
5. Stockton Calaveras River Pump Station
6. Stockton Duck Creek Pump Station
7. Stockton Mosher Slough Pump Station
8. Stockton Smith Canal Pump Station
9. Tracy Drainage Basin 10 Outflow
10. Tracy Drainage Basin 5 Outflow
11. Tracy Lateral to Sugar Cut Slough

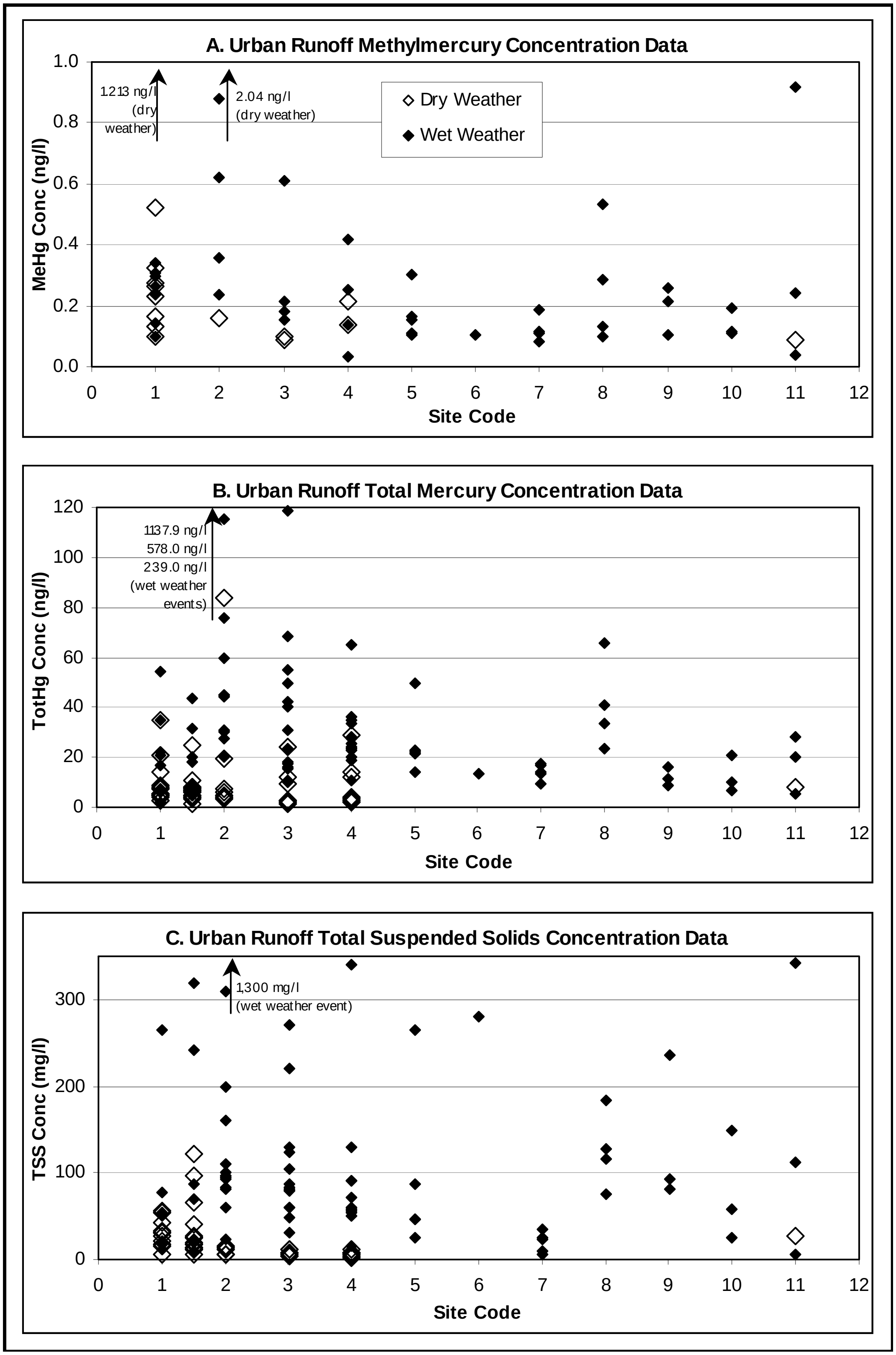

Figure H.1: Urban Runoff Constituent Concentrations.
(Site codes are defined on the next page. Appendix L provides the raw data and data sources.)

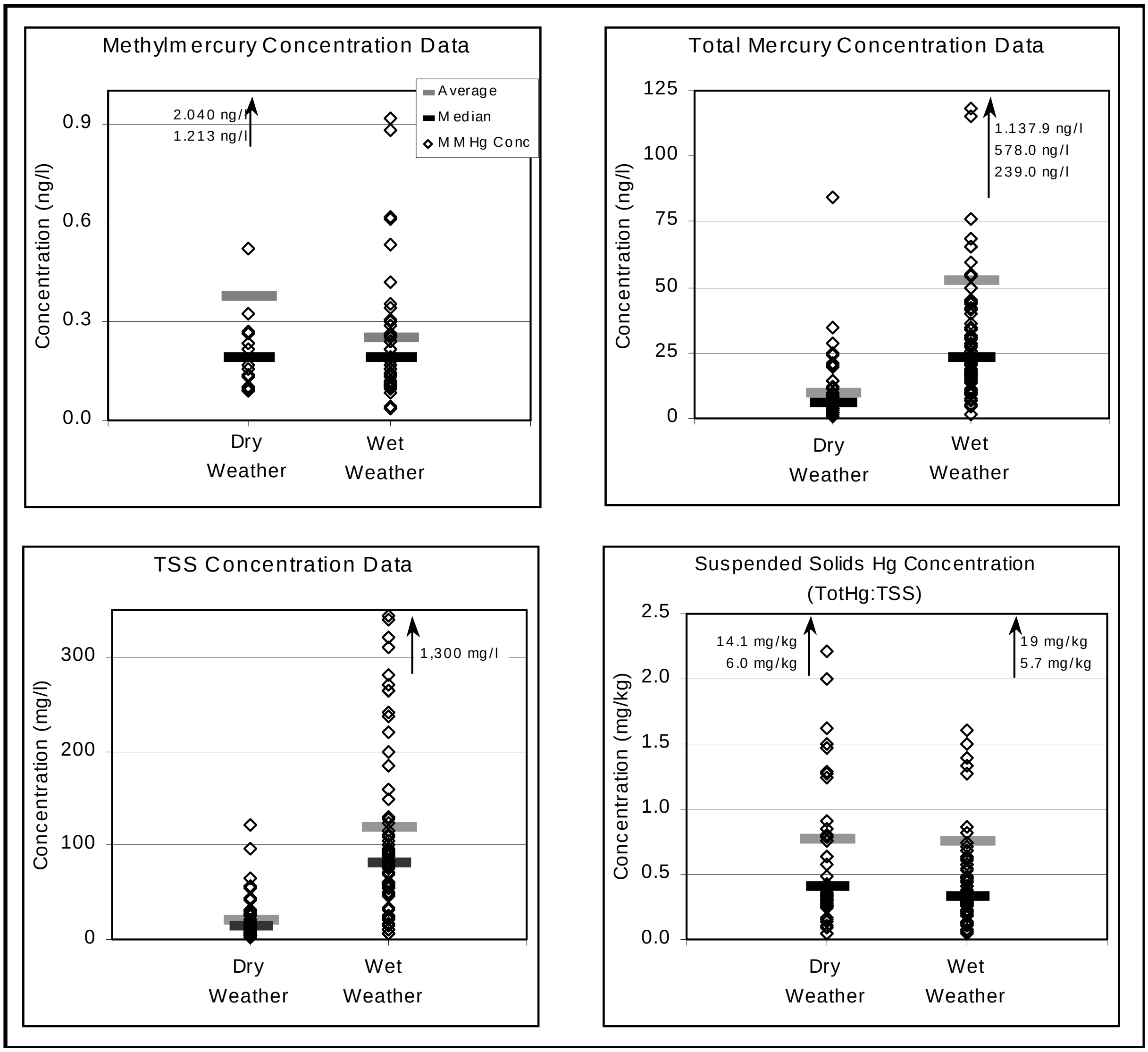

Figure H.2: Pooled Urban Runoff Constituent Concentrations.

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I. SUMMARY OF TOTAL MERCURY AND TSS CONCENTRATION DATA FOR MAJOR DELTA TRIBUTARY INPUT AND EXPORT LOADS

This appendix is organized into six sections that provide the following information:

1. Figures that summarize available total mercury and TSS concentration data for monitoring stations.
2. Load and confidence interval calculation methods for tributary locations with statistically significant total mercury and/or TSS concentration/flow regressions and linear regression plots for the stations with statistically significant regressions.
3. Load and confidence interval calculation methods for tributary sampling locations without statistically significant concentration/flow regressions.
4. Error propagation calculation methods for the mass balances presented in Chapter 7.
5. Figures that illustrate the regressions between total mercury and TSS concentrations used to calculate “Method B. Linear Regression Slope for Paired TotHg/TSS” cited in Table 7.17 for Delta inputs and exports.
6. Tables that provide the regression-based annual mercury loads and sums of the three, five, and ten highest daily mercury loads in each water year for the Sacramento River at Freeport and Yolo Bypass at Prospect Slough.

I.1 Total Mercury and TSS Concentration Time Series Plots

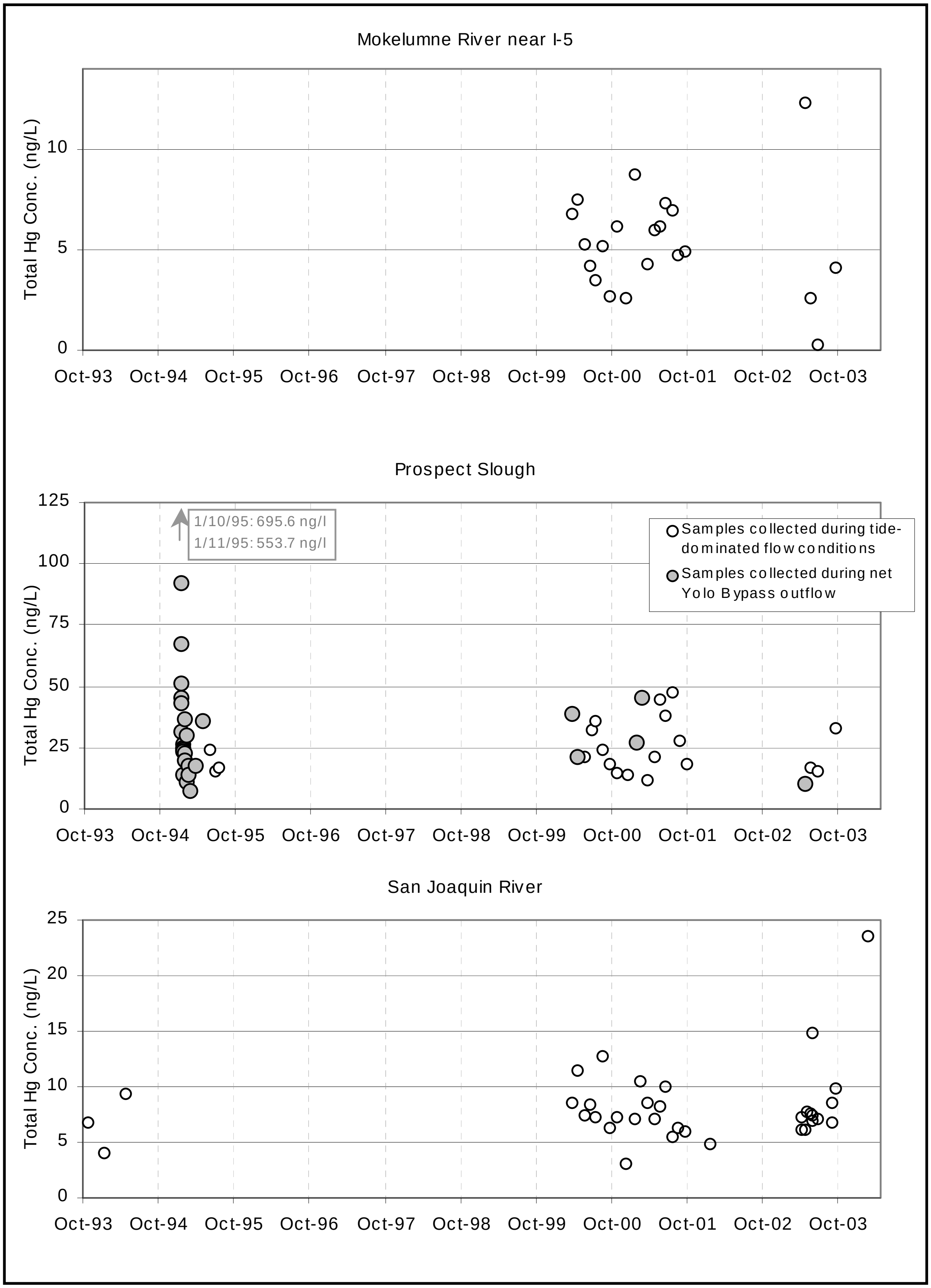


Figure I.1a: Available Total Mercury Concentration Data for the Mokelumne River, Prospect Slough and San Joaquin River.

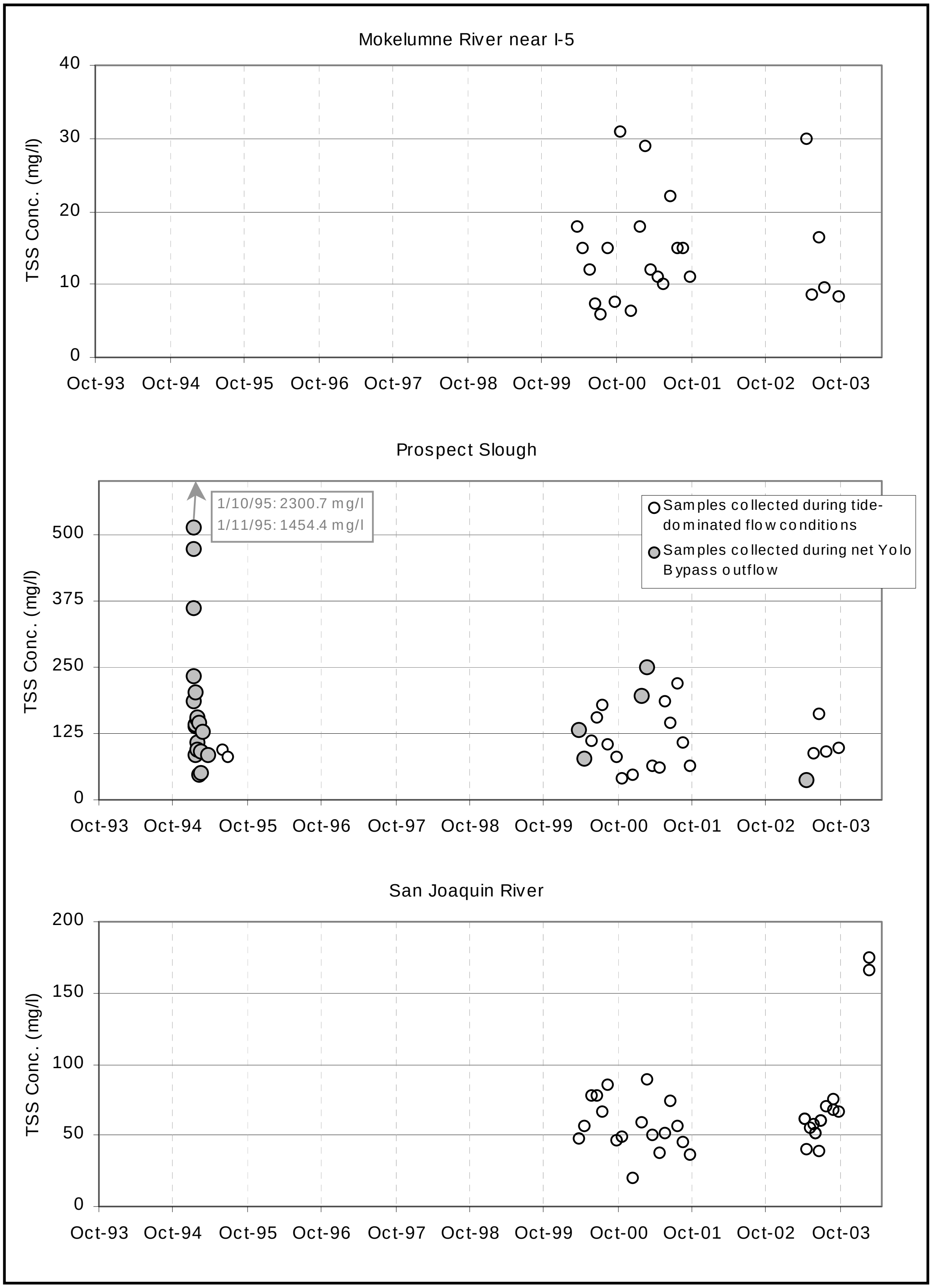


Figure I.1b: Available TSS Concentration Data for the Mokelumne River, Prospect Slough and San Joaquin River.

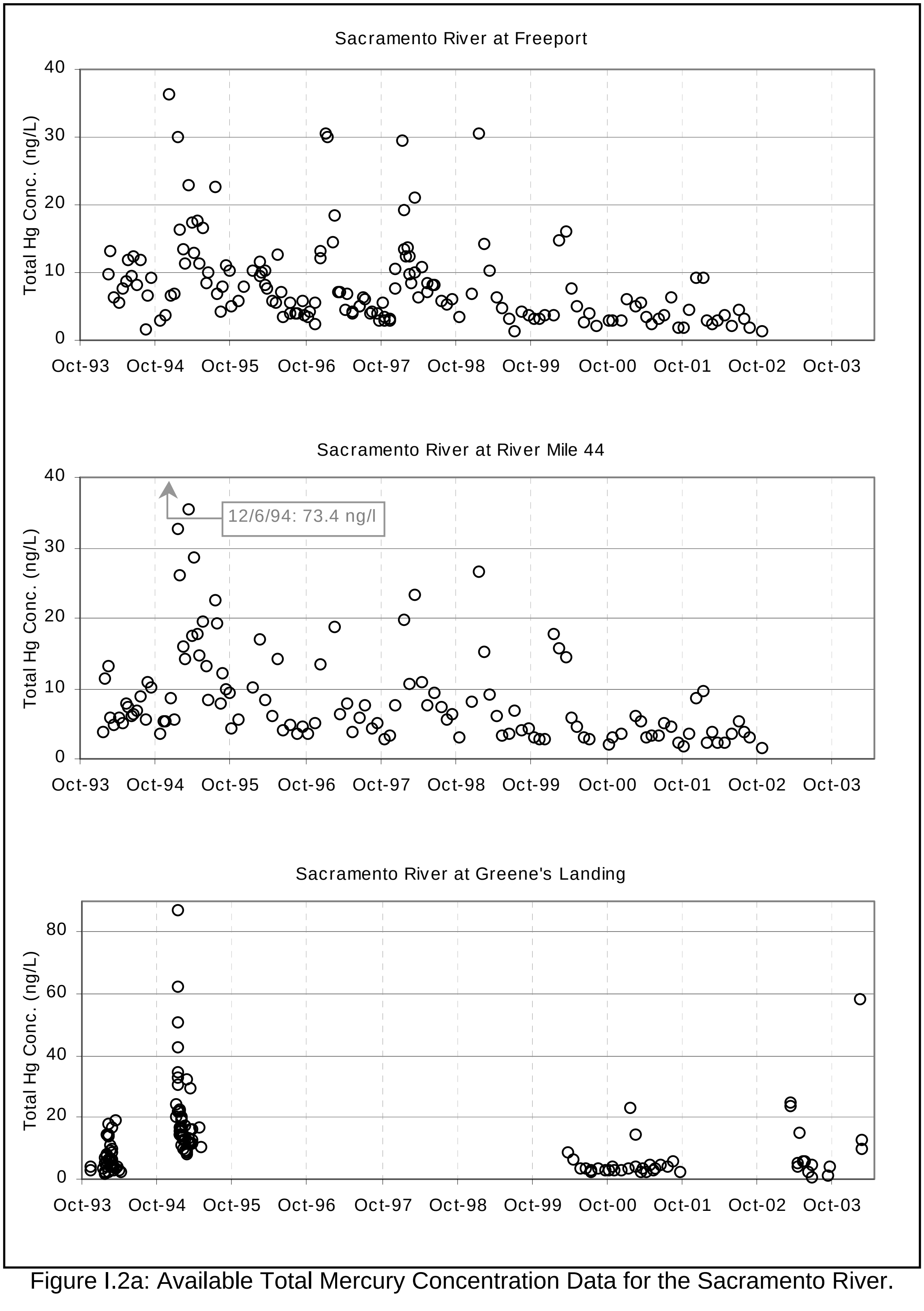
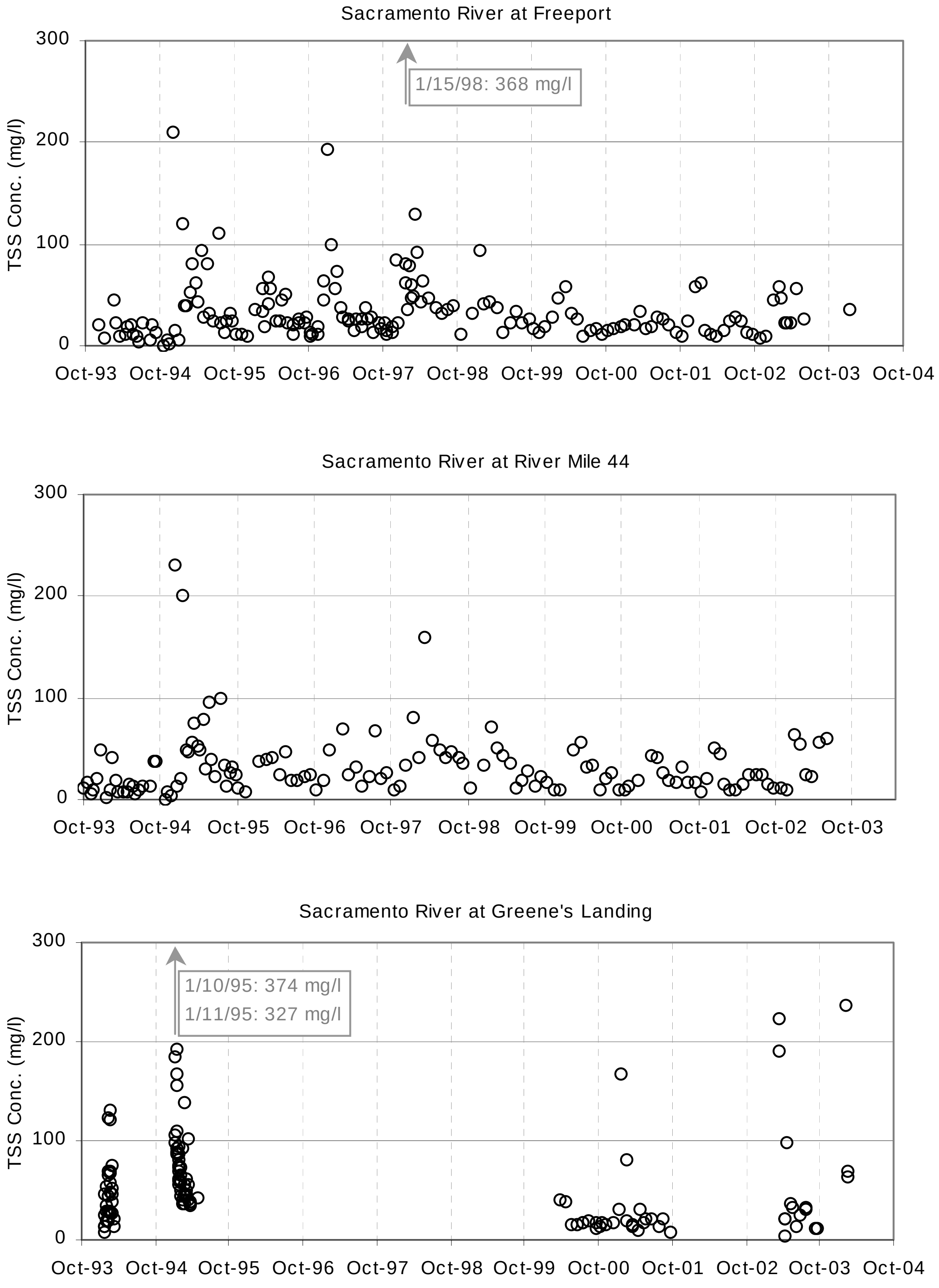


Figure I.2a: Available Total Mercury Concentration Data for the Sacramento River.


Sacramento River at Freeport

1/15/98: 368 mg/l

Sacramento River at River Mile 44

Sacramento River at Greene's Landing

1/10/95: 374 mg/l
1/11/95: 327 mg/l

Figure I.2b: Available TSS Concentration Data for the Sacramento River.

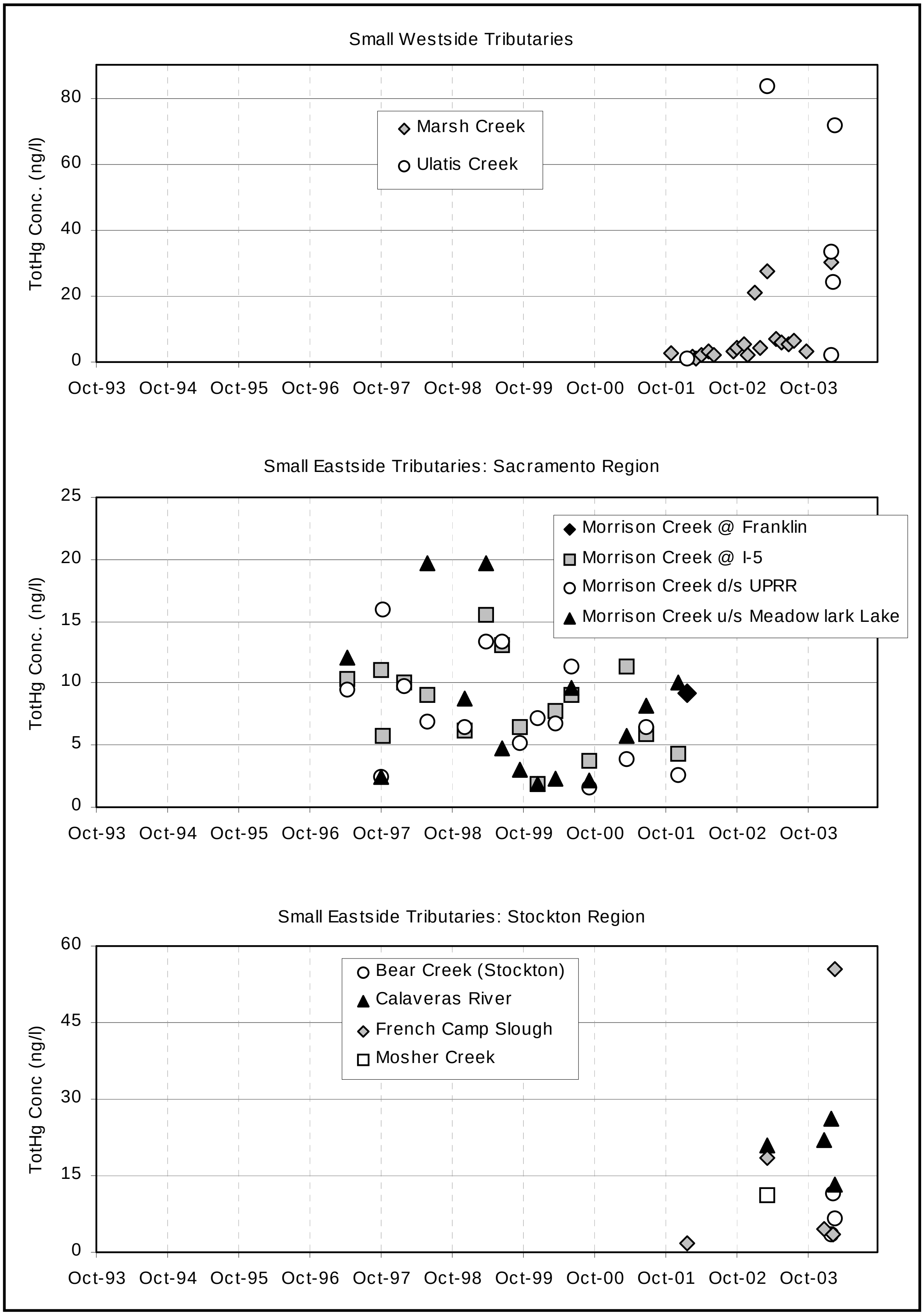


Figure I.3a: Available Total Mercury Concentration Data for Small Westside and Eastside Tributaries.

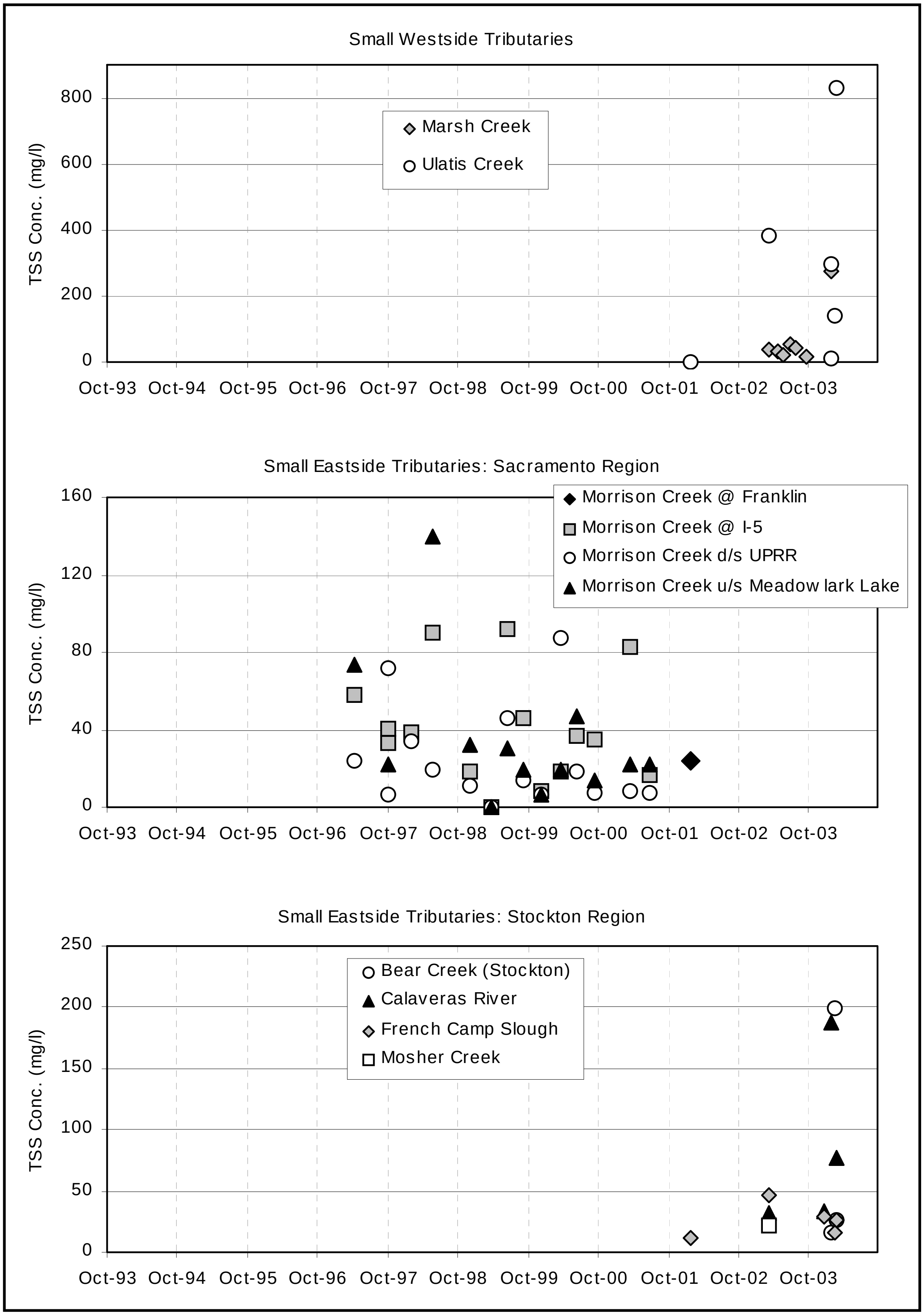


Figure I.3b: Available TSS Concentration Data for Small Westside and Eastside Tributaries.

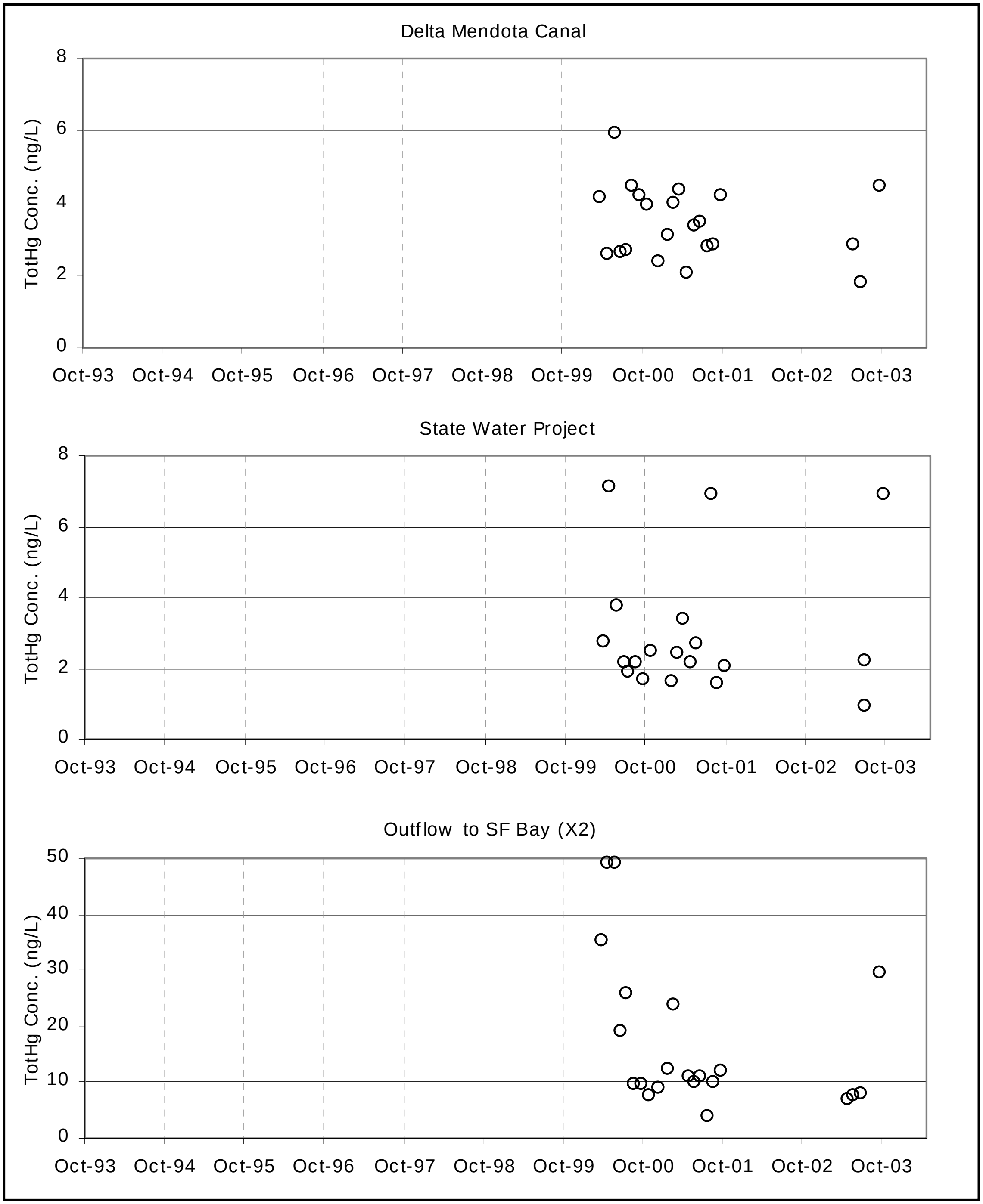


Figure I.4a: Available Total Mercury Concentration Data for Major Delta Exports.

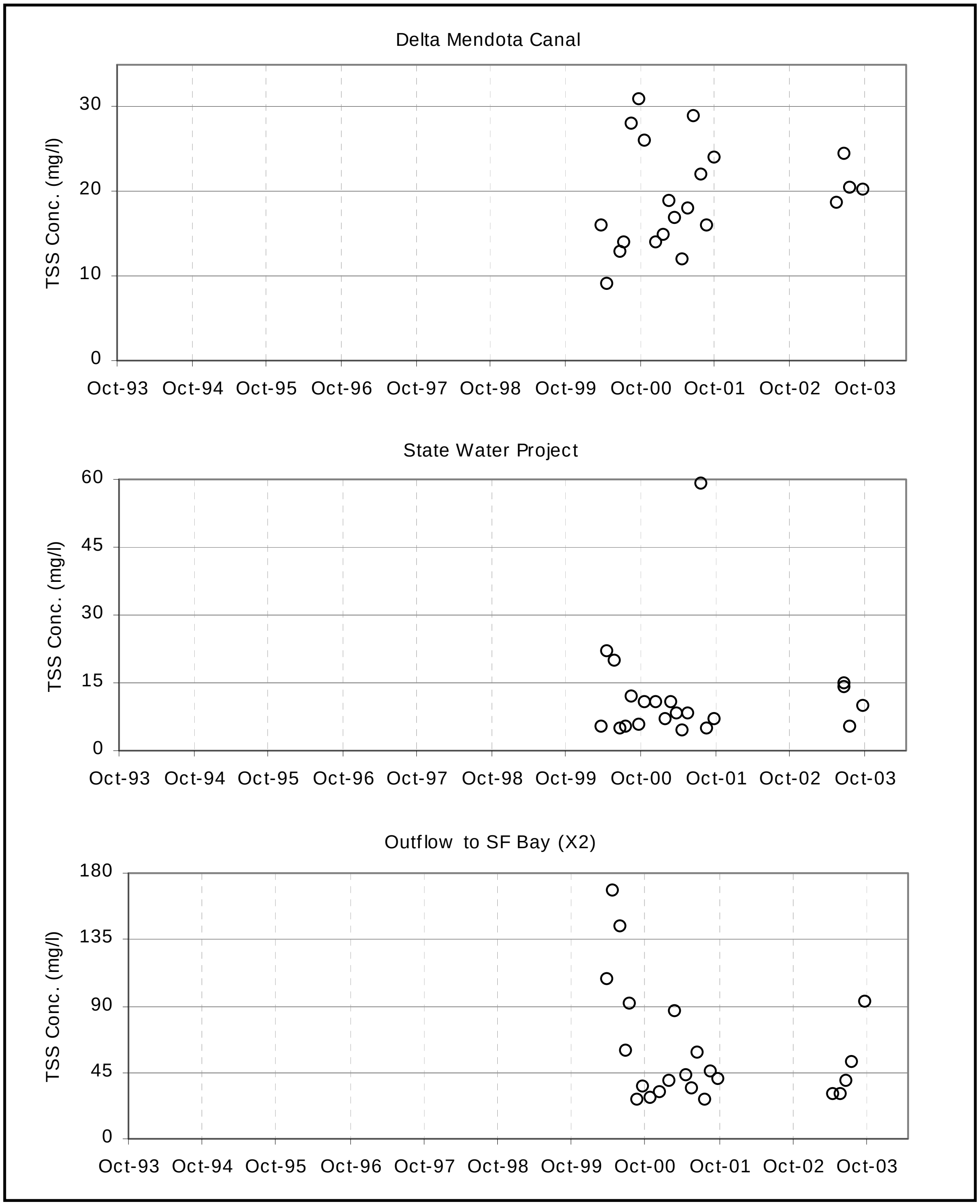


Figure I.4b: Available TSS Concentration Data for Major Delta Exports.

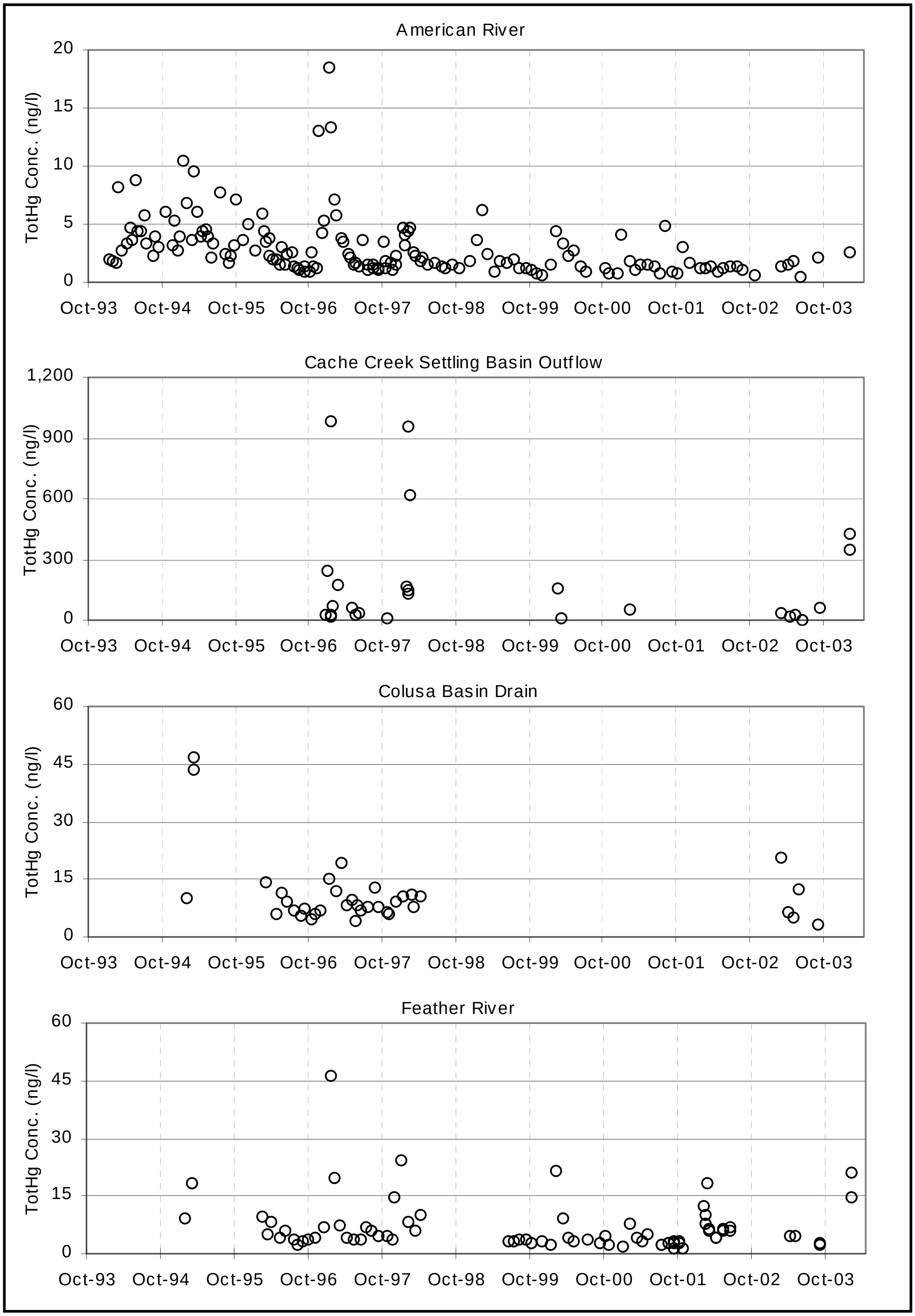


Figure I.5a: Available Total Mercury Concentration Data for American River, Cache Creek, Colusa Basin & Feather River Watershed Outflow Locations.

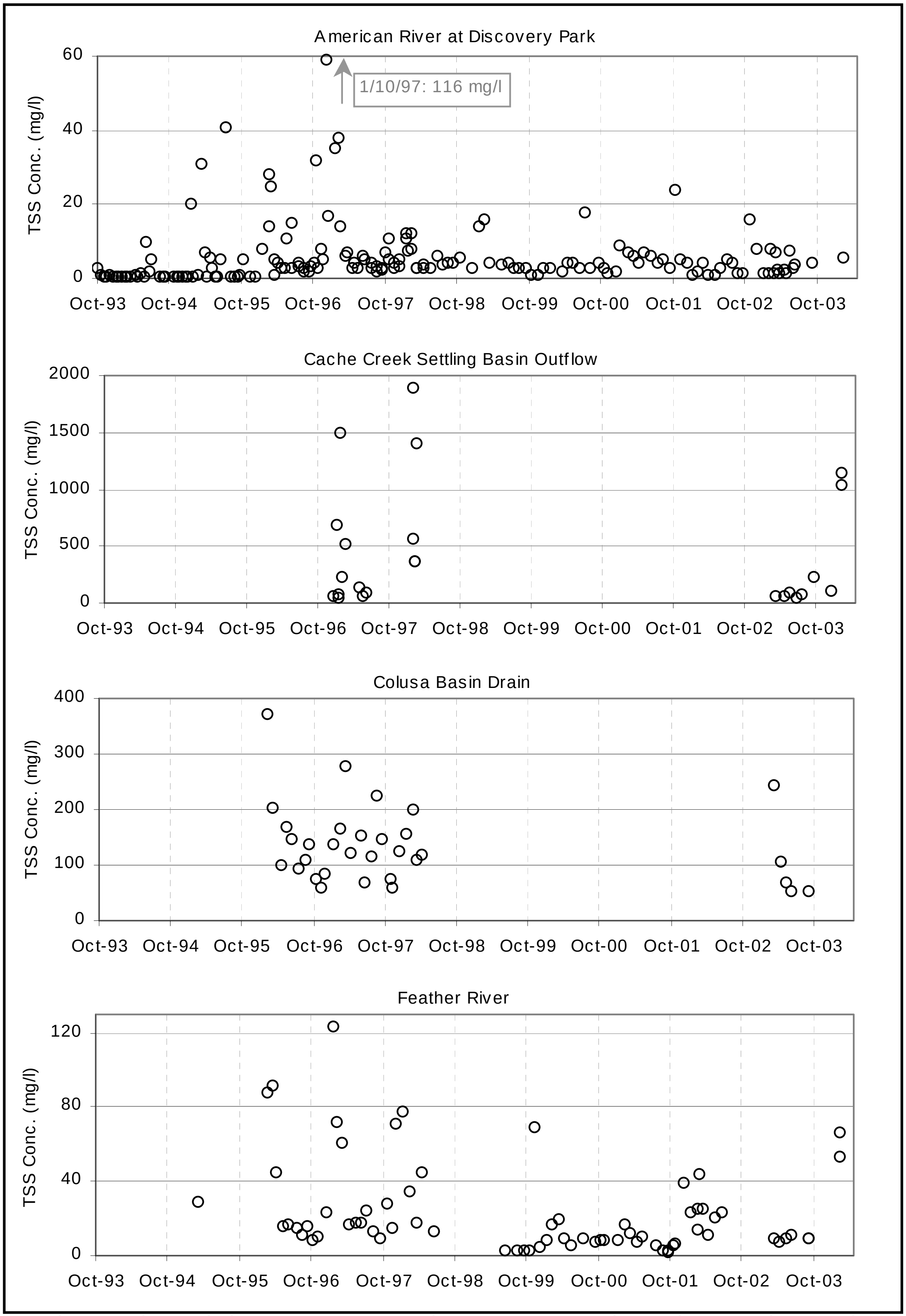
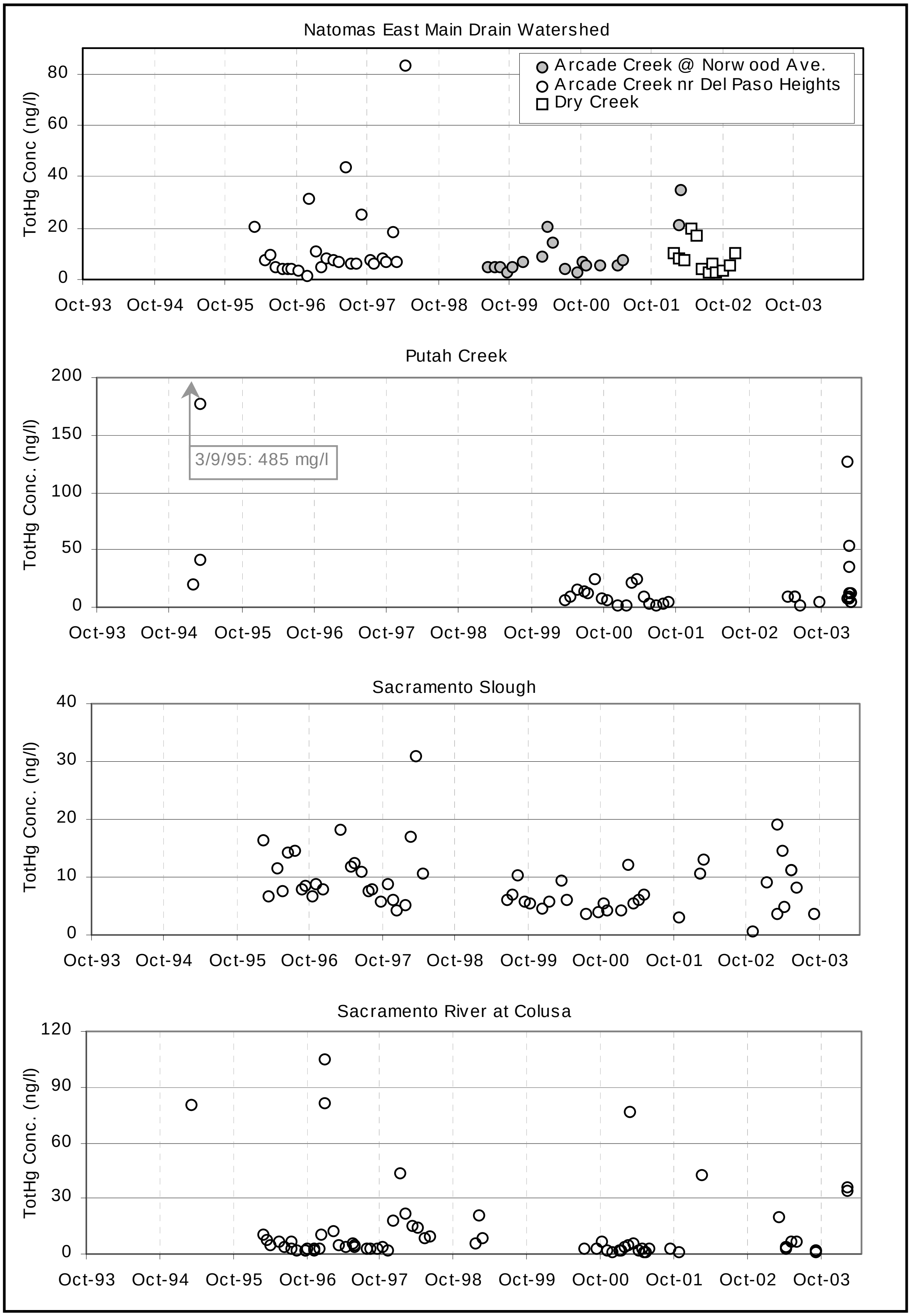


Figure I.5b: Available TSS Concentration Data for American River, Cache Creek, Colusa Basin & Feather River Watershed Outflow Locations.


Natomas East Main Drain Watershed

Putah Creek

Sacramento Slough

Sacramento River at Colusa

Figure I.6a: Available Total Mercury Concentration Data for Natomas East Main Drain, Putah Creek, Sacramento Slough (Sutter Bypass) & Sacramento River above Colusa Watershed Outflow Locations.

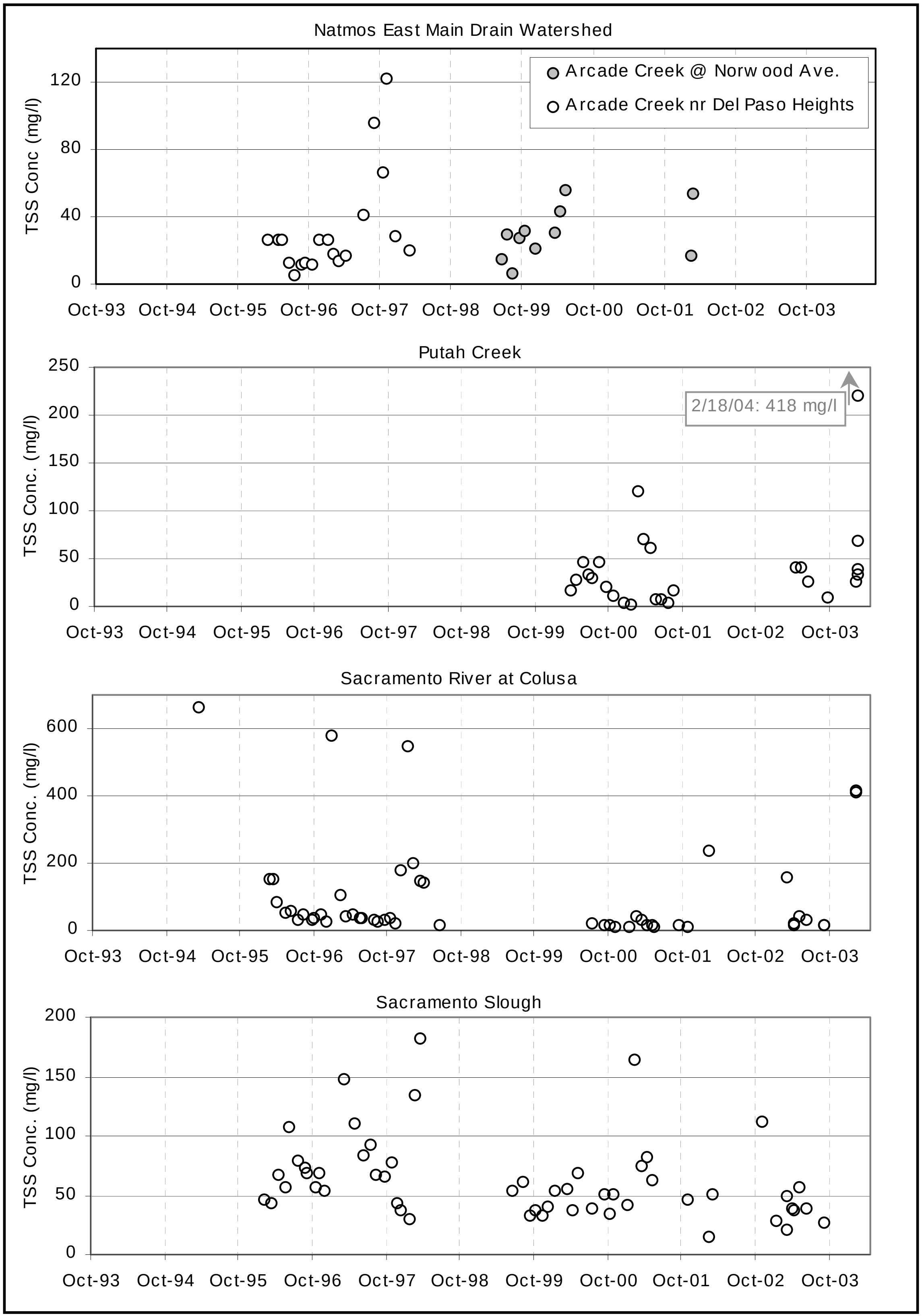


Figure I.6b: Available TSS Concentration Data for Natomas East Main Drain, Putah Creek, Sacramento Slough (Sutter Bypass) & Sacramento River above Colusa Watershed Outflow Locations.

I.2 Average Annual Load and Confidence Interval Calculations for Tributary Sampling Stations with Statistically Significant Concentration / Flow Regressions

Staff predicted the concentration of total mercury and/or TSS from flow for tributary sampling stations with significant ($P < 0.05$) concentration/flow linear regressions (Table I.1 and Figures I.7a and I.7b). Daily mercury and/or TSS concentrations were predicted for each tributary for two periods: WY2000-2003 and WY1984-2003. Daily loads were calculated using daily average flow data (Appendix E). Average annual loads were calculated using Equation I.1.

Equation I.1:

$$\text{Average Annual Load} = \frac{1}{H}\sum c_i \bar{Y}^* + \frac{b_1}{H}\sum c_i (X_i - \bar{X}^*)$$

Where:

H = Number of years being averaged (20 or 4 years)
c_i = Constant of proportionality
$\bar{Y}^*$ = Average concentration (i.e. Total mercury or TSS) of the data used for the regression
b_1 = Slope derived from the linear regression
X_i = Daily average flow (cfs) from the flow record for 20 or 4 years
$\bar{X}^*$ = Average of the daily average flow of the data used for the regression

The variance of the average annual loads was calculated from Equation I.2.

Equation I.2:

$$\text{Variance } (s^2) \quad \left(\frac{1}{H}\right)^2 \left(\sum c_i\right)^2 \left(\frac{\sigma^2}{n^*}\right) + \left(\frac{\sum c_i (X_i - \bar{X}^*)}{H}\right)^2 \left(\frac{\sigma^2}{\sum (X_i^* - \bar{X}^*)^2}\right) =$$

Where:

H = Number of years being averaged (20 or 4 years)
c_i = Constant of proportionality
σ^2 = Residual mean square (*MSE*) from the regression
n^* = Sampled population size of the data on which the regression was based
X_i = Daily average flow (cfs) from the flow record for 20 or 4 years
X_i^* = Daily average flow (cfs) of the data used for the regression
$\bar{X}^*$ = Average of the daily average flow of the data used for the regression

From the variance, standard error was calculated using Equation I.3.

Equation I.3:

Standard Error (*SE*) = $\left(s^2 \Big/ \left(n^* - 2 \right) \right)^{1/2}$

Where:

s^2 = Variance calculated by Equation I.2

n^* = Sampled population size of the data on which the regression was based

Using the above standard error, the confidence interval was calculated from Equation I.4.

Equation I.4:

Confidence Interval (*CI*) = Average Annual Load $\pm SE \times t_{\alpha,df}$

Where:

SE = Standard error calculated by Equation I.3

$t_{\alpha,df}$ = Critical t-value with the probability (α) of 0.05 and (n^* -2) degrees of freedom

This method was developed by Professor Neil Willits (Willits, 2005-2006) at the University of California at Davis. All calculations were made using Microsoft Excel's Data Analysis ToolPak.

The method for calculating average annual loads and confidence intervals for tributary sampling stations without statistically significant concentration/flow regressions is described in Section J.3 after Table I.1 and Figures I.7a and 7.b.

Table I.1: Statistical Significance of Linear Regressions Between Concentration and Daily Flow at Tributary and Export Sampling Stations.

Sampling Stations (a)	Total Mercury/Flow Regression Statistically Significant ($P < 0.05$)	TSS/Flow Regression Statistically Significant ($P < 0.05$)
Delta Imports		
American River at Discovery Park	Yes	Yes
Cache Creek d/s Settling Basin	Yes	Yes
Colusa Basin Drain	Yes	Yes
Feather River	Yes	Yes
Mokelumne River d/s I-5	No	No
Putah Creek at Mace Blvd	Yes	Yes
Sacramento River at Colusa	Yes	Yes
Sacramento River at Freeport	Yes	Yes
San Joaquin River at Vernalis	No	No
Marsh Creek	Yes	No
Prospect Slough (Yolo Bypass)	Yes	Yes
Delta Exports		
Export to San Francisco Bay Delta (X2 and Chipps Island)	No	No
Delta Mendota Canal at Byron Highway	No	No
State Water Project at Bethany Reservoir	No	No

(a) Bear, Mosher, Morrison and Ulatis Creeks, Calaveras River, Natomas East Main Drain, and French Camp Slough tributary stations were not evaluated because there are no flow gages near the stations. The flow gage near the Sacramento Slough station is not rated for high flows and is therefore not adequate for this analysis.

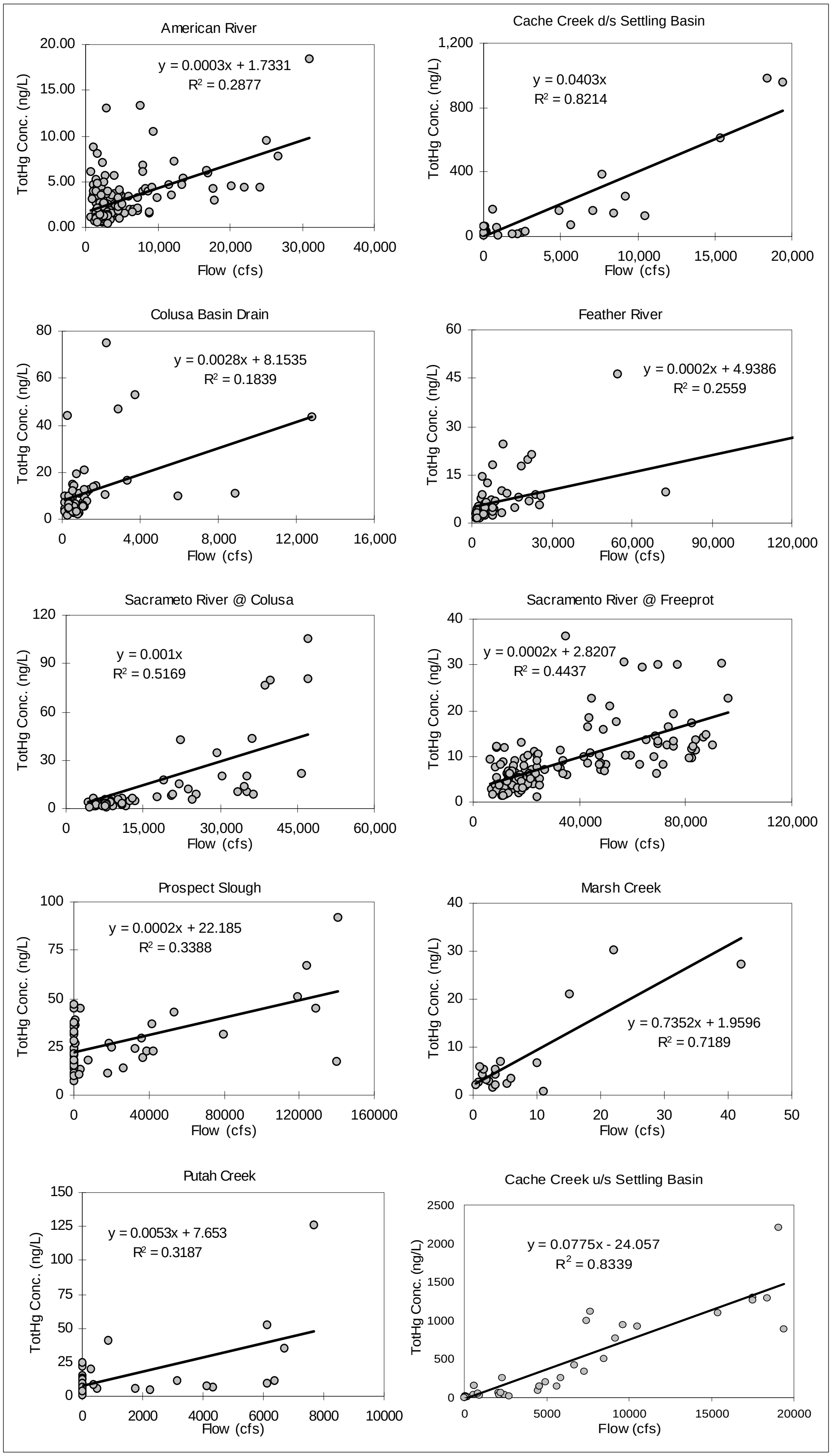


Figure I.7a: Total Mercury Concentration versus Daily Flow for Tributary Inputs with Statistically Significant ($P < 0.05$) Linear Regressions.

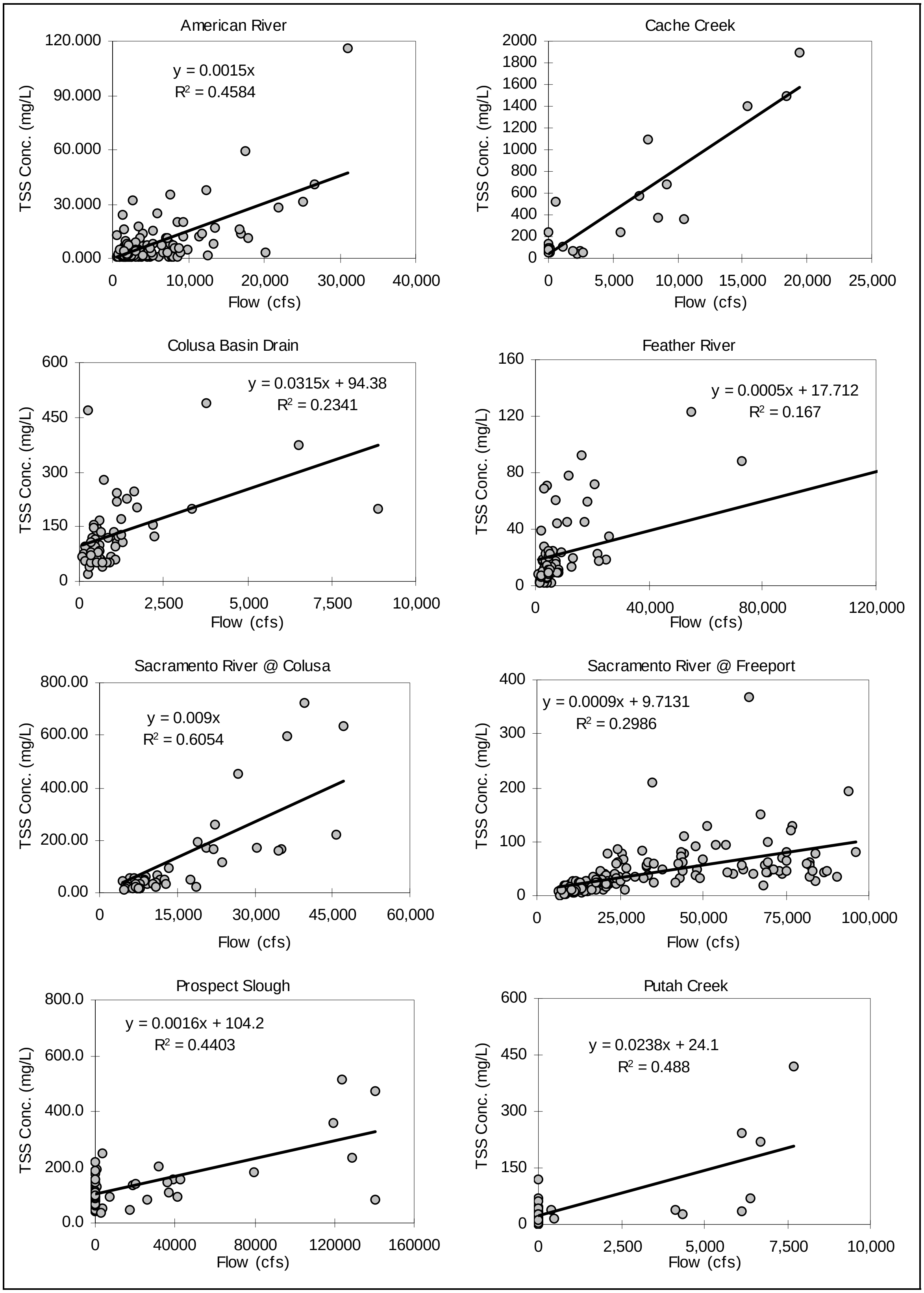


Figure I.7b: TSS Concentration versus Daily Flow for Tributary Inputs with Statistically Significant ($P < 0.05$) Linear Regressions.

I.3 Annual Average Load and Confidence Interval Calculations for Tributary Sampling Stations without Statistically Significant Concentration / Flow Regressions

For the tributary and export sampling locations where linear regressions were not statistically significant ($P < 0.05$, see Table I.1), the daily loads for total mercury and TSS were calculated by multiplying the mean concentration for the sampled data by each water bodies' daily flow for two different periods: WY2000-2003 and WY1984-2003. Then the daily loads were summed (1461 days for 4 years or 7305 days for 20 years) and divided by the appropriate number of years to determine the average annual loads for each period. If the flow record was missing or unavailable for any number of days, then the sums of the daily loads were normalized to 7305 days for 20 years or 1461 days for 4 years before dividing by the number of years. For example, a 20-year record would be normalized by dividing 7305 (the number of days in the 20-year period) by the number of days with a recorded value in the flow record and then multiplying the resulting quotient by the calculated sum of loads; the result was then divided by 20 to obtain the average annual load.

To determine the upper and lower confidence intervals for the annual loads, the upper and lower 95% confidence limits of the concentration means, respectively, were multiplied by each water bodies' daily flow for 20 and 4 years, summed, and divided by the appropriate number of years.

The sampled data's concentration mean, standard error, and 95% confidence interval were calculated using the Microsoft Excel Data Analysis ToolPak option, "Descriptive Statistics".

I.4 Calculations for Error Propagation for the Mass Balances

To determine the confidence intervals of the mass balance components (i.e., sum of input loads or sum of export loads), staff determined the propagated error of the summed loads using Equation I.5 and the confidence interval for the summed loads using Equation I.6. This method was developed by Professor Neil Willits (Willits, 2005-2006) at the University of California at Davis. All calculations were made using Microsoft Excel's Data Analysis ToolPak.

Equation I.5:

Standard Error of Summed Loads (SE_{all}) = $\sqrt{\left(SE_{load_1}\right)^2 + \left(SE_{load_2}\right)^2 + \left(SE_{load_3}\right)^2 + \ldots.}$

Equation I.6:

Confidence Interval of the Summed Loads (CI_{all}) = Summed Loads $\pm\ SE_{all} \times t^*_{\alpha,df}$

Where:

SE_{all} = Standard error calculated in *Equation I.5*

$t^*_{\alpha,df}$ = Critical t-value with the probability ( ) of 0.05 and (n_{all}-1) degrees of freedom.

n_{all} = $\sum\left(n^*_{load_1} + n^*_{load_2} + n^*_{load_3} + \ldots.\right)$

I.5 Regressions between Total Mercury and TSS Concentrations for Delta Inputs and Exports

Figure I.8: TotHg:TSS Regressions for Delta Inputs

Figure I.9: TotHg:TSS Regressions for Tributary Inputs to the Sacramento Basin

Figure I.10: TotHg:TSS Regressions for Delta Exports

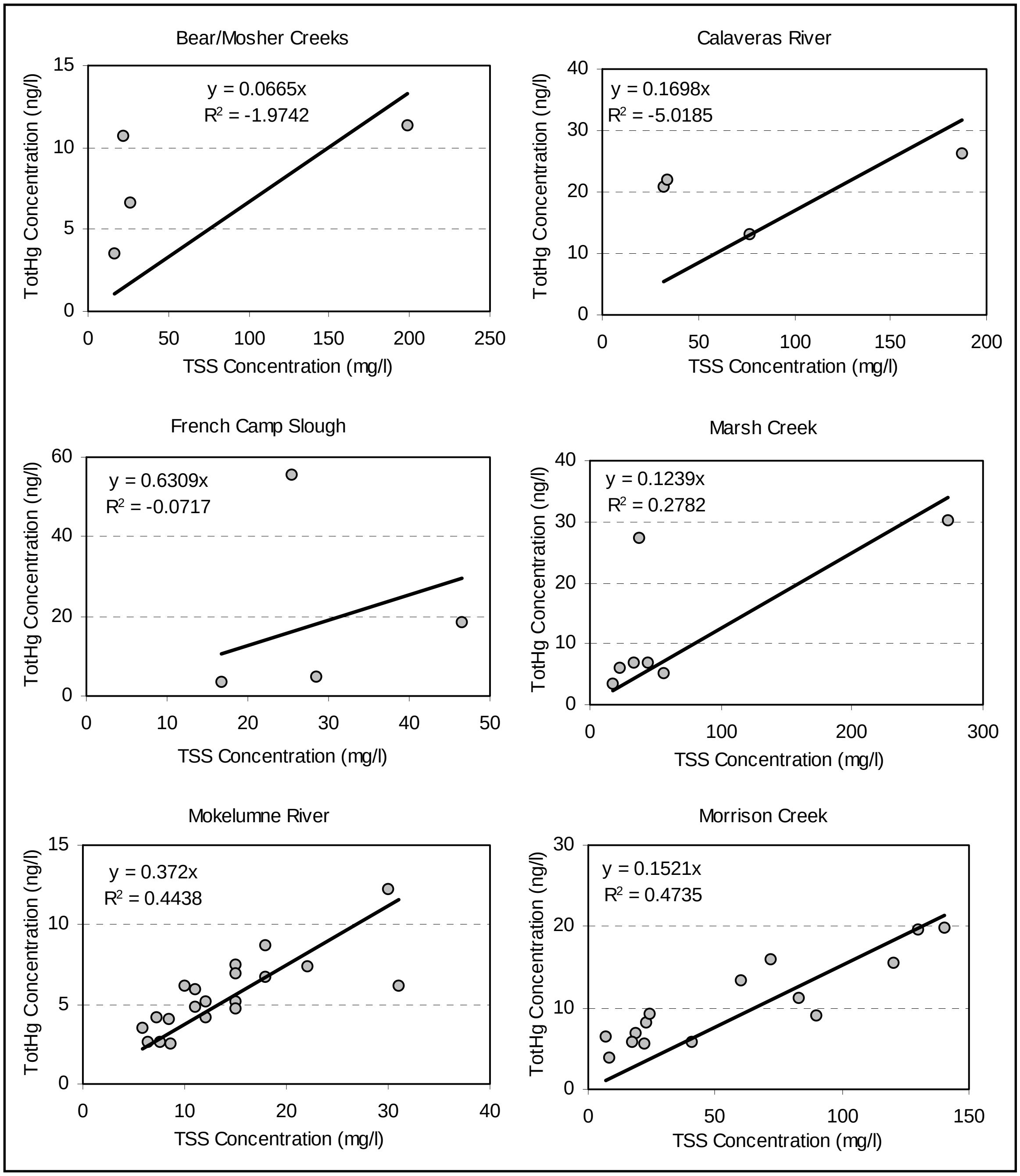


Figure I.8a: TotHg:TSS Regressions for Delta Inputs

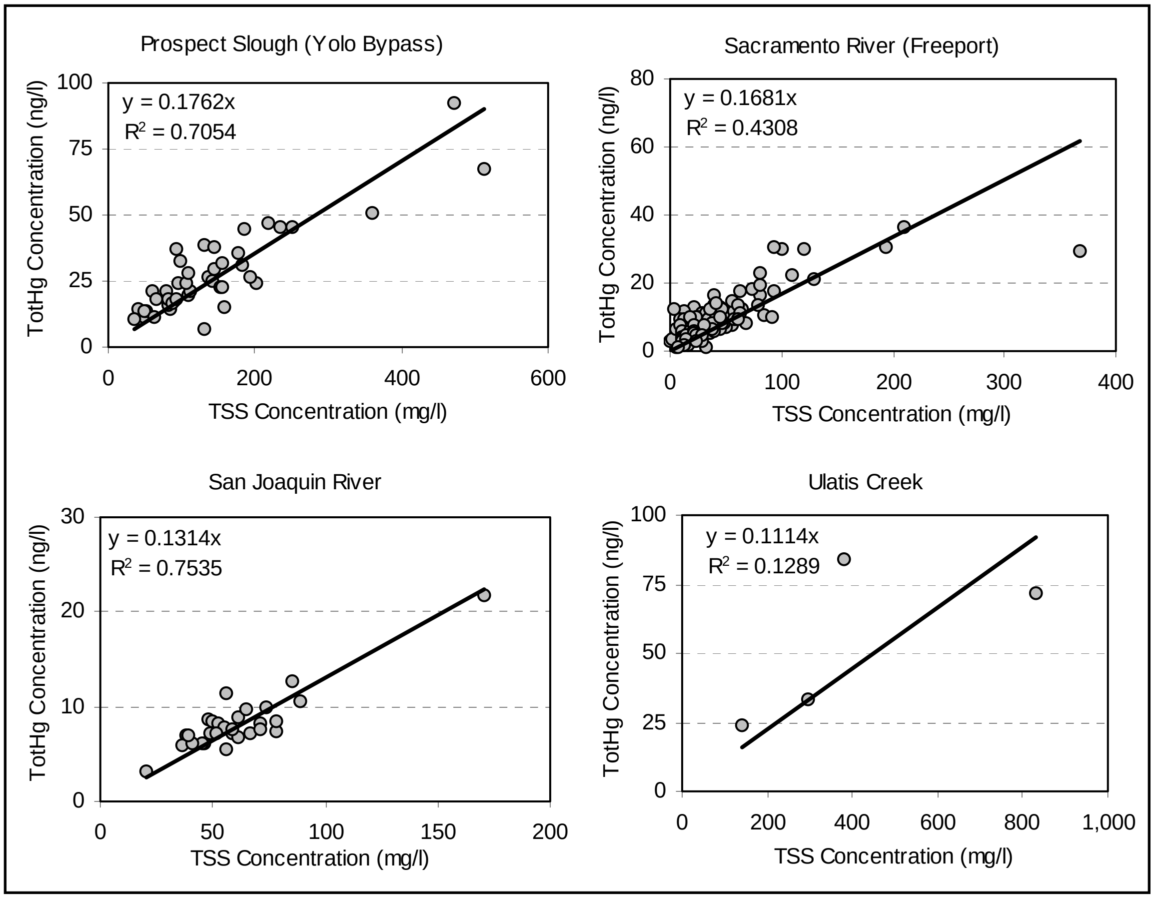


Figure I.8b: TotHg:TSS Regressions for Delta Inputs

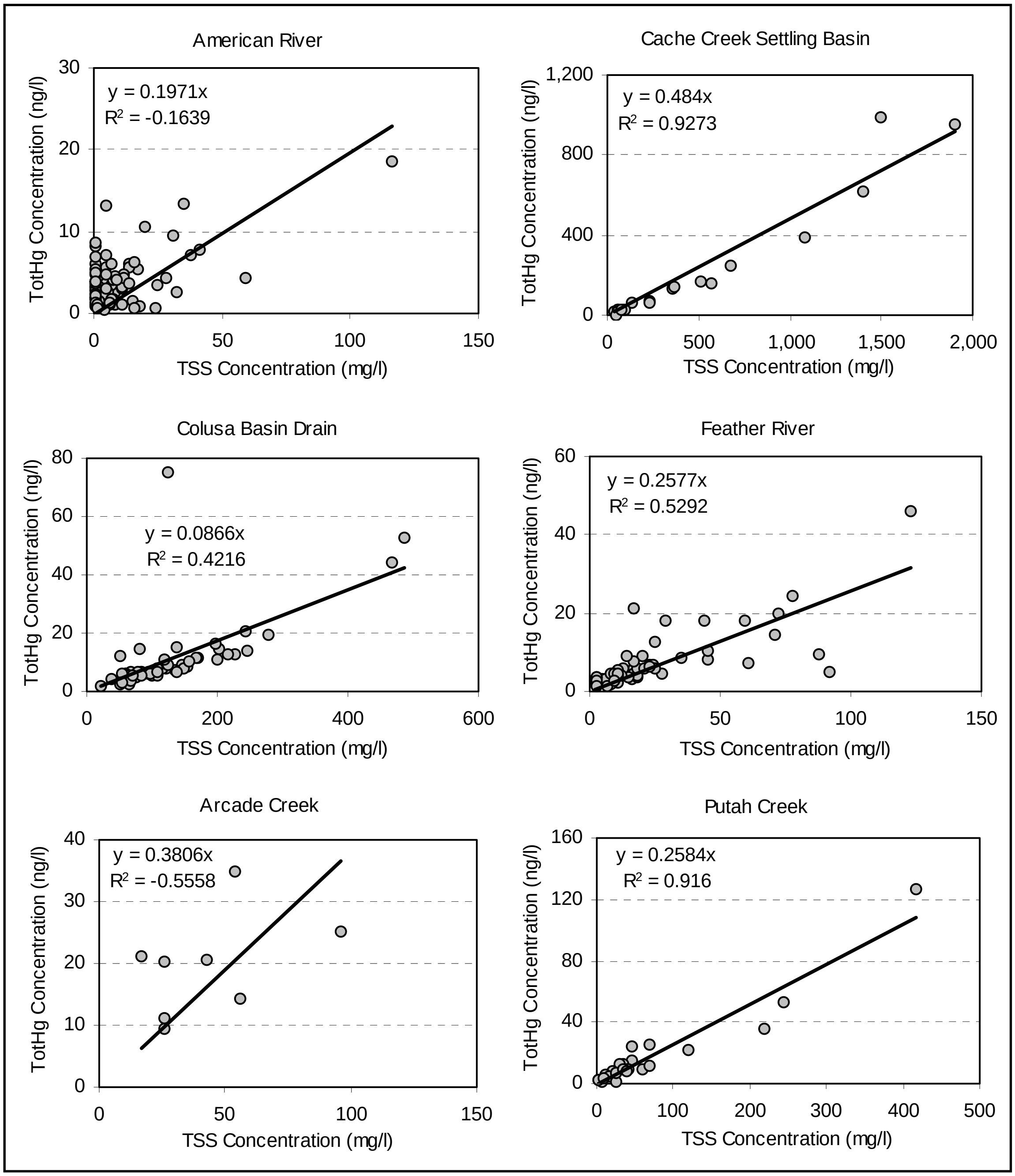


Figure I.9a: TotHg:TSS Regressions for Tributary Inputs to the Sacramento Basin

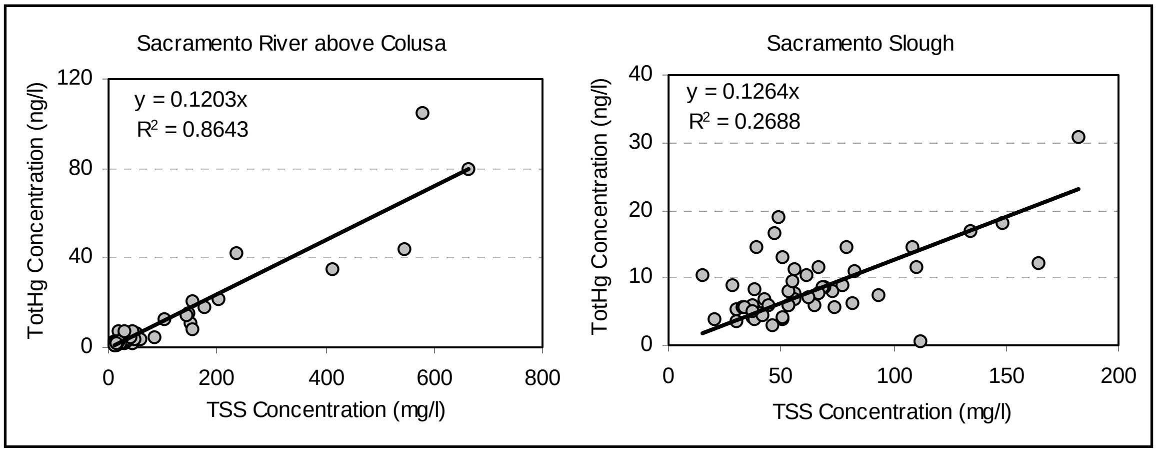


Figure I.9b: TotHg:TSS Regressions for Tributary Inputs to the Sacramento Basin

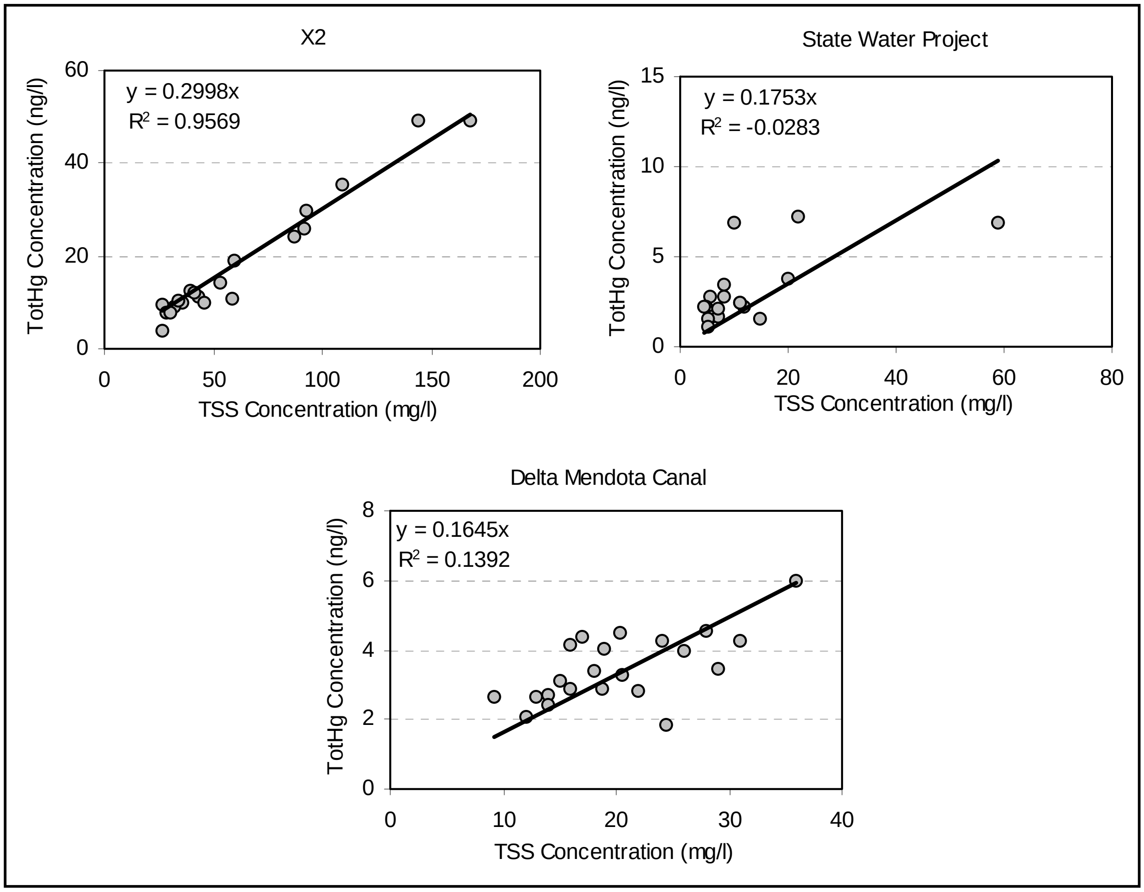


Figure I.10: TotHg:TSS Regressions for Delta Exports

I.6 Regression-based Annual and Highest Daily Mercury Loads for the Sacramento Basin

Table I.2 provides the regression-based annual mercury loads and sums of the three, five, and ten highest daily mercury loads in each water year for the Sacramento River at Freeport, Yolo Bypass at Prospect Slough, and total Sacramento Basin outflows (Sacramento River + Yolo Bypass). The daily and annual loads were calculated using the daily total mercury concentrations predicted by the concentration/flow regressions described in Section J.2 and daily average flow data for WY1984-2003 described in Appendix E.

Table I.2: Regression-based Annual Mercury Loads and Sums of the Three, Five, and Ten Highest Daily Mercury Loads in Each Water Year for Sacramento Basin Outflows.

A. Sacramento River @ Freeport					B. Yolo Bypass @ Prospect Slough					C. Sacramento Basin Outflows (a)				
Water Year	Annual TotHg Load (kg/yr)	Sum of 3 Highest Daily Loads (kg)	Sum of 5 Highest Daily Loads (kg)	Sum of 10 Highest Daily Loads (kg)	Water Year	Annual TotHg Load (kg/yr)	Sum of 3 Highest Daily Loads (kg)	Sum of 5 Highest Daily Loads (kg)	Sum of 10 Highest Daily Loads (kg)	Water Year	Annual TotHg Load (kg/yr)	Sum of 3 Highest Daily Loads (kg)	Sum of 5 Highest Daily Loads (kg)	Sum of 10 Highest Daily Loads (kg)
1984	268	11	18	34	1984	230	92	131	168	1984	497	103	148	200
1985	85	3	4	9	1985	3	1	1	1	1985	88	3	5	10
1986	212	15	24	43	1986	833	355	491	628	1986	1045	370	515	668
1987	59	2	4	7	1987	0	0	0	0	1987	59	3	4	7
1988	57	2	4	7	1988	2	1	1	2	1988	59	3	4	8
1989	93	7	10	19	1989	1	0	1	1	1989	94	7	11	19
1990	56	2	3	5	1990	0	0	0	0	1990	56	2	3	5
1991	40	3	5	8	1991	1	1	1	1	1991	41	4	6	9
1992	47	3	6	10	1992	2	1	1	2	1992	49	4	6	12
1993	219	9	15	29	1993	61	12	20	33	1993	280	21	34	61
1994	54	2	3	5	1994	0	0	0	0	1994	54	2	3	5
1995	385	12	20	37	1995	600	121	188	301	1995	985	131	205	335
1996	266	10	17	32	1996	122	26	39	60	1996	388	36	55	91
1997	269	14	22	42	1997	704	279	382	498	1997	972	294	404	536
1998	391	11	17	33	1998	408	73	114	187	1998	799	83	130	218
1999	248	10	16	30	1999	43	7	11	19	1999	291	16	26	48
2000	194	10	16	31	2000	102	15	25	45	2000	296	24	40	75
2001	65	3	5	9	2001	4	1	1	2	2001	69	4	6	11
2002	100	6	10	18	2002	14	5	6	9	2002	114	11	16	27
2003	179	6	10	20	2003	24	4	6	8	2003	203	10	16	27

(a) The predicted daily mercury loads for the Sacramento River at Freeport and Yolo Bypass at Prospect Slough were summed by date to estimate total daily outflows from the Sacramento Basin and then ranked within each water year to determine the highest three, five and ten daily loads in each water year for the Sacramento Basin. As a result, the highest daily loads in (C) may not equal the sum of the highest daily loads in (A) and (B).

J. 2002 ANNUAL TOTAL MERCURY LOADS FROM AIR EMISSION FACILITIES THAT REPORTED TO THE CALIFORNIA AIR RESOURCES BOARD (ARB, 2003)

FACILITY TYPE / TOTAL MERCURY LOAD (kg)	American River below Folsom Dam	Bear Creek, Fresno R. & San Joaquin R. abv Res.	Butte Creek / Sutter Bypass	Cache Creek	Colusa Basin	Coon Creek & Cross Canal	**Delta**	Feather River below Oroville Dam	Morrison Creek	Natomas East Main Drain & Arcade Creek	Putah - Cache Low-lands	Sacra-mento River abv Colusa	Sacra-mento River abv Keswick Dam	San Joaquin River abv Vernalis	Ulatis Creek	**Grand Total**
ANIMAL & MARINE FATS AND OILS	4.048															**4.048**
BEET SUGAR							**1.438**									**1.438**
BRICK AND STRUCTURAL CLAY TILE									0.006							**0.006**
CANNED FRUITS AND VEGETABLES											0.00026			0.384		**0.384**
CANNED SPECIALTIES														0.000045		**0.000045**
CEMENT, HYDRAULIC												35.337				**35.337**
CHOCOLATE AND COCOA PRODUCTS														0.000076		**0.00008**
COLLEGES & UNIVERSITIES, NEC	0.002															**0.002**
COMMERCIAL PRINT / LITHOGRAPH									0.803							**0.803**
CONCRETE PRODUCTS, NEC									10.579							**10.579**
CONSTRUCTION SAND AND GRAVEL	0.004			2.275					0.104			0.00005				**2.383**
CORRECTIONAL INSTITUTIONS															0.012	**0.012**
COTTON GINNING														0.077		**0.077**
COTTONSEED OIL MILLS														8.844		**8.844**
CROP PREPARATION SVCS FOR MKT			0.001		0.006	0.001		0.003								**0.011**

FACILITY TYPE / TOTAL MERCURY LOAD (kg)	American River below Folsom Dam	Bear Creek, Fresno R. & San Joaquin R. abv Res.	Butte Creek / Sutter Bypass	Cache Creek	Colusa Basin	Coon Creek & Cross Canal	**Delta**	Feather River below Oroville Dam	Morrison Creek	Natomas East Main Drain & Arcade Creek	Putah - Cache Low-lands	Sacra-mento River abv Colusa	Sacra-mento River abv Keswick Dam	San Joaquin River abv Vernalis	Ulatis Creek	**Grand Total**
CRUSHED AND BROKEN STONE, NEC					0.018											**0.018**
DRILLING AND OIL AND GAS WELLS			0.003													**0.003**
ELECTRIC & OTHER SERVICES COMB					9.934		**4.193**					0.324	0.658	0.00004		**15.109**
ELECTRIC SERVICES							**3.656**									**3.656**
FOOD PREPARATIONS, NEC									1.313							**1.313**
FUNERAL SERVICE & CREMATORIES	1.643							0.617	7.194	2.343		2.801				**14.598**
GENERAL MED/SURGICAL HOSPITALS	0.00042								0.00011							**0.001**
GLASS CONTAINERS														0.00014		**0.00014**
GUIDED MISSILES AND SPACE VEH	0.00025															**0.00025**
INDUSTRIAL ORGANIC CHMLS, NEC									0.00005							**0.00005**
LAMINATED PLSTCS PLATE & SHEET						0.025										**0.025**
LAND MINERAL WILDLIFE CONSERV	0.006															**0.006**
MILLWORK										0.018						**0.018**
MISC NONMETALLIC MINERALS													0.053			**0.053**
NATIONAL SECURITY							**0.000**	13.041	0.001							**13.042**

FACILITY TYPE / TOTAL MERCURY LOAD (kg)	American River below Folsom Dam	Bear Creek, Fresno R. & San Joaquin R. abv Res.	Butte Creek / Sutter Bypass	Cache Creek	Colusa Basin	Coon Creek & Cross Canal	**Delta**	Feather River below Oroville Dam	Morrison Creek	Natomas East Main Drain & Arcade Creek	Putah - Cache Low-lands	Sacra-mento River abv Colusa	Sacra-mento River abv Keswick Dam	San Joaquin River abv Vernalis	Ulatis Creek	**Grand Total**
NITROGENOUS FERTILIZERS														0.00035		**0.00035**
PAPER MILLS							**0.577**									**0.577**
PAVING MIXTURES AND BLOCKS		0.030							0.045	0.079		5.382		0.002		**5.538**
PLASTICS MATERIALS AND RESINS									0.00010							**0.00010**
PREPARED FEEDS, NEC							**0.00132**									**0.00132**
RICE MILLING			0.0006		0.014		**0.00093**				0.001					**0.017**
SANITARY SERVICES, NEC												2.050				**2.050**
SAWMILLS & PLANING MILLS, GNL						0.005						0.068	3.062			**3.134**
SEMICONDUCTORS /RELATED DEVICES	0.002															**0.002**
VEGETABLES OIL MILLS, NEC					0.00059											**0.00059**
VET SERV, SPECIALISTS	0.009									0.232						**0.241**
Grand Total	**5.714**	**0.030**	**0.005**	**2.275**	**9.972**	**0.031**	**9.867**	**13.661**	**20.045**	**2.672**	**0.001**	**45.964**	**3.772**	**9.308**	**0.012**	**123.330**

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K. FISH MERCURY CONCENTRATION DATA INCORPORATED IN TMDL REPORT

Regional Board staff compiled and evaluated mercury concentration results for more than 2,800 fish samples collected from Delta waterways between 1970 and 2002. Because of the extensive nature of the raw data, a paper copy of the data set is not included in this report. Instead the database is available electronically in a Microsoft Excel file upon request or from the following website:

http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/

The database includes sample results from the following sources:

CDFG. 1973. Department of Fish and Game Striped Bass Mercury Data, 1970-1973.

Davis, J.A, B.K. Greenfield, G. Ichikawa and M. Stephenson. 2003. *Mercury in Sport Fish from the Delta Region.* Final report submitted to the CALFED Bay-Delta Program for the project: An Assessment of the Ecological and Human Health Impacts of Mercury in the Bay-Delta Watershed (Task 2A). San Francisco Estuary Institute and Moss Landing Marine Laboratories. Available at: http://loer.tamug.tamu.edu/calfed/FinalReports.htm.

Davis, J.A., M.D. May, G. Ichikawa, and D. Crane. 2000. *Contaminant Concentrations in Fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River – 1998*. San Francisco Estuary Institute report. Richmond, California. September 2000. Available at: http://www.sfei.org/sfeireports.htm.

ICEM. 1971. *Mercury in the California Environment.* Compiled by the Interagency Committee on Environmental Mercury, July 1970 - July 1971. Published by the California State Department of Public Health, Environmental Health and Consumer Protection Program. Berkeley, California.

LWA. 2003. *Sacramento River Watershed Program Annual Monitoring Report: 2001–2002 (Final Draft).* Larry Walker and Associates (LWA). Davis, CA. June 2003. Available at: http://www.sacriver.org/.

Schwarzbach, S. and T. Adelsbach. 2002. *Field Assessment of Avian Mercury Exposure in the Bay-Delta Ecosystem.* Submitted to the CALFED Bay-Delta Program for the project: An Assessment of the Ecological and Human Health Impacts of Mercury in the Bay-Delta Watershed (Task 3A). U.S. Geological Survey Biological Research Division and U.S. Fish and Wildlife Service. September 2002. Available at: http://loer.tamug.tamu.edu/calfed/FinalReports.htm.

SWRCB-DWQ. 2002. State Mussel Watch Program / Toxic Substances Monitoring Program. Electronic databases. State Water Resources Control Board, Division of Water Quality (SWRCB-DWQ). Available at: http://www.waterboards.ca.gov/programs/smw/.

Slotton, D.G., S.M. Ayers, T.H. Suchanek, R.D. Weyland, A.M. Liston, C. Asher, D.C. Nelson, and B. Johnson. 2002. The Effects of Wetland Restoration on the Production and Bioaccumulation of Methylmercury in the Sacramento-San Joaquin Delta, California. Draft final report submitted to the CALFED Bay-Delta Program for the project: An Assessment of the Ecological and Human Health Impacts of Mercury in the Bay-Delta Watershed. University of California, Davis, Dept. of Environmental Science and Policy, Dept. of Wildlife, Fish & Conservation Biology, and Division of Microbiology; U.S. Fish and Wildlife Service, Division of Environmental Contaminants. Available at: http://loer.tamug.tamu.edu/calfed/DraftReports.htm.

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L. AQUEOUS METHYLMERCURY, TOTAL MERCURY AND TSS CONCENTRATION DATA INCORPORATED IN TMDL REPORT

Central Valley Water Board staff compiled and evaluated methylmercury, total mercury, and TSS concentration results for thousands of water and effluent samples characterizing Delta inputs and exports. Because of the extensive nature of the raw data, a paper copy of the data set is not included in this report. Instead the database is available electronically in a Microsoft Excel file upon request or from the following website:

http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/

The database includes sample results from ongoing Central Valley Water Board sampling programs, NPDES facility and MS4 monitoring reports, and the following sources:

Alpers, C.N., R.C. Antweiler, H.E. Taylor, P.D. Dileanis, and J.L. Domagalski, 2000. *Metals Transport in the Sacramento River, California, 1996-1997, Volume1: Methods and Data.* U.S. Geological Survey Water-Resources Investigation Report 99-4286. Sacramento, CA.

CMP. 2004. Microsoft Access database of Coordinated Monitoring Program water quality data through August 2003. Database and updates provided by Larry Walker Associates (Mike Trouchon) and Sacramento Regional County Sanitation District (Steve Nebozuk, CMP Program Manager) to Central Valley Regional Water Quality Control Board (Michelle Wood, Environmental Scientist, Sacramento).

Domagalski J, Slotton DG, Alpers CN, Suchanek TH, Churchill RK, Bloom NS, Ayers SM, Clinkenbeard JP, 2002. *Summary and Synthesis of Mercury Studies in the Cache Creek Watershed, California, 2000-2001.* Final Report. U.S. Geological Survey; UC Davis; U.S. Fish and Wildlife Service; California Department of Conservation; California Geological Survey; and Frontier Geosciences, Inc. Prepared for the CALFED Bay-Delta Program, Directed Action #99-B06. Available at: http://loer.tamug.tamu.edu/calfed/FinalReports.htm.

Domagalski, J.L., P.D. Dileanis, D.L. Knifong, C.M. Munday, J.T. May, B.J. Dawson, J.L. Shelton, and C.N. Alpers. 2000. *Water-Quality Assessment of the Sacramento River Basin, California: Water-Quality, Sediment and Tissue Chemistry, and Biological Data, 1995-1998.* U.S. Geological Survey Open-File Report 00-391. Available at: http://ca.water.usgs.gov/sac_nawqa/waterindex.html

DWR. 2001. California Department of Water Resources Special Tributary Project and Offstream Storage Investigation (OSI). Unpublished electronic data e-mailed by DWR (Jerry Boles) to Central Valley Regional Water Quality Control Board (Michelle Wood, Environmental Scientist, Sacramento) on October 15, 2001.

Foe, C.G. 2003. *Mercury Mass Balance for the Freshwater Sacramento-San Joaquin Bay-Delta Estuary*. Final report submitted to the CALFED Bay-Delta Program for the project: An Assessment of the Ecological and Human Health Impacts of Mercury in the Bay-Delta Watershed (Task 1A). California Regional Water Quality Control Board, Central Valley Region. Sacramento, CA. Available at: http://loer.tamug.tamu.edu/calfed/FinalReports.htm.

Foe, C.G. and W. Croyle. 1998. *Mercury Concentrations and Loads from the Sacramento River and from Cache Creek to the Sacramento-San Joaquin Delta Estuary.* California Regional Water Quality Control Board, Central Valley Region. Sacramento, CA. Staff report. June 1998.

Jones, R. 2002. Unpublished mercury concentration data for Morrison Creek and Laguna Creek provided by Roger Jones (Wildlife Biologist, Sacramento Regional County Sanitation District Bufferlands, Sacramento County) to Michelle Wood (Environmental Scientist, Central Valley Water Board) in an emailed Excel file on 22 March 2002.

NADP. 2004. *National Atmospheric Deposition Program (NRSP-3).* NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820. Mercury Deposition Network available at: http://nadp.sws.uiuc.edu/mdn/.

Slotton, D.G., S.M. Ayers, T.H. Suchanek, R.D. Weyland, A.M. Liston, C. Asher, D.C. Nelson, and B. Johnson. 2002. *The Effects of Wetland Restoration on the Production and Bioaccumulation of Methylmercury in the Sacramento-San Joaquin Delta, California.* Draft final report submitted to the CALFED Bay-Delta Program for the project: An Assessment of the Ecological and Human Health Impacts of Mercury in the Bay-Delta Watershed. University of California, Davis, Dept. of Environmental Science and Policy, Dept. of Wildlife, Fish & Conservation Biology, and Division of Microbiology; U.S. Fish and Wildlife Service, Division of Environmental Contaminants. Available at: http://loer.tamug.tamu.edu/calfed/DraftReports.htm.

SRWP. 2004. Microsoft Access database that compiles Sacramento River Watershed water quality data collected for the Sacramento River Watershed Program. Database provided by Larry Walker Associates (Claus Suverkropp) to Central Valley Regional Water Quality Control Board (Michelle Wood, Environmental Scientist, Sacramento).

Stephenson, M., B. Sohst and S. Mundell. 2002. *Mercury Lagrangian Study Between Colusa and Hamilton City.* Study Conducted by Moss Landing Marine Labs and California Department of Fish and Game for the Sacramento Regional County Sanitation District. January 2002.

USGS. 2003. Microsoft Excel Spreadsheets of unpublished data for Bear River Mercury Cycling Project. Data provided by USGS (Charlie Alpers, Research Chemist) to Central Valley Regional Water Quality Control Board (Michelle Wood, Environmental Scientist, Sacramento).