CENTRAL VALLEY REGIONAL
WATER QUALITY CONTROL BOARD

DELTA MERCURY CONTROL PROGRAM PHASE 1 REVIEW OF THE SACRAMENTO – SAN JOAQUIN DELTA ESTUARY TOTAL MAXIMUM DAILY LOAD FOR METHYLMERCURY

STAFF REPORT FOR SCIENTIFIC PEER REVIEW

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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 to inform a future Basin Plan amendment to the Water Quality Control Plan for the Sacramento and San Joaquin River Basins. Mention of specific products does not represent endorsement of those products by the Central Valley Water Board.

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TABLE OF CONTENTS

List of Appendices

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

GLOSSARY

Term	Definition of Term
2010 TMDL Staff Report	Sacramento – San Joaquin Delta Estuary TMDL for Methylmercury Staff Report, April 2010
2010 BPA	Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Methylmercury and Total Mercury in the Sacramento-San Joaquin River Delta Estuary (Resolution R5-2010-0043)
2011 TMDL	Total Maximum Daily Load, adopted by the Central Valley Regional Water Quality Control Board on 22 April 2010 and approved by the United States Environmental Protection Agency on 20 April 2011
AGR	Agriculture (irrigation and stock watering) beneficial use
Agricultural lands	Any lands in the Delta under agricultural production
Agricultural return	Surface water discharged from farmed Delta islands
Agricultural source water	Surface water diverted for irrigation onto farmed Delta islands
Average	Arithmetic mean, also referred to as mean
Basin Plan	Central Valley Region Water Quality Control Plan for the Sacramento River and San Joaquin River Basins
Board staff	Central Valley Regional Water Quality Control Board staff
BREW study	Balancing Regional Export with Wildlife Health Control Study, conducted by USGS
CalEPA	California Environmental Protection Agency
CALFED	California Bay-Delta Authority (State-federal program)
Caltrans	California Department of Transportation
CCCWP	Contra Costa Clean Water Program
CCSB	Cache Creek Settling Basin
CDCR	California Department of Corrections and Rehabilitation
CDEC	California Data Exchange Center
CDOF	California Department of Finance
CDFW	California Department of Fish and Wildlife
CEDEN	California Environmental Data Exchange Network
Central Valley Water Board	Central Valley Regional Water Quality Control Board, also referred to as Region 5
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CIWQS	California Integrated Water Quality System
CNRA	California Natural Resources Agency
COLD	Freshwater habitat (cold water species) beneficial use
COMM	Commercial and sports fishing beneficial use
CSD	Community Sanitary District
CSS	Combined Sewer System
CSSIP	Combined Sewer System Improvement Plan

Term	Definition of Term
CTF	Consolidated Treatment Facility
CTR	California Toxics Rule
CUL	Tribal Tradition and Culture Beneficial Use
CVCWA	Central Valley Clean Water Association
CVP	Central Valley Project
CWA	Federal Clean Water Act
CWWCTS	Combined Wastewater Collection and Treatment System
D-MCM	Dynamic Mercury Cycling Model
DEIR	Draft Environmental Impact Report
Delta	The area within the legal Delta boundary, also referred to as the Upper San Francisco Estuary and Sacramento – San Joaquin Delta
Delta MeHg TMDL Boundary	The area within the scope of the Delta Methylmercury TMDL that includes all waterways within the Delta, Yolo Bypass north of the Delta, and the CCSB
DGM	Dissolved gaseous mercury
DICU	Delta Island Consumptive Use
DMCP	Delta Mercury Control Program; a term collectively referring to the TMDL for methylmercury in the Delta and the associated implementation plan
DMCP Review	Phase 1 of the DMCP required a program review to incorporate more recent data and methodologies, including information provided in the control and characterization studies, to determine if there are any needed modifications to the DMCP
DMPS	Dredged material placement site
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DOM	Dissolved organic matter
DSM2	Delta Simulation Model II
DTMC	Delta Tributaries Mercury Council
DVI	Deuel Vocational Institution
DWQ	Division of Water Quality
DWR	California Department of Water Resources
DWR Open Water Report	Mercury Open Water Final Report for Compliance with the Delta Mercury Control Program, conducted by DWR
DWR Tidal Wetlands Report	Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance Report, conducted by DWR
DWSC	Deep water ship channel
e.g.	*Exempli gratia*, meaning “for example”
EC	Electrical conductivity
eSMR	electronic Self-Monitoring and Reporting
Farmed Delta islands	Any islands in the Delta under agricultural production
GAM	Generalized additive model

Term	Definition of Term
GIS	Geographic Information System
GWTS	Groundwater Treatment System
HCI	Hydrologic Classification Index
Hg	Mercury
i.e.	*Id est*, meaning “that is”
IND	Industry (service supply) beneficial use
ISRP	Independent Scientific Review Panel
JRAD	Jurisdictional runoff area within the Delta MeHg TMDL Boundary
LA	Load Allocation
LID	Low Impact Development
LWA	Larry Walker Associates
MDL	Method detection limit
MDN	Mercury Deposition Network
MeHg	Monomethyl mercury, also referred to as methylmercury in this report
MIGR	Migration of aquatic organisms (warm and cold water species) beneficial use
MOU	Memorandum of Understanding
MS4	Municipal Separate Storm Sewer System
MUN	Municipal and domestic supply beneficial use
NA	Not applicable
NADP	National Atmospheric Deposition Program
NAV	Navigation beneficial use
ND	Non-detect
NLS	Nonlinear least squares
NMFS	National Marine Fisheries Service
No.	Number, also referred to as #
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWI	National Wetland Inventory
NWIS	National Water Information System
OEHHA	Office of Environmental Health Hazard Assessment
POTW	Publicly Owned Treatment Works
PROC	Industry (process) beneficial use
QAPP	Quality Assurance Project Plan
RAA	Reasonable Assurance Analysis
RCP	Representative Concentration Pathway
REC-1	Water contact recreation beneficial use
REC-2	Non-contact recreation beneficial use
Report	Staff Report for Scientific Peer Review
RL	Reporting limit
RMP	Regional Monitoring Program

Term	Definition of Term
San Francisco Bay Water Board	San Francisco Bay Regional Water Quality Control Board, also referred to as Region 2 or SFBRWQCB
SD	Sanitary District
SER	Standard error of regression, also called the residual standard error, is a measure of dispersion of observed values around the regression line, normalized by the complexity of the model
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SFEI	San Francisco Estuary Institute
SPG	Special Project Group
SRWP	Sacramento River Watershed Program
State Water Board	State Water Resources Control Board, also see SWRCB
Statewide Mercury Provisions	Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions as Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California, adopted by State Water Board
SSC	Suspended sediment concentration
SSQP	Sacramento Stormwater Quality Partnership
SUB	Subsistence Fishing Beneficial Use
SWAMP	Surface Water Ambient Monitoring Program
SWP	State Water Project
SWRCB	State Water Resources Control Board
T-SUB	Tribal Subsistence Fishing Beneficial Use
TAC	Technical Advisory Committee
THg	Total mercury, also referred to as inorganic mercury
TL2, TL3, TL4	Trophic level two, three, or four, respectively
TLG	Trophic level group
TMDL	Total Maximum Daily Load
TSS	Total suspended solids
USACE	United States Army Corps of Engineers
USACE Methylmercury Summary Report	Methylmercury Summary Report – Sacramento and Stockton Deep Water Ship Channels Operation and Maintenance Dredging
USBR	United States Bureau of Reclamation
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WARM	Freshwater habitat (warm water species) beneficial use
WDID	Waste Discharger Identification
WILD	Wildlife habitat beneficial use
WLA	Waste load allocation
WPCF	Water Pollution Control Facility
WQO	Water Quality Objectives
WRF	Water Recycling Facility

Term	Definition of Term
WWCF	Wastewater Control Facility
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant
WWQCF	Wastewater Quality Control Facility
WY	Water Year: the period between 1 October and 30 September of the following year (for example, WY 2000 is the period between 1 October 2000 and 30 September 2001)
X2	Location in the Estuary with 2 parts per thousand bottom salinity

UNITS OF MEASURE

Abbreviated Unit of Measure	Definition of abbreviation
µg	microgram
µg/L	microgram per liter
µg/m^2/yr	microgram per square meter per year
ac	acre
ac-ft	acre-feet
ac-ft/yr	acre-feet per year
cfs	cubic feet per second
cy	cubic yard
cy/yr	cubic yard per year
g	gram
g/cy	gram per cubic yard
g/day	gram per day
g/month	gram per month
g/ng	gram per nanogram
g/yr	gram per year
g/yr/ac	gram per year per acre
gal	gallon
in	inch
in/yr	inch per year
kg	kilogram
kg/cy	kilogram per cubic yard
kg/m^3	kilogram per cubic meter
kg/yr	kilogram per year
L	liter
m	meter
m^2	square meter
M ac-ft/yr	million acre-feet per year
mg	milligram
MGD	million gallon per day
mg/kg	milligram per kilogram
mm	millimeter
ng	nanogram
ng/g	nanogram per gram
ng/L	nanogram per liter
ng/L/day	nanogram per liter per day
ng/m^2/day	nanogram per square meter per day
NTU	nephelometric turbidity unit
ppm	parts per million; usually mg/kg or µg/g

Abbreviated Unit of Measure	Definition of abbreviation
yd	yard
yd/day	yard per day
yd^2	square yard
yd^2/ac	square yard per acre
yr	year

CONVERSION FACTORS

Measurement Type	Original Unit	Multiply By	Final Unit
Length	centimeter	0.3937	inch
Length	inches	0.0277778	yard
Length	meter	3.281	foot
Length	meter	1.094	yard
Length	millimeter	0.03937	inch
Area	acre	43,560	square foot
Area	acre	4,047	square meter
Area	acre	4,840	square yard
Area	hectare	2.471	acre
Area	hectare	0.003861	square mile
Area	square foot	0.000029568	acre
Area	square meter	0.0002471	acre
Area	square meter	10.76	square foot
Area	square mile	640	acre
Volume	acre-foot	1,233.48	cubic meter
Volume	acre-foot	1,233,481.855	liter
Volume	acre-foot	325,851	gallon
Volume	cubic centimeter	0.06102	cubic inch
Volume	cubic feet	0.0000230	acre-foot
Volume	cubic feet	28.317	liter
Volume	cubic hectometer	810.7	acre-foot
Volume	cubic meter	0.0008107	acre-foot
Volume	cubic meter	264.2	gallon
Volume	cubic meter	0.0002642	million gallons
Volume	cubic meter	1,000	liter
Volume	cubic yard	0.764555	cubic meter
Volume	cubic yard	27	cubic feet
Volume	cubic yard	764.555	liter
Volume	gallon	1,000,000	million gallons
Volume	liter	0.000000810714	acre-foot
Volume	liter	61.02	cubic inch
Volume	liter	0.2642	gallon
Volume	liter	33.81402	ounce, fluid
Volume	liter	2.113	pint
Volume	liter	1.057	quart
Volume	million gallons	3.0688833	acre-foot

Measurement Type	Original Unit	Multiply By	Final Unit
Time	second	60	minute
Time	second	3,600	hour
Time	second	86,400	day
Flow	cubic feet per second	2,446,589	liters per day
Flow	cubic feet per second	1.98	acre-foot per day
Flow	cubic meter per second	70.07	acre-foot per day
Flow	cubic meter per year	0.000811	acre-foot per year
Flow	cubic meter per second	35.31	cubic foot per second
Flow	liter per second	15.85	gallon per minute
Flow	million acre-feet per year	892.74	million gallons per day
Mass	gram	1,000,000,000	nanogram
Mass	gram	0.03527	ounce
Mass	kilogram	1,000	gram
Mass	kilogram	1,000,000	milligram
Mass	kilogram	2.205	pound, avoirdupois
Density	gram per cubic centimeter	62.422	pound per cubic foot

EXECUTIVE SUMMARY

The total maximum daily load (TMDL) for methylmercury in the Sacramento – San Joaquin Delta Estuary (Delta) and associated implementation plan, collectively referred to as the Delta Mercury Control Program (DMCP), was adopted by the Central Valley Regional Water Quality Control Board (Central Valley Water Board) on 22 April 2010 as an amendment to the Central Valley Region Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan; CVRWQCB 2019). The TMDL was approved by the United States Environmental Protection Agency (USEPA) on 20 April 2011 (USEPA 2011) and is referred to as the 2011 TMDL. The DMCP is a phased approach to manage methylmercury (MeHg) and includes a control program to reduce both MeHg and total mercury (THg) in the Sacramento-San Joaquin Delta Estuary (Delta) and the Yolo Bypass.

The first phase of the DMCP requires entities responsible for discharging methylmercury in the Delta to conduct source control studies and subsequently develop and evaluate MeHg management methods. The DMCP required the studies to be reviewed by an independent scientific peer review panel, which was coordinated through the Delta Stewardship Council's Delta Science Program. Phase 1 of the DMCP also required a program review, referred to as the DMCP Review, to incorporate more recent data and methodologies, including information provided in the control and characterization studies, to determine if there are any needed modifications to the DMCP.\

Phase 2 began on October 20, 2022, and requires dischargers to implement MeHg control programs to meet allocations, continue total mercury reduction programs, and conduct compliance monitoring.

The Staff Report for Scientific Peer Review (Report) presents Central Valley Water Board staff (Board staff) recommendations as part of the required Phase 1 DMCP Review. This report contains reevaluations of water quality objectives (WQO), sources, allocations, and mercury reduction recommendations for Phase 2 DMCP implementation to address the mercury impairment in the Delta.

This Report is structured similarly to the Sacramento – San Joaquin Delta Estuary TMDL for Methylmercury Staff Report, April 2010 (2010 TMDL Staff Report; Wood *et al.* 2010) and is comprised of the following key sections: introduction, problem statement, potentially controllable processes, numeric targets, linkage analysis, methylmercury and total mercury source analysis, and allocations.

Board staff evaluated each section of the 2010 TMDL Staff Report and determined that certain sections required updates. Each section in this Report reflects Board staff's decisions regarding the corresponding section of the 2010 TMDL Staff Report. It is advised to have the 2010 TMDL Staff Report (https://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/archived_delta_hg_info/april_2010_hg_tmdl_hearing/apr2010_tmdl_staffrpt_final.pdf) readily available while reading this Report. Additionally, key points are provided at the end of each section to summarize the main recommendations and findings.

ES.1 Scope & Extent of Impairment

The federal Clean Water Act (CWA) requires states to identify water bodies that do not meet their designated beneficial uses and develop programs to eliminate impairments. Section 303(d) of the CWA requires states to develop TMDLs for impaired waterbodies. 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 identified the Delta as impaired for mercury in 1990 because elevated mercury levels in fish posed a health risk for human and wildlife consumers. In 2000, USEPA promulgated the California Toxics Rule (CTR) that includes a water quality criterion for priority pollutants, including a criterion of 50 nanograms per liter (ng/L) for total mercury in water (40 CFR § 131.38(b)(1)). The numeric criteria were determined to be necessary in California to protect human health and the environment. In addition, the San Francisco Bay Regional Water Quality Control Board (San Francisco Bay Water Board) identified Central Valley outflows from the Delta as one of the primary sources of total mercury to San Francisco Bay and in 2006 assigned the Central Valley a load reduction of 110 kilograms per year (kg/yr) (Looker and Johnson 2004; SFBRWQCB 2006). Therefore, the DMCP is designed to protect human and wildlife health in the Delta and meet the Central Valley's total mercury load allocation from the San Francisco Bay Water Board.

The TMDL geographic scope included all areas within the legal Delta boundary and the entire Yolo Bypass. This scope was divided into eight Delta TMDL subareas based on hydrologic characteristics and mixing of the source waters. For example, the Yolo Bypass was split into two subareas: Yolo Bypass - North and Yolo Bypass - South. Board staff refers to this geographic scope as the Delta MeHg TMDL Boundary. While the Cache Creek Settling Basin (CCSB) was not included within the TMDL boundary for the 2010 TMDL Staff Report, Board staff proposes including the CCSB as part of the Yolo Bypass - North subarea in this report. Therefore, source loads from the CCSB are considered to occur within the Yolo Bypass - North subarea rather than as a tributary source, as in the 2010 TMDL Staff Report.

Total mercury load reductions in the Delta are needed to maintain compliance with the CTR total mercury criterion of 50 ng/L, comply with the San Francisco Bay mercury control program load allocation, and decrease the detrimental health effects of methylmercury bioaccumulation.

The 2010 TMDL Staff Report identified both methylmercury and total mercury sources; however, only allocations for methylmercury were assigned to dischargers. For the DMCP Review, Board staff focused on methylmercury sources and updated the methylmercury allocations assigned to dischargers. Board staff also updated different sections of the 2010 TMDL Staff Report (e.g., numeric targets, linkage analysis, methylmercury source analysis, methylmercury allocations) as summarized below.

ES.2 Numeric Targets

The 2010 TMDL Staff Report selected methylmercury concentration in fish tissue as the numeric target for the TMDL. The 2010 numeric targets were developed to protect humans and wildlife based on fish consumption rates using a method approved by the USEPA and Delta-specific information. In order to protect humans eating one serving a week of large fish, as well as wildlife species that consume large and small fish, the following methylmercury numeric targets were recommended and adopted into the Basin Plan as WQOs:

- 0.24 milligram per kilogram (mg/kg) in large trophic level four (TL4) fish
- 0.08 mg/kg in large trophic level three (TL3) fish
- 0.03 mg/kg in whole trophic level two (TL2) and TL3 fish less than 50 millimeters (mm) in length

In the 2010 TMDL Staff Report, these numeric targets were used to predict equivalent mercury concentrations in a standardized 350 mm largemouth bass. The lowest predicted mercury concentration in 350 mm largemouth bass was found to be 0.24 mg/kg and determined to be the most protective of both human and wildlife health. Therefore, the mercury concentration of 0.24 mg/kg was set as the standardized 350 mm largemouth bass implementation goal. The largemouth bass implementation goal was used in the linkage model to determine the ambient aqueous MeHg implementation goal. The aqueous MeHg implementation goal was used to develop allocations.

Methods and assumptions of the 2010 TMDL Staff Report, including the numeric targets listed above, were maintained for the DMCP Review's reevaluation of the Numeric Targets (Section 4), except for the following:

2010 TMDL Staff Report Numeric Targets	**DMCP Review Numeric Targets**
Used term "Trophic Level Food Group Evaluation".	Shortened term to "Trophic Level Group Evaluation" for brevity and clarity.
Used fish data collected between 1998 and 2001.	Used fish data collected between 1998 and 2019 to incorporate new data.
Only identified whole-body data used for the TL3 group evaluation.	Clarified that both fillet and whole-body data were used for the TL3 group evaluation.
Yolo Bypass - North and - South subareas not included in trophic level group analysis because of inadequate information.	Yolo Bypass - North and - South subareas included in the trophic level group analysis.

2010 TMDL Staff Report Numeric Targets	DMCP Review Numeric Targets
Developed a largemouth bass implementation goal.	Developed a black bass implementation goal using largemouth bass (*M. salmoides*), smallmouth bass (*M. dolomieu*), and spotted bass (*M. punctulatus*) to include bass data for the Sacramento River subarea, which did not contain largemouth bass as part of the Delta Regional Monitoring Program (RMP) data set.
Evaluated linear, exponential, logarithmic, and power regression models for standardizing largemouth bass mercury concentrations to 350 mm and developing the largemouth bass implementation goal.	Evaluated nonlinear least squares (NLS) and generalized additive model (GAM) regression models in addition to linear, exponential, logarithmic, and power regression models.
The regression curve that provided the highest R^2 value was selected.	The regression curve with the lowest standard error of regression (SER) was selected.
Determined the largemouth bass implementation goal to be 0.24 mg/kg, which was used to determine a protective aqueous methylmercury concentration.	Determined the black bass implementation goal to be 0.258 mg/kg, which was used to determine a protective aqueous methylmercury concentration.

ES.3 Linkage

The linkage analysis in the 2010 TMDL Staff Report focused on the comparison of methylmercury concentrations in water and biota, specifically fish. This assumed that ambient aqueous methylmercury concentrations are the primary factor in determining fish tissue methylmercury concentrations, based on empirical evidence.

Methods and assumptions of the 2010 TMDL Staff Report were maintained for the DMCP Review's reevaluation of the Linkage Analysis (Section 5), except for the following:

2010 TMDL Staff Report Linkage Analysis	DMCP Review Linkage Analysis
Used the largemouth bass implementation goal to determine the aqueous MeHg implementation goal.	Used the black bass implementation goal to determine the aqueous MeHg implementation goal.
Evaluated largemouth total mercury data collected in 1998 through 2000 and aqueous methylmercury data collected in 2000 through 2004.	Evaluated black bass total mercury and aqueous methylmercury data collected in 2000 through 2019.

2010 TMDL Staff Report Linkage Analysis	DMCP Review Linkage Analysis
Board staff choose aqueous methylmercury and largemouth bass mercury (Hg) concentrations from year 2000 to maximize overlap of data.	The year range of aqueous methylmercury and black bass total mercury concentrations overlapped but not every year contained overlapping data. Board staff evaluated three year ranges (2000-2019, 2012-2019, and 2016-2019).
Evaluated whether the mean or median would be a better measure of central tendency for aqueous methylmercury concentrations.	Evaluated whether the mean, geomean, weighted average, or median would be a better measure of central tendency for aqueous methylmercury concentrations and black bass total mercury concentrations.
Regressed aqueous methylmercury concentrations on largemouth bass total mercury concentrations using linear, exponential, logarithmic, and power regression models.	Regressed aqueous methylmercury concentrations on black bass total mercury concentrations using NLS and GAM regression models in addition to linear, exponential, logarithmic, power regression models.
Evaluated a total of 8 linkage models using median or mean as a measure of central tendency and the four regression models.	Evaluated a total of 405 linkage models using the different measures of central tendency and six regression models.
The regression curve that provided the highest R^2 value was selected.	The regression curve with the lowest SER was selected.
The final linkage model paired the mean methylmercury concentration with the largemouth bass Hg concentration standardized to 350 mm using data from year 2000.	The final linkage model paired the median aqueous methylmercury concentration with the median black bass Hg concentration standardized to 350 mm using aqueous methylmercury and black bass Hg data from 2016-2019 Delta RMP.
An explicit margin of safety of 0.006 ng/L was applied to the protective aqueous methylmercury concentration of 0.066 ng/L to set the aqueous MeHg implementation goal of 0.06 ng/L, which equates to a margin of safety of about 10%.	The probability distribution of the protective aqueous methylmercury concentration was determined using random resampling of the linkage model data. The 5th percentile value, 0.059 ng/L, from the probability distribution was set as the aqueous MeHg implementation goal, which equates to a margin of safety of 3.3%.

ES.4 Source Analysis – Methylmercury

The methylmercury source analysis section of the 2010 TMDL Staff Report estimated average annual methylmercury inputs and exports for water years (WY) 2000 to 2003, a relatively dry period. Sources were identified as: tributary inputs from upstream watersheds; sediment flux from wetlands, open water, and floodplains; municipal and non-municipal wastewater; agricultural drainage; urban runoff; dredged material placement site (DMPS) return water; atmospheric deposition; and runoff from rangeland and other open space areas. Of these sources, not all were incorporated numerically into the source analysis. Those that were not quantified and only included as a qualitative assessment were the following:

- Sediment flux from floodplains, when inundated
- Agricultural areas in the Yolo Bypass north of the legal Delta boundary
- Runoff from agricultural areas
- Runoff from rangeland and other open-space areas
- DMPS return water

Losses were identified as outflows to the San Francisco Bay and southern California, dredging projects, photodegradation, particle settling, and accumulation. Losses that were only included as a qualitative assessment were the following:

- Photodegradation
- Particle settling
- Accumulation in biota

Board staff reviewed and updated the methylmercury source analysis section using information and data collected by the Delta RMP, dischargers in Phase 1 control and characterization studies, recent studies, and other sources (Section 6). Key differences between the DMCP Review and 2010 TMDL Staff Report methylmercury source analyses are as follows:

2010 TMDL Staff Report Methylmercury Source Analysis	DMCP Review Methylmercury Source Analysis
Used data from WYs 2000 through 2003, a relatively dry period.	Used data from WYs 2000 through 2019, a period that encompasses a mix of wet and dry conditions, unless otherwise stated in respective sections.
Primarily used arithmetic means to summarize data.	Primarily used medians to summarize data. Thus, Board staff cautions comparisons of estimates between the two documents: just because a load value is lower in the DMCP Review does not indicate a reduction has occurred.

2010 TMDL Staff Report Methylmercury Source Analysis	DMCP Review Methylmercury Source Analysis
Evaluated evaporation rates over open water area in the Delta.	Evaluated evaporation rates over open water, wetland, agricultural, and native vegetation area in the Delta.
Considered CCSB outside the Delta MeHg TMDL Boundary, and therefore was included in tributary loading.	Considered CCSB to be within the Yolo Bypass - North subarea. Board staff evaluated loading from Cache Creek inflows to the CCSB and outflows from CCSB using medians, stream flow gages, and aqueous methylmercury samples. Board staff used the difference of CCSB (includes outflow and overflow weir) and Cache Creek (inflow to the CCSB) as the CCSB annual water volume and methylmercury loading.
Did not estimate loads from Sacramento Weir spills.	Estimated loads from Sacramento Weir spills.
Used one benthic flux rate for all wetlands and determined all wetlands were a methylmercury source.	Separately considered loading from tidal and nontidal wetlands, which concluded tidal wetlands are a net methylmercury sink.
Accounted for one month of atmospheric deposition loading.	Accounted for annual atmospheric deposition loading.
Used effluent flow and methylmercury data from 2000 through 2003 to calculate loading from National Pollutant Discharge Elimination System (NPDES) wastewater treatment facilities (WWTFs).	Used five most recent years of available data from 2010 through 2021 of effluent discharges to calculate loading from NPDES WWTFs.
Did not quantitatively estimate particle settling and photodegradation loss terms, assuming them to be equal to the difference between estimated sources and losses.	Quantified methylmercury losses from particle settling and photodegradation.
Calculated methylmercury loads for NPDES WWTFs with more than one discharge location by pooling aqueous and flow data from all discharge locations and then performing the load calculation.	Calculated methylmercury loads for NPDES WWTFs with more than one discharge location by summing the calculated loads from each discharge location.
Quantified the methylmercury loss in dredged sediment only, noting that dredging may be a methylmercury source to be assessed in the DMCP Review.	Quantified dredging methylmercury source and loss in water and sediment, resulting in a net loss.

ES.5 Source Analysis – Total Mercury & Suspended Sediment

The 2010 TMDL Staff Report included a total mercury and suspended sediment (measured as total suspended solids, or TSS) source analysis. The assessment concluded that more than 97% of the identified total mercury loading to the Delta MeHg TMDL Boundary came from tributary inputs, and that within-Delta sources are a very small component of overall loading (Wood *et al*. 2010).

In the DMCP Review, Board staff evaluated the total mercury and suspended sediment section of the 2010 TMDL Staff Report for revision and determined a revision was not within the scope of the review of Phase 1 (Section 7). Further, Board staff anticipates the development of future upstream mercury control programs will include specific and more detailed analyses of total mercury and suspended sediment.

ES.6 Methylmercury Allocations & Total Mercury Limits

The 2010 TMDL Staff Report's methylmercury allocations were made in terms of the assimilative capacity of each Delta TMDL subarea. To determine the reduction of methylmercury in ambient Delta waters needed to achieve the fish targets, the average methylmercury concentration in ambient water in each Delta TMDL subarea was compared to the aqueous methylmercury implementation goal of 0.06 ng/L. The amount of reduction needed in each subarea was expressed as a percent of the ambient methylmercury concentration to the aqueous methylmercury implementation goal. For the DMCP Review, Board staff recalculated the methylmercury allocations using more recent data and the proposed aqueous methylmercury implementation goal of 0.059 ng/L.

A total mercury load reduction strategy was developed in the 2010 TMDL Staff Report to comply with the San Francisco Bay mercury control program, to maintain compliance with the CTR criterion of 50 ng/L, and to help reduce aqueous methylmercury in the Delta. Board staff concluded that 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. The development of future upstream mercury control programs to implement strategies for minimizing total mercury loading to the Delta and ultimately the San Francisco Bay is necessary for compliance and attainment of mercury and methylmercury goals. Board staff maintains the conclusions and recommendations of the 2010 TMDL Staff Report's total mercury limits in the DMCP Review.

Board staff reviewed and updated the methylmercury allocations, margin of safety, and periodic variability sections (Section 8) using the findings from the DMCP Review methylmercury source analysis (Section 6). Key differences between the DMCP Review and 2010 TMDL Staff Report methylmercury allocations are as follows:

2010 TMDL Staff Report Methylmercury Allocations	**DMCP Review Methylmercury Allocations**
Used data from WYs 2000 through 2003, a relatively dry period.	Used data from WYs 2000 through 2019, a period that encompasses a mix of wet and dry conditions, unless otherwise stated in respective sections.
Used gross and net methylmercury loading of identified sources to and within Delta TMDL subareas.	Used gross methylmercury loading of sources to and within Delta TMDL subareas. For sources that are net sinks of methylmercury, Board staff assigned the source a 100% allocation.
Considered CCSB as a tributary source and assigned it an LA, which incorporated methylmercury loads from Cache Creek.	Incorporated Cache Creek Settling Basin within the Delta MeHg TMDL Boundary and assigned it an LA based on gross methylmercury loads at the outflow and overflow weir. Cache Creek was assigned an LA based on gross methylmercury loads prior to the basin.
Did not estimate Sacramento Weir spills, therefore did not assign a tributary LA for the Sacramento Weir.	Assigned an LA for Sacramento Weir spills.
Dredging was not included due to lack of source loading data availability.	Dredging gross loading included in allocations.
Estimated the average population growth to be 120% by 2050.	Estimated the median population growth to be 25% from 2020 through 2060.
60%, half of the average population growth, was used to calculate unassigned allocations for NPDES WWTFs.	Median population growth of 25% used to calculate unassigned allocations for NPDES WWTFs.
60%, half of the average population growth, used to calculate future growth allocations for NPDES WWTFs with effluent concentrations less than the aqueous MeHg implementation goal.	50%, double the median population growth, used to calculate future growth allocations for NPDES WWTFs with effluent concentrations less than the aqueous MeHg implementation goal.
California Department of Transportation (Caltrans) jurisdictional areas were not identified separately, being both within and outside other Municipal Separate Storm Sewer System (MS4) jurisdictional areas, resulting in Caltrans having a shared WLA with other MS4s and an LA of urban runoff from nonpoint sources.	Caltrans jurisdictional areas outside other MS4 jurisdictional areas were estimated, resulting in Caltrans having a shared WLA with other MS4s for areas within those MS4 jurisdictional areas and specific WLAs for Caltrans jurisdictional areas outside other MS4 jurisdictional areas.

2010 TMDL Staff Report Methylmercury Allocations	DMCP Review Methylmercury Allocations
MS4 methylmercury concentration used to estimate loads was average of all wet weather concentrations, 0.241 ng/L.	MS4 methylmercury concentration used to estimate loads was the weighted annual median concentration, 0.180 ng/L.
Incorporated an unassigned allocation for future flows from NPDES WWTFs that were not evaluated in the DMCP.	Incorporated an unassigned allocation for future flows from NPDES WWTFs, and MS4s in the Delta MeHg TMDL Boundary that were not evaluated in the DMCP Review.
Did not detail methylmercury allocation compliance calculation recommendations.	Board staff detailed recommended methylmercury allocation compliance calculations in Section 8.1.4.

1 INTRODUCTION

The federal CWA requires states to identify waterbodies that do not meet their designated beneficial uses and develop programs to eliminate impairments. Section 303(d) of the CWA requires states to develop TMDLs for impaired waterbodies. A TMDL is the total maximum daily load of a pollutant that a waterbody can assimilate and still attain beneficial uses. The CWA does not expressly require the implementation of TMDLs; TMDL implementation is largely a function of state law, which requires a program of implementation to achieve water quality objectives be incorporated into Water Quality Control Plans. (Cal. Wat. Code, §§ 13050, subd. (j), 13242.)

The Central Valley Water Board identified the Delta as impaired for mercury in 1990 because elevated fish mercury levels posed a risk for consumption by humans and wildlife. In addition, the San Francisco Bay Water Board identified Central Valley outflows through the Delta as one of the primary sources of total mercury to San Francisco Bay and assigned the Central Valley a load reduction of 110 kg/yr (Looker and Johnson 2004; SFBRWQCB 2006). Therefore, the final mercury TMDL control plan for the Delta is designed to protect human and wildlife health in the Delta and meet the Central Valley's mercury load allocation from the San Francisco Bay Water Board.

In 2010, the Central Valley Water Board adopted the DMCP as an amendment (2010 BPA; Central Valley Water Board Resolution R5-2010-0043) to the Basin Plan. The DMCP required dischargers to conduct methylmercury control and characterization studies. The DMCP also requires Board staff to review the DMCP and consider revising objectives, allocations, implementation strategies and schedules, and the Final Compliance Date for dischargers. The period of implementation development is referred to as Phase 1 and Board staff's review of the DMCP Phase 1 is referred to as the DMCP Review. The DMCP expected the DMCP Review to be completed by 20 October 2020 and allowed for up to a two-year extension of the DMCP Review if the control study schedule was extended. Due to delays in dischargers submitting final control study reports, staffing shortages, and the COVID-19 pandemic, the DMCP Review was not completed by 20 October 2022. The DMCP further states that Phase 2 begins after the DMCP Review or 20 October 2022, whichever comes first. Therefore, Phases 1 and 2 are concurrent until Central Valley Water Board approval of the DMCP Review.

This Report presents Board staff's review of and proposed updates to the phased DMCP. The next steps in the DMCP Review process are to consider feedback from the scientific peer reviewers, incorporate necessary revisions and develop a draft staff report, and write a Basin Plan amendment along with all of the required substitute environmental documentation (SED). The draft staff report and Basin Plan amendment, and SED package will go through the regulatory public review process that includes: a public meeting; Central Valley Water Board adoption hearing; and State Water Board consideration for approval hearing and then approval by the Office of Administrative Law, and USEPA.

This Report contains a reevaluation of methylmercury implementation goals, sources, losses, allocations, and recommended reduction strategies to eliminate the Delta mercury impairment. Board staff updated sections of the 2010 TMDL Staff Report using Delta-specific studies and data collected during Phase 1. To meet state and federal requirements for TMDL development, this report is comprised of the following key sections:

- **Section 2** – Problem Statement: Updates the timeline and process of the DMCP, proposes incorporation of the CCSB into the Delta MeHg TMDL Boundary, and lists the existing and potential beneficial uses of waterways within the scope of the TMDL
- **Section 3** – Potentially Controllable Processes: Describes recent developments in mercury science related to the potentially controllable methylation processes in the Delta, including findings on control measures tested in the Phase 1 DMCP characterization and control studies
- **Section 4** – Numeric Targets: Updates the black bass implementation goal that, if met, would protect beneficial uses of Delta waters
- **Section 5** – Linkage Analysis: Updates the mathematical relationship between aqueous methylmercury concentrations and the black bass total mercury concentrations. This relationship is used to determine an aqueous methylmercury implementation goal that guides methylmercury source reduction allocations within the Delta MeHg TMDL Boundary
- **Section 6** – Methylmercury Source Analysis: Updates quantified concentrations and loads of methylmercury sources
- **Section 7** – Total Mercury Source Analysis: Describes reasons Board staff determined to not update the 2010 TMDL Staff Report’s Total Mercury and Total Suspended Solids Source Analysis in the DMCP Review
- **Section 8** – Allocations: Updates recommended methylmercury allocations for Delta sources to reduce fish mercury concentrations and comply with regulatory limits. Describes the margin of safety afforded by the analyses’ uncertainties and consideration of seasonal variation, climate change, and critical conditions

2 PROBLEM STATEMENT

Board staff reviewed Section 2 of the 2010 TMDL Staff Report and determined that revising portions of the Problem Statement were necessary in the DMCP Review. Board staff maintains the information provided in the 2010 TMDL Staff Report Section 2 continues to be accurate, with the following updated information provided below.

2.1 Regulatory Background & TMDL Timeline

In the 2010 TMDL Staff Report, this section included an overview of federal and state regulatory background, an overview of the TMDL timeline and process, and defined units and terms used in the report. Board staff determined providing updates for the TMDL timeline (Section 2.1.3 below) were necessary in the DMCP Review and maintains the provided regulatory background information and definitions are applicable for this report.

2.1.1 Clean Water Act 303(d) Listing & TMDL Development

After evaluation of this section in the 2010 TMDL Staff Report, no revision is necessary for the DMCP Review and Board staff maintains the section as is.

2.1.2 Porter-Cologne Basin Plan Amendment Process

After evaluation of this section in the 2010 TMDL Staff Report, no revision is necessary for the DMCP Review and Board staff maintains the section as is.

2.1.3 Timeline & Process for the Delta Mercury Management Strategy

The 2010 TMDL Staff Report Section 2.1.3 included an overview of the DMCP timeline and process of the DMCP development and associated documents. An update to this timeline is provided below.

On 22 April 2010, the DMCP was adopted by the Central Valley Water Board as a Basin Plan amendment and included a phased approach for addressing the methylmercury impairment in the Delta (Central Valley Water Board Resolution R5-2010-0043). It was approved by the State Water Resources Control Board (State Water Board) and the California Office of Administrative Law on 15 September 2011 (SWRCB 2011). Final approval by the USEPA was received on 20 October 2011 (USEPA 2011).

The DMCP requires Board staff to review the DMCP and consider revising objectives, allocations, implementation strategies and schedules, and the Final Compliance Date for dischargers. The DMCP expected the DMCP Review to be completed by 20 October 2020 and allowed for up to a two-year extension of the DMCP Review if the control study schedule was extended. Due to delays in submission of final control study reports, extension requests being granted, staffing shortages, and the COVID-19 pandemic, the DMCP Review was not completed by 20 October 2022. The DMCP further states that Phase 2 of the DMCP begins after the DMCP Review or 20 October 2022, whichever occurs first. Therefore, Phases 1 and 2 are concurrent until Central Valley Water Board approval of the DMCP Review.

Public and tribal input on the DMCP Review is sought throughout the TMDL and Basin Plan amendment processes which include tribal consultations, public scoping meetings, public workshops, and formal hearings. Tribal consultations under AB 52 were completed in 2020 and the California Environmental Quality Act (CEQA) Scoping and Public Workshop was held on 24 February 2021. This Report will be scientifically peer reviewed, the reviews will be provided publicly, and addressed as appropriate in a draft version of the DMCP Review TMDL Staff Report. The draft DMCP Review TMDL Staff Report may incorporate additional information and address public and tribal input received on this Report, including modification of implementation recommendations. The draft DMCP Review TMDL Staff Report will be presented to the Central Valley Water Board for their consideration at the DMCP Adoption Hearing. The final DMCP Review TMDL Staff Report package will be submitted for approval by the State Water Board, Office of Administrative Law, and USEPA. Due to the extensive review and approval process, the timeline of Basin Plan amendments varies.

2.1.4 Units & Terms Used in this Report

The 2010 TMDL Staff Report defined units and terms in Section 2.1.4 used in the report. For the DMCP Review, Board staff included a Glossary table and a Units of Measure table in the beginning of this report.

2.2 Delta Characteristics & TMDL Scope

This section incorporates applicable revisions to the 2010 TMDL Staff Report Section 2.2: updated statistics on the characteristics and geography of the Delta (Section 2.2.1), and updated Delta MeHg TMDL Boundary to include the CCSB (Section 2.2.2).

2.2.1 Delta Geography

The 2010 TMDL Staff Report included an overview of the geography and summarized characteristics of the Delta in Section 2.2.1.

Board staff maintain the geographic overview and summarized characteristics of the Delta are relevant and applicable, as written in Section 2.2.1 in the 2010 TMDL Staff Report, for the DMCP Review.

2.2.2 TMDL Scope & Delta Subarea

In the DMCP Review, Board staff propose the only update required for Section 2.2.2 of the 2010 TMDL Staff Report is the incorporation of the CCSB within the Delta MeHg TMDL Boundary, specifically within the Yolo Bypass - North subarea (Figure 2.1). Though the CCSB was not encompassed within the Yolo Bypass - North subarea boundary, the DMCP included requirements for a CCSB improvement plan and schedule. Cache Creek was assigned a tributary watershed methylmercury allocation for flows that enter the Yolo Bypass, which are the outflows of CCSB. However, the

DMCP specified that the CCSB has an allocation with a greater reduction assigned by the Cache Creek TMDL. Board staff propose removing the CCSB allocation from the Cache Creek TMDL and incorporating it within the Delta MeHg TMDL Boundary in the DMCP Review. This will remove overlaps of the two mercury TMDL requirements on the basin and will provide an updated allocation based on more and recent data collected. Proposed incorporation and adoption of the DMCP Review would result in an amended methylmercury allocation for the CCSB under the Delta MeHg TMDL (Table 8.21). The rest of the section is maintained as is.

The 2010 TMDL Staff Report included maps of the waterways within the scope of the TMDL boundary in Appendix A. For the DMCP Review, Board staff updated these maps, as seen in Figure 2.2 through Figure 2.6. Table 2.1 provides the names of labeled waterways from Figure 2.2 through Figure 2.6.

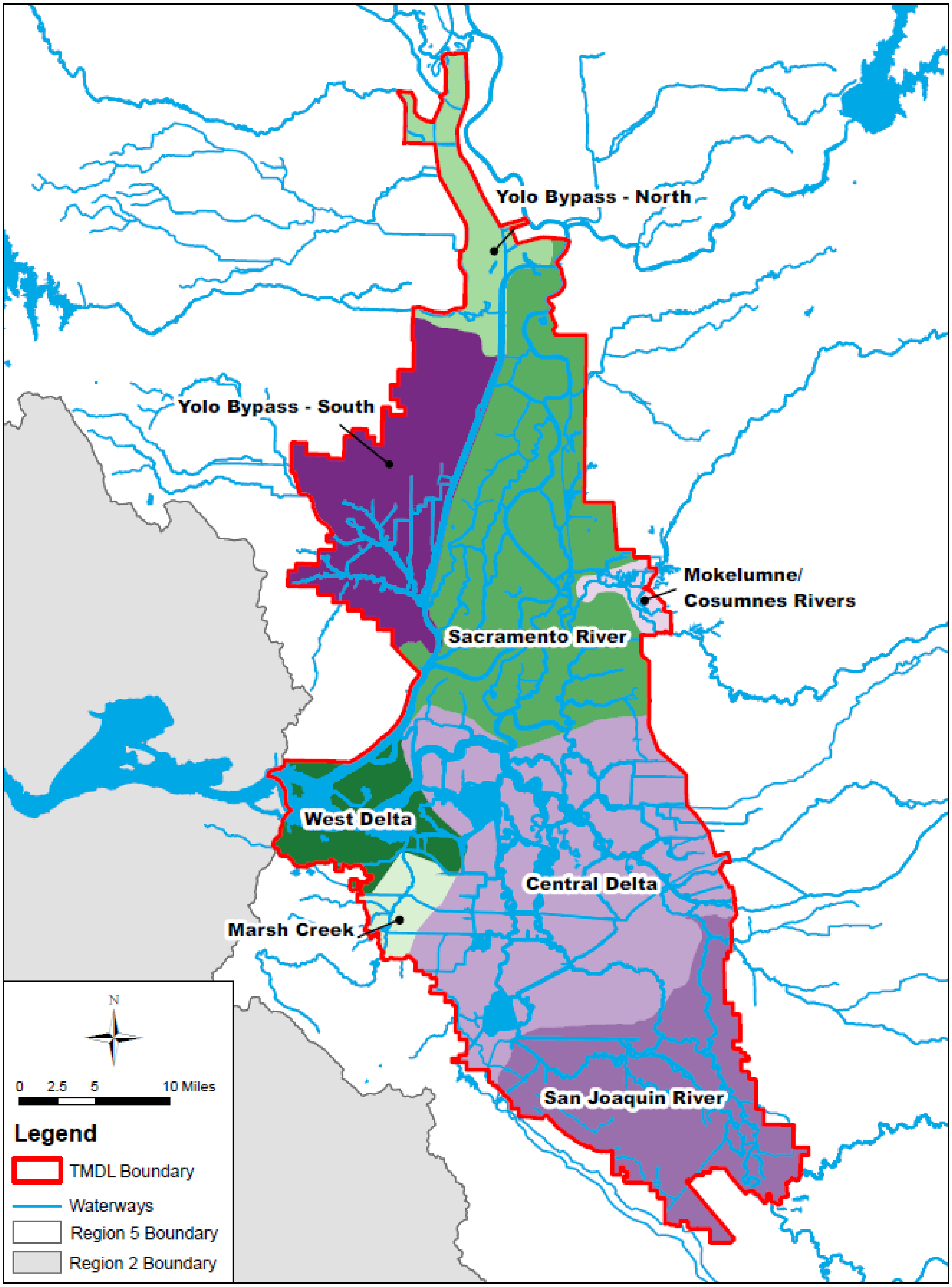

Figure 2.1: Subareas of the Delta Methylmercury Control Program Review

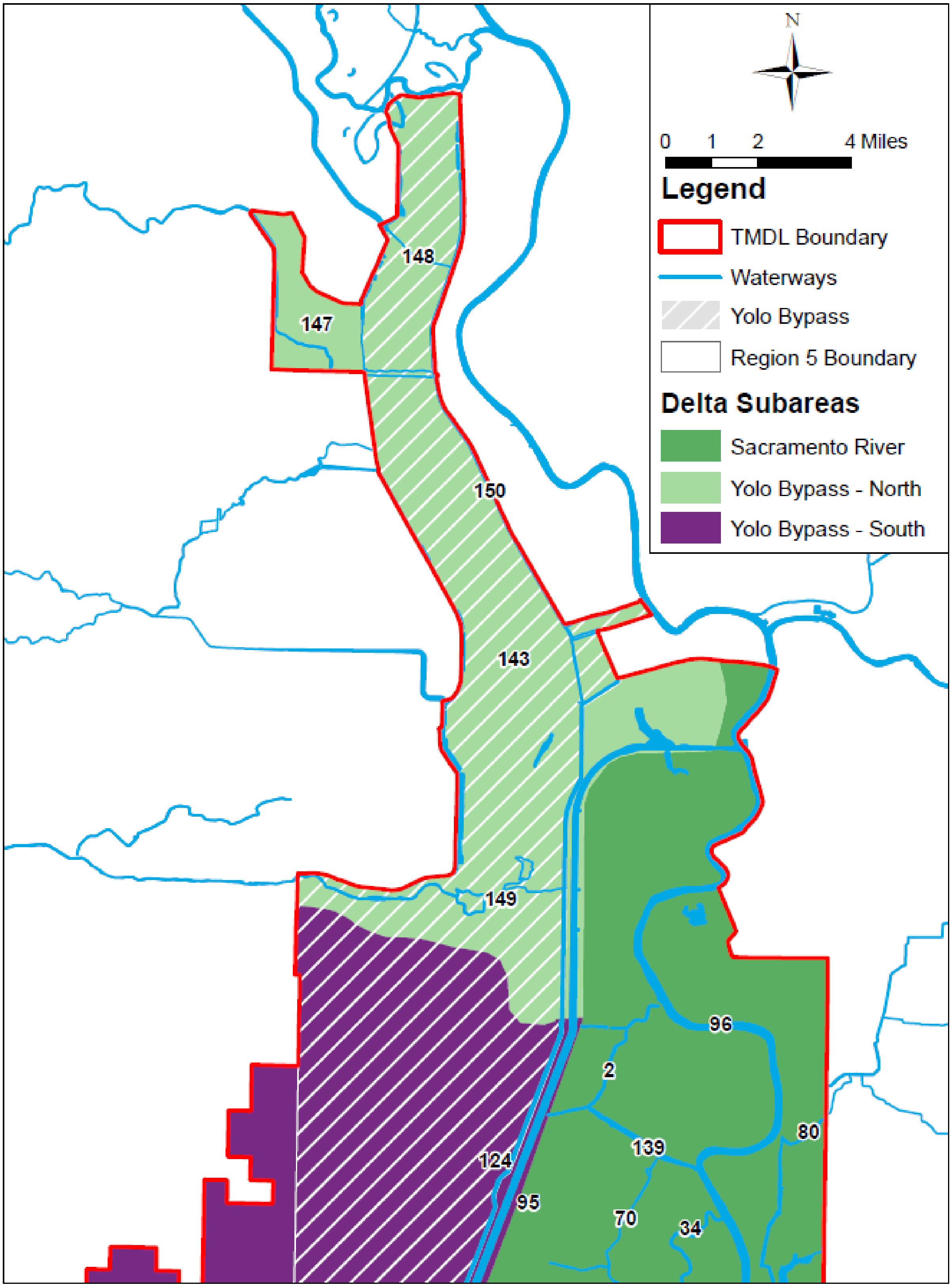

Figure 2.2: Waterways in the Yolo Bypass - North Subarea and Portions of the Sacramento River and Yolo Bypass - South Subareas

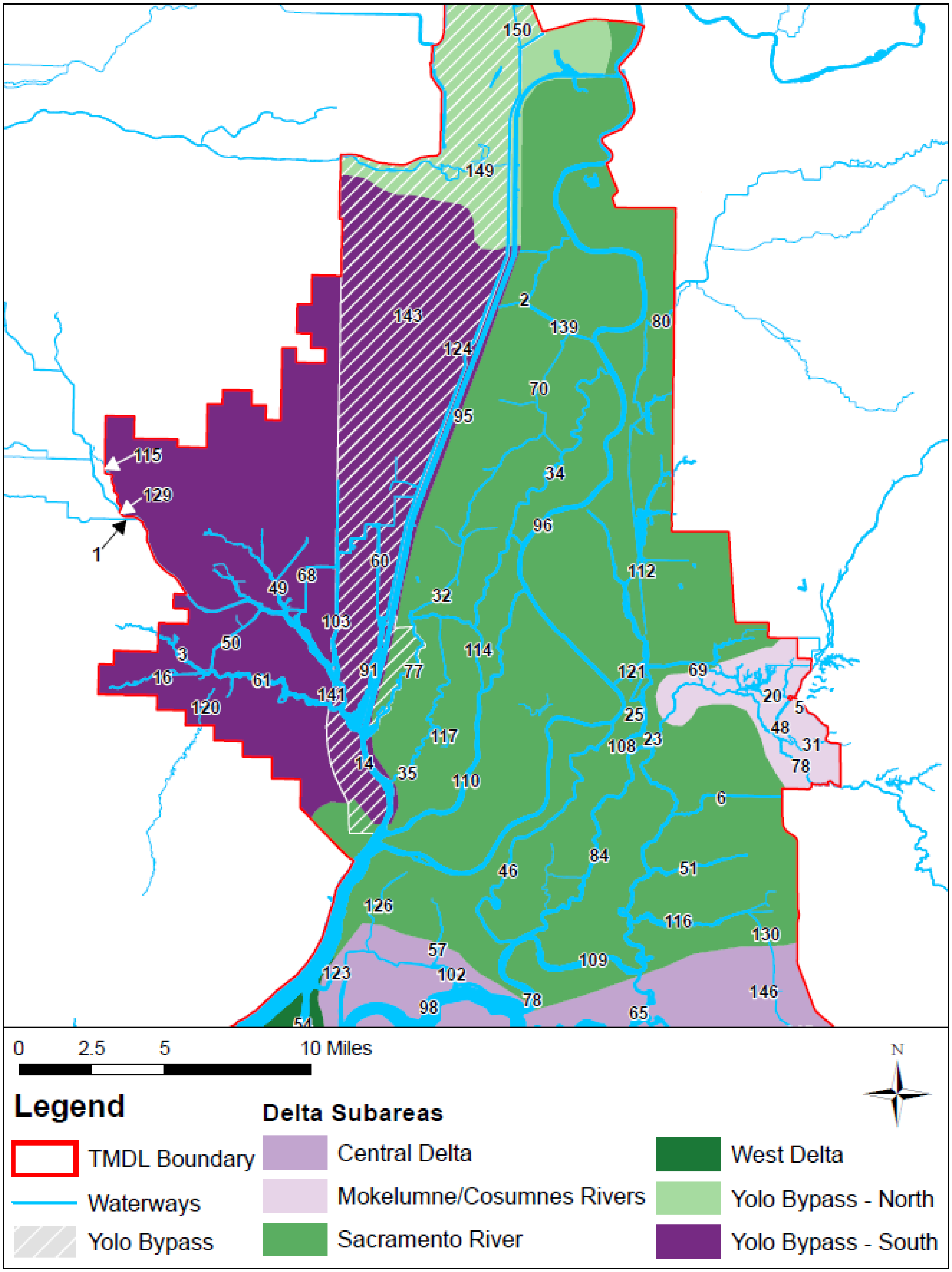

Figure 2.3: Waterways in the Yolo Bypass - South, Sacramento River, and Mokelumne/Cosumnes Rivers Subareas

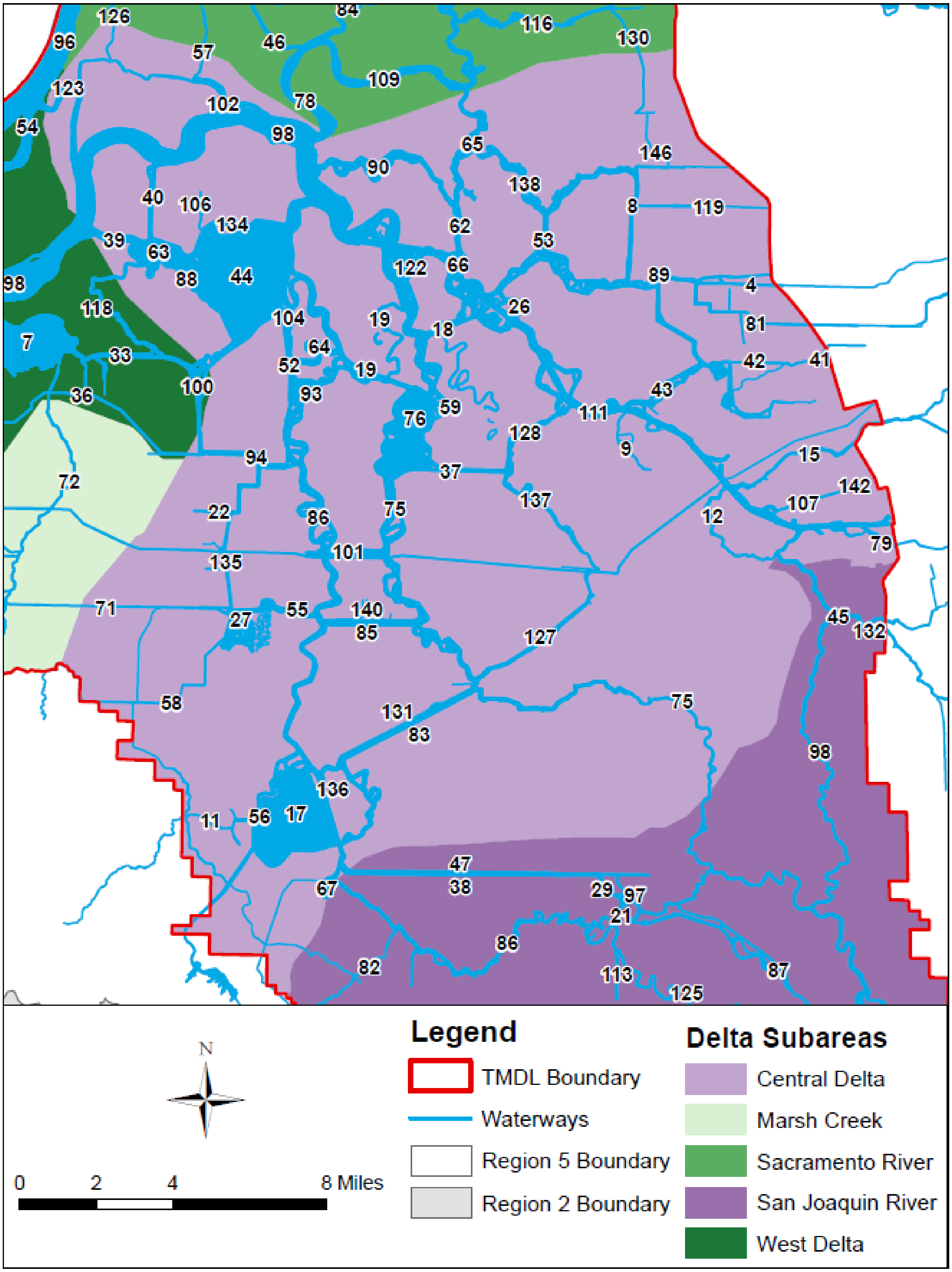

Figure 2.4: Waterways in the Central Delta Subarea

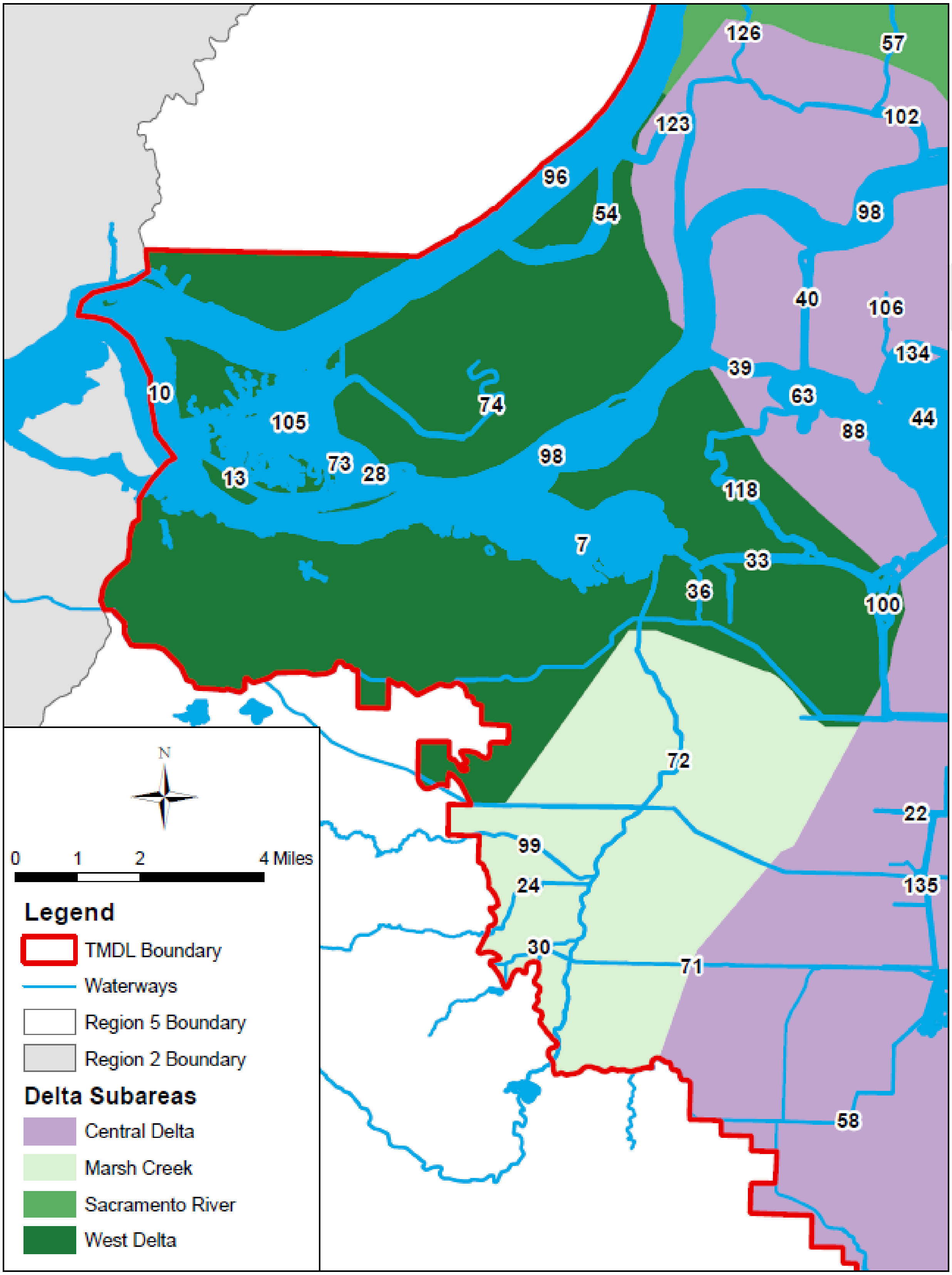

Figure 2.5: Waterways in the West Delta and Marsh Creek Subareas

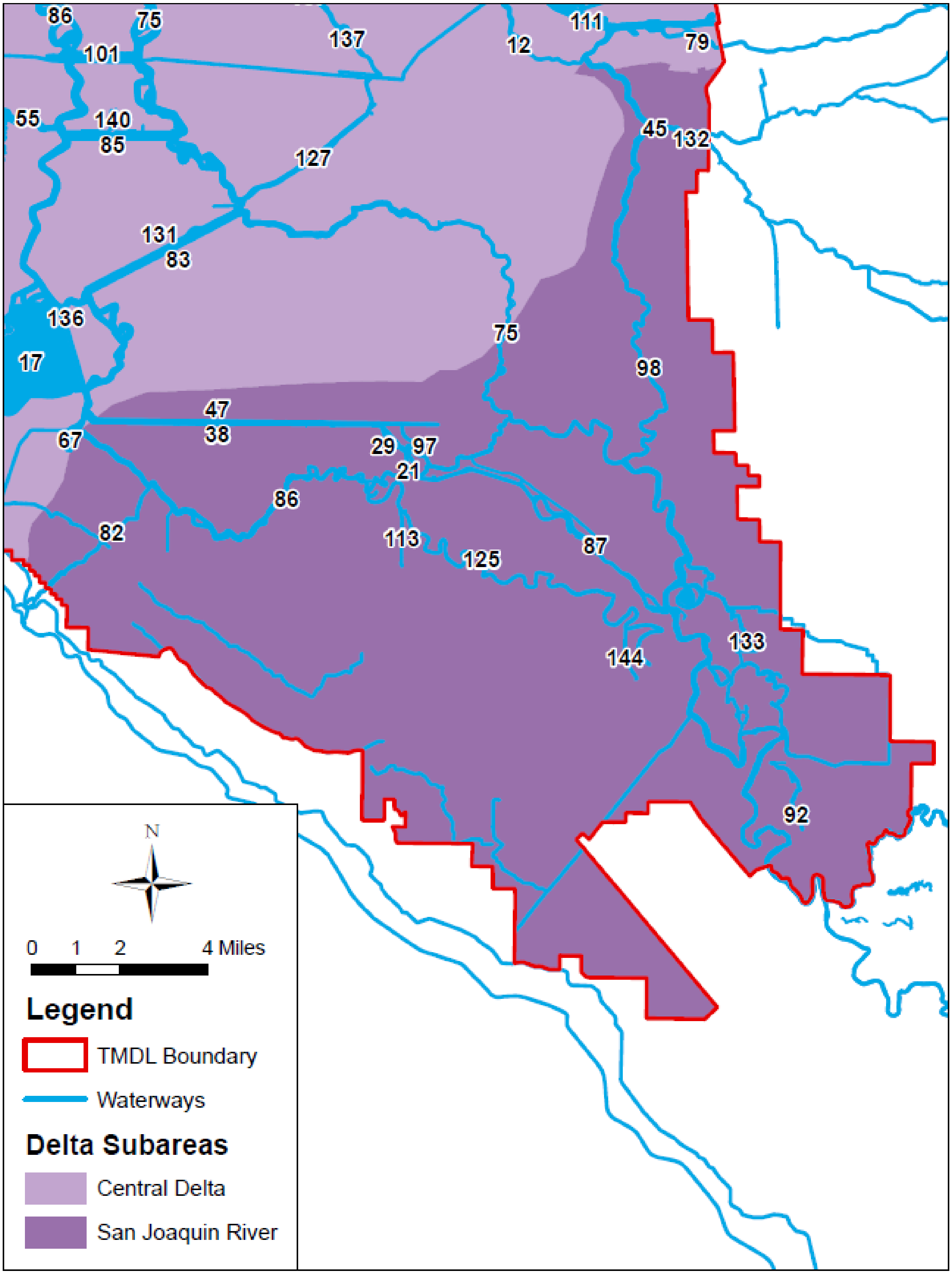

Figure 2.6: Waterways in the San Joaquin River Subarea

Table 2.1: Numbered Delta and Yolo Bypass Waterbodies within the Delta MeHg TMDL Boundary

Map Label Number	Waterbody 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

Map Label Number	Waterbody Name
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
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

Map Label Number	Waterbody Name
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
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)

Map Label Number	Waterbody Name
119	Telephone Cut
120	The Big Ditch
121	The Meadows Slough
122	Three River Reach
123	Threemile Slough
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 (includes Fremont Weir and Sacramento Weir)
144	Deuel Drain
145	Dredger Cut
146	Highline Canal
147	Cache Creek Settling Basin (includes Outflow and Overflow Weir)
148	Knights Landing Ridge Cut
149	Putah Creek
150	Tule Canal

2.3 Mercury Effects & Sources

After evaluation of this section in the 2010 TMDL Staff Report, no revision is necessary for the DMCP Review and Board staff maintains the section as is.

2.4 Beneficial Uses, Applicable Standards, & Extent of Impairment

This section incorporates applicable revisions to the 2010 TMDL Staff Report Section 2.4. Section 2.4.1 includes updated beneficial use information for the Delta and Yolo Bypass. Board staff determined revisions to Section 2.4.2 of the 2010 TMDL Staff Report were not necessary in the DMCP Review.

2.4.1 Sacramento-San Joaquin Delta Estuary Beneficial Uses

The 2010 TMDL Staff Report provided an overview of the beneficial uses in the Delta in Section 2.4.1, which included the proposal of the commercial and sport fishing (COMM) designation. With the adoption of the 2010 BPA, COMM is a designated beneficial use for the Delta, Yolo Bypass, Marsh Creek, and tributaries of Marsh Creek. The portion of Cache Creek from Clear Lake to the Yolo Bypass, which includes the CCSB, has a COMM designated beneficial use by the Cache Creek, Bear Creek, and Harley Gulch Mercury TMDL that was adopted by the Central Valley Water Board as a Basin Plan amendment on 21 October 2005 (Central Valley Water Board Resolution R5-2005-0146). Table 2.2 displays the beneficial uses of the Delta, Yolo Bypass, and Cache Creek from Clear Lake to the Yolo Bypass at the time of the DMCP Review.

On 2 May 2017, the State Water Board adopted the Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions as Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California (Statewide Mercury Provisions; SWRCB 2017). The Statewide Mercury Provisions set statewide mercury limits to protect the same beneficial uses as the DMCP. The Statewide Mercury Provisions also establish three new beneficial use definitions for Tribal Tradition and Culture (CUL), Tribal Subsistence Fishing (T-SUB), and Subsistence Fishing (SUB). The Statewide Mercury Provisions do not supersede any existing mercury TMDL or site-specific mercury objectives, including the 2011 DMCP and this DMCP Review. At the time of the DMCP Review, tribal beneficial uses have not been designated for the Delta, Yolo Bypass, and portion of Cache Creek from Clear Lake to the Yolo Bypass.

2.4.2 Applicable Standards & Extent of Impairment

After evaluation of this section in the 2010 TMDL Staff Report, no revision is necessary for the DMCP Review and Board staff maintains the section as is.

Table 2.2: Beneficial Uses of the Delta, Yolo Bypass, and Portion of Cache Creek from Clear Lake to the Yolo Bypass

Beneficial Use	Delta Status	Yolo Bypass Status	Cache Creek (Clear Lake to Yolo Bypass) Status
Municipal and domestic supply (MUN)	Existing	Not designated	Existing
Agriculture – irrigation and stock watering (AGR)	Existing	Existing	Existing
Industry – process (PROC) and service supply (IND)	Existing	Not designated	Existing
Contact recreation (REC-1)	Existing	Existing	Existing
Canoeing and rafting recreation (REC-1)	Not designated	Not designated	Existing
Non-contact recreation (REC-2)	Existing	Existing	Existing
Freshwater habitat – warm water species (WARM)	Existing	Existing	Existing
Freshwater habitat – cold water species (COLD)	Existing	Potential	Potential
Spawning, reproduction, or early development of fish – warm water species (SPWN)	Existing	Existing	Existing
Wildlife habitat (WILD)	Existing	Existing	Existing
Migration of aquatic organisms – warm and cold water species (MIGR)	Existing	Existing	Not designated
Navigation (NAV)	Existing	Not designated	Not designated
Commercial and sports fishing (COMM)	Existing	Existing	Existing

2.5 Key Points

- Board staff maintained the information provided in Section 2 of the 2010 TMDL Staff Report, with the following updates:
    - This report provides Board staff recommendations after review and reevaluation of the first phase of the DMCP.
    - Board staff propose incorporating the Cache Creek Settling Basin within the scope of the Delta MeHg TMDL Boundary.
    - With the adoption of the 2010 BPA, the COMM beneficial use was designated to the waterways of the Delta and Yolo Bypass.

3 POTENTIALLY CONTROLLABLE METHYLATION PROCESSES IN THE DELTA

The 2010 TMDL Staff Report Section 3 evaluated potentially controllable methylation processes in the Delta. The section included an overview of the dynamics and dangers of the different forms of mercury in the environment and potential options to decrease mercury concentrations and availability. The relationships of methylmercury with sulfate reducing bacteria and other parameters, such as sulfide, electrical conductivity (EC), and salinity, was discussed in Section 3.1. Section 3.2 described the effect of new water impoundments on sediment microbial activity and methylmercury concentrations. Study findings on the link between total mercury concentrations in sediment and methylmercury production were summarized in Section 3.3. The history of the transport of different forms of mercury was detailed in Section 3.4. A summary of study results on methylmercury production in wetlands was included in Section 3.5. And lastly, the loss of methylmercury by sedimentation and photodemethylation were described in Section 3.6.

For the DMCP Review, Board staff reviewed the 2010 TMDL Staff Report Section 3, maintains that the information is accurate and relevant, and determined that it was necessary to include updates to the section below in order to provide results from more recent studies and the Phase 1 characterization and control studies (see Appendix E for Board staff summaries of each characterization and control study).

3.1 Sulfate

After evaluation of this section in the 2010 TMDL Staff Report, no revision is necessary for the DMCP Review and Board staff maintains the section as is.

3.2 New Water Impoundments

The 2010 TMDL Staff Report stated concern that new water impoundment projects may impact sediment microbial activity and increase methylmercury concentrations in sediment, water, and biota.

With the recent severe droughts in California and the prospective effects of climate change, the need for effective and efficient water storage and conveyance has become a higher priority. Board staff included overviews on potential impacts of climate change on the water balance in Section 6.1.13, potential impacts of climate change on the methylmercury mass balance in Section 6.4.1, and future water infrastructure projects that may impact mercury and methylmercury levels in Section 8.4. Environmental planning for these projects should evaluate the potential impacts a project may have on mercury impairments of effected waterways.

3.3 Sediment Mercury Concentrations & Controls

The 2010 TMDL Staff Report summarized study findings that linked methylmercury production to total mercury content in sediment, showed potential variation by land use type, and determined fish mercury concentrations declined after implementing control measure to reduce incoming mercury loads. For the DMCP Review, Board staff provide the following information as an update to this section of the 2010 TMDL Staff Report.

One of the studies mentioned in the 2010 TMDL Staff Report compared concentrations at 21 basins across the United States and found that the methylmercury concentration in sediment increased logarithmically with the increase of the total mercury concentration (Krabbenhoft *et al.* 1999). A more recent study compiled samples on mercury and methylmercury in sediment in different aquatic environments from over 11,000 locations across western North American and only found a weak correlation between methylmercury and total mercury concentrations (Fleck *et al.* 2016). The study also found that methylmercury and total mercury concentrations varied by land use. Additionally, the entire dataset's median percent of methylmercury to total mercury displayed a low methylation efficiency; however, a significant subset of the data displayed an elevated methylation efficiency.

The San Francisco Water Board assigned outflows from the Central Valley a total mercury load reduction of 110 kg/yr (SFBRWQCB 2006). The 2010 TMDL Staff Report stated management actions of the DMCP could consider controlling mercury from upstream watersheds that have high mercury and sediment loads to the Delta to meet the San Francisco Water Board's goal. The 2010 TMDL Staff Report included a total mercury and suspended sediment source analysis. For the DMCP Review, Board staff maintained the 2010 TMDL Staff Report's total mercury and suspended sediment source analysis, see Section 7 for more information.

Outcomes of DMCP Phase 1 characterization and control studies that tested sediment mercury controls are included as follows: storm water and use of Low Impact Development (LID) features in Section 3.3.1, agricultural practices on farmed Delta islands in Section 3.3.2, and deep water ship channel (DWSC) dredging activities in Section 3.3.3. Additional information on other characterization and control study results for wetland can be found in Section 3.5, for sedimentation and photodegradation can be found in Section 3.6, and for NPDES municipal facility wastewater in Section 3.7.

3.3.1 Urban Runoff

Though the 2010 TMDL Staff Report did not include information on potentially controllable methylation processes for urban runoff, it did estimate urban runoff to be a source of methylmercury in Section 6.2.5. The DMCP assigned MS4s and urban nonpoint source methylmercury allocations and required control studies for Phase I MS4 entities with service areas within and upstream of the Delta MeHg TMDL Boundary. Board staff used more recent MS4 data to reevaluate urban runoff methylmercury loads and allocations in Section 6.2.6 and Section 8.1, respectively.

The following entities conducted urban runoff control studies and tested sediment control measures: the City of Stockton and County of San Joaquin, the Contra Costa Clean Water Program (CCCWP), the Port of Stockton, and the Sacramento Stormwater Quality Partnership (SSQP). Board staff summaries on each of these control study reports can be found in Appendix E.

The City of Stockton and County of San Joaquin found that using LID features, such as detention basins, reduced total mercury and methylmercury loads through settling and removal of sediment (LWA 2018b). The CCCWP found that (1) LID infiltration and bioretention practices can reduce suspended sediment and methylmercury concentrations in storm water runoff, (2) source control of total mercury in sediment and preventing water stagnation can reduce methylmercury production, and (3) tidally inundated bioretention cells can enhance methylation and increase effluent concentrations of methylmercury (ADH and Wood 2020). The SSQP found that LID features, such as regional detention basins, significantly reduced methylmercury loading (SSQP 2018). The Port of Stockton did not find a relationship between sediment or aqueous methylmercury concentrations in managed or control LID catch basins in their study but did find that other maintenance practices like removing water and sediment from the basins, street sweeping, implementing erosion and sediment control best management practices, and applying filtration materials in and around the basins removed the amount of sediment and methylmercury from urban runoff (RBI 2018). The results of these studies suggest that implementing LID features, such as basins, and implementing sediment control measures upland of LID features may be effective at reducing sediment mercury and methylmercury loads from urban storm water runoff to Delta waterways.

3.3.2 Farmed Delta Islands

The 2010 TMDL Staff Report did not include information on potentially controllable methylation processes in farmed Delta islands in Section 3. However, agricultural return flows were determined to be a source of methylmercury in Section 6.2.4 of the report and were assigned methylmercury load allocations in the DMCP. Additionally, the DMCP required control studies for irrigated agricultural lands subject to methylmercury source reductions that drain to the Delta MeHg TMDL Boundary. Tetra Tech, with support from the USEPA and Central Valley Water Board, completed the *Characterization of Methylmercury Loads for Irrigated Agriculture in the Delta Final Report* to satisfy the DMCP control study requirement (Tetra Tech 2016). Board staff provided a summary on Tetra Tech's report in Appendix E.1. Data collected by this study, and other more recent studies, were used by Board staff to update the methylmercury source analysis of agricultural return flows in Section 6.2.5. Board staff provide the following information to update the potentially controllable methylation processes section in DMCP Review.

Farmed Delta islands may act as sinks of total mercury in the summer because outflow volumes are less than inflows, but there can be remobilization of sediment-bound mercury during winter flooding (Tetra Tech 2016). Management practices to control methylmercury production in farmed Delta islands have included reducing discharges during irrigation flooding "hot moments" that contain higher total mercury content (McCord and Heim 2015). These flood volumes could be diverted to adjacent deep cells or ponds to allow particle settling before discharge (Marvin-DiPasquale *et al.* 2018). Also, the use of single and dual drawdown and flood-up hydrologic management practices has resulted in decreased mercury concentrations in both water and fish in Cosumnes River Preserve seasonal wetland habitats (Eagles-Smith *et al*. 2014).

However, drawdown and flood-up hydrologic management practices in farmed wetlands may conflict with land use or regulatory restrictions, and potentially increase biotic exposure to methylmercury due to increased water residence time (Windham-Myers *et al.* 2010; McCord and Heim 2015).

In addition to reducing discharge volumes, limiting vegetation may reduce methylmercury production. Farmed wetlands have higher sediment methylmercury concentrations during the growing season, possibly due to increased microbial activity and transpiration processes that amplify concentrations in the root zone (Windham-Myers *et al.* 2014b). Lower methylmercury production rates have been found in fields where vegetation have been removed compared to vegetated fields (Windham-Myers *et al.* 2014b). The DWR Mercury Open Water Final Report for Compliance with the Delta Mercury Control Program (DWR Open Water Report) also found limiting available organic carbon by baling or disking vegetation may effectively reduce methylmercury production in the Yolo Bypass (DiGiorgio *et al.* 2020). Although not related to agriculture, the United States Army Corps of Engineers (USACE) report on dredging found that removing vegetation from DMPSs prior to placing dredging slurry resulted in lower methylmercury production (USACE 2019). However, a study on de-vegetation in seasonal wetlands showed contrary findings, with higher methylmercury production rates in fields where vegetation was removed (Eagles-Smith *et al*. 2014). The conflicting findings of these studies further emphasize the site-specific nature of methylmercury cycling and the need for appropriate site-specific control measures.

3.3.3 Dredging

Though the 2010 TMDL Staff Report did not include information on potentially controllable methylation practices for dredging activities, it did list dredging return waters as a possible source of methylmercury in the Delta. For the DMCP Review, Board staff estimated the net methylmercury load from dredging activities in Section 6.3.5 and proposes assigning dredging activities a methylmercury load allocation in Section 8.1.3.4.

The DMCP listed dredging, and dredge material disposal and reuse, as activities subject to the open water methylmercury allocations and required responsible agencies to conduct a control study. The USACE performed several studies and developed the Methylmercury Summary Report – Sacramento and Stockton Deep Water Ship Channels Operation and Maintenance Dredging (USACE Methylmercury Summary Report; USACE 2019) to fulfil the DMCP control study requirements (see Appendix E.13 for the Board staff summary of the report). USACE estimated that dredging the accumulated sediment at the bottom of river channels is a large net removal of methylmercury and total mercury from Delta waterways. The studies conducted by USACE tested several mercury controls and found that holding dredged slurry water within DMPSs after placement allowed for particle settling and sedimentation of mercury, and releasing water from DMPSs within one to three days after placement may be ideal for reducing methylmercury production (USACE 2019). While the use of DMPSs to allow sedimentation of mercury and subsequent removal of mercury contaminated sediment may be a viable control option, the water and solids retention times need to be optimized to prevent methylmercury production.

3.4 Forms of Mercury

After evaluation of this section in the 2010 TMDL Staff Report, no revision is necessary for the DMCP Review and Board staff maintains the section as is.

3.5 Wetlands

The 2010 TMDL Staff Report included information on the potential for wetland habitats in the Delta to increase methylmercury production in Section 3.5. Not much information on tidal wetland characteristics nor potentially controllable methylation processes within different wetland habitats was included in the report. United States Geological Survey (USGS) and California Department of Water Resources (DWR) conducted the Balancing Regional Export with Wildlife Health Control study (BREW study; Marvin-DiPasquale *et al.* 2018) and the Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance Report (DWR Tidal Wetlands Report; Lee and Manning 2020) on different wetland habitats to satisfy DMCP requirements (see Appendix E.2 and Appendix E.10 for Board staff summaries on these reports). For the DMCP Review, Board staff used data from these studies, and other more recent studies, to determine separate methylmercury loads from nontidal wetland habitats in Section 6.2.3 and tidal wetland habitats in Section 6.3.6.

Board staff provide the below information as an update to this section of the 2010 TMDL Staff Report.

Wetland conditions vary based on factors such as geomorphology, hydrology, biogeochemistry, and vegetation. Such factors can also influence methylmercury production and export. Wetland soils have low to no oxygen and host reactions that influence chemical stratification. Conditions of wetland environments, such as low dissolved oxygen (DO) and high dissolved carbon, tend to favor in situ methylmercury production (Sassone *et al.* 2008). The seasonality of methylmercury production and export varies depending on a wetland's site-specific conditions. For example, two adjacent ponds in Twitchell Island have substantially different methylmercury concentrations during peak production in the spring (Sassone *et al.* 2008). Accurately characterizing methylmercury production in wetlands is a challenge. It requires continuous monitoring of multiple parameters, which can be costly and time consuming (Bergamaschi *et al.* 2011). New techniques in optical profiling and the use of proxies could provide helpful insights into specific conditions throughout the Delta (Downing *et al*. 2009).

Research has shown that wetlands in the Delta are overall net sources of methylmercury (Sassone *et al.* 2008; Fleck *et al.* 2007; Stephenson *et al.* 2008), however results from the DWR Tidal Wetlands Report show that tidal wetlands may be overall net sinks of methylmercury (Lee *et al.* 2020). Tidal wetlands are depositional environments characterized by channels, wind-wave interactions, barometric pressure, and tidal currents (Ganju *et al*. 2005). Characteristics such as vegetation, organic matter, geomorphology, storm and wind events, and hydrology vary and interact in complex ways, causing tidal wetlands to act as net sinks or sources of methylmercury depending on the timeframe (Bergamaschi *et al.* 2011). Over longer periods of time, tidal wetlands appear to be a net sink for methylmercury (Fleck *et al.* 2007; Lee *et al.* 2020). However, with climate change and sea level rise, there may be changes to the amount and timing of sediment and mercury deposition in tidal wetlands. DWR did not test control strategies in the DWR Tidal Wetlands Report, instead focusing on characterizing mercury, methylmercury, and other parameters in tidal wetland habitats. Thus, there are no updated information on potentially controllable methylation processes within tidal wetland habitats to include in this section at the time of the DMCP Review.

As an initiative to offset species impacts from large water diversion projects in the Delta, such as the Central Valley Project (CVP) and State Water Project (SWP), wildlife protection agencies required mitigation of impacts to effected species. This resulted in the completion of large habitat restoration projects within the Delta MeHg TMDL Boundary. For instance, EcoRestore projects largely involve converting existing agricultural lands within the Delta to complex systems of wetlands, swales, shallow channels, and habitat islands to create more and improved rearing habitat for impacted endangered and special status species. As mentioned in the 2010 TMDL Staff Report Section 3.5, there was an anticipated increase of up to 90,000 acres of additional Delta wetland habitat. The Central Valley Water Board has received several CWA Section 401 Water Quality Certification applications for these large wetland restoration projects. Board staff compiled a list of some of these projects in Appendix D.5, which shows an increase of wetland habitat in recent years (Table D.4). At the time of the DMCP Review, these projects have either been completed, are breaking ground, or are still in the planning stage. For planned projects, the ratio of tidal to nontidal wetland area is currently unknown, and additional nontidal wetlands have the potential to increase methylmercury loading in the Delta. Utilizing control strategies like deep outlet cells and fill-and-maintain hydrology in managed wetlands may increase particulate settling and reduce aqueous methylmercury export (Marvin-DiPasquale *et al.* 2018).

3.6 Methylmercury Loss by Sedimentation & Photodemethylation

The 2010 TMDL Staff Report included information on methylmercury loss by sedimentation and photodegradation. For the DMCP Review, Board staff included the following information to update this section of the report.

Characterization and control studies conducted in Phase 1 of the DMCP may help inform ways of increasing methylmercury loss via sedimentation and photodegradation (see Appendix E for Board staff summaries on these reports). USGS found that particle settling and photodegradation are both important loss processes in constructed deep-cells downstream of seasonal wetlands (Marvin-DiPasquale *et al.* 2018). The City of Stockton and San Joaquin County determined detention basins can increase sedimentation of mercury-bound sediment (LWA 2018b). The Port of Stockton observed

(1) storm drain catch-basins act as a depositional environment and (2) removal of sediment from these basins prevented the mobilization of mercury contaminated sediment to receiving waters (RBI 2018). The USACE found that the act of dredging sediment from the DWSCs removed mercury from the Delta, however, the USACE also found that holding slurry water in DMPSs for longer than one to three days to allow particle setting resulted in increased aqueous methylmercury concentrations prior to release back into surface waters (USACE 2019). Thus, while the use of basins to allow sedimentation of mercury and subsequent removal of mercury contaminated sediment may be a viable control option, the water and solids retention times need to be optimized to prevent methylmercury production.

The hydrology of the Delta creates what is referred to as the “donut hole effect”, where suspended sediment concentration (SSC) is lowest in the central portion of the Delta and higher closer to the legal Delta boundary. The Delta Simulation Model II (DSM2) shows this effect even when high levels of sediment are entering the central portion of the Delta (DWR 2019). This finding is consistent with the DWR Open Water Report, which used a modified version of the same model, DSM2-Hg. The DWR Open Water Report determined that the central portion of the Delta has lower relative levels of unfiltered total mercury, methylmercury, and SCC, under a wide range of flow conditions (DiGiorgio *et al.* 2020). The model also found that the Delta is an overall sink for all three constituents. This pattern suggests that there is a higher rate of settling and sedimentation at regions that border the central portion of the Delta. A better understanding of the processes that lead to this phenomenon may provide insights on how to increase particulate settling in managed environments. In addition, further developments of the DSM2-Hg model may enable exploration of control options that would increase methylmercury loss via sedimentation or photodegradation.

Light exposure is the primary factor directly influencing methylmercury photodegradation rates. Environments with less light exposure, or more light attenuation, have relatively lower photodegradation rates. Such environments can be caused by shade (e.g., from cloud cover, turbidity, vegetation) or increased depth in the water column. The BREW study found that within only 20 to 40 cm below the water surface, light transmission was reduced by half (Marvin-DiPasquale *et al.* 2018). Furthermore, various portions of the light spectrum can have significantly different photodegradation rates (Windham-Myers *et al.* 2010). Some reports showed initial methylmercury concentrations strongly influenced photodegradation rates (Gill 2008c; Windham-Myers *et al.* 2010; Sellers *et al.* 1996), while others found that photodegradation rates were unrelated to initial methylmercury concentration (Fleck *et al.* 2014; Marvin-DiPasquale *et al.* 2018). The association between dissolved organic matter (DOM) and initial methylmercury concentrations has also been shown to influence photodegradation rates. Though DOM contributes to photodegradation processes, the relationship between them is complex (Fleck *et al.* 2014). When the ratio of methylmercury to DOM increases to a certain level, binding conditions can be affected and hinder photodegradation. High levels of DOM can attenuate light in the water column and hinder methylmercury photodegradation. DOM itself can be degraded in different ways by light, further complicating the reactions (Fleck *et al.* 2014). Thus, limiting turbidity, vegetation coverage, and DOM in aquatic environments may better allow the photodegradation of methylmercury, but more information is needed to confirm this.

3.7 Wastewater

The 2010 TMDL Staff Report Table 3.2 listed several examples of control measures that effected mercury levels in fish, including an example of fish tissue concentrations decreasing 60-80% 22 years after discharges from a NPDES WWTF affecting the area had ceased. The 2010 TMDL Staff Report estimated NPDES WWTFs methylmercury loads in Section 6.2.3. The DMCP assigned NPDES WWTFs methylmercury waste location allocations and required control studies from WWTFs that discharge in the Delta MeHg TMDL Boundary. For the DMCP Review, Board staff reevaluated NPDES WWTF discharge methylmercury loads in Section 6.2.4 and methylmercury waste load allocations in Section 8.1.

The following entities conducted NPDES permitted facility control studies and tested mercury control measures in their control studies: the City of Sacramento Combined Sewer System (CSS), the Deuel Vocational Institution (DVI), and the Central Valley Clean Water Association (CVCWA). Board staff summaries on each of these control study reports can be found in Appendix E.

The City of Sacramento CSS found that the treatment processes evaluated did not significantly affect methylmercury concentrations or loads, implementing LID controls would reduce methylmercury loads but would not be effective during high flow, and that reducing flow was the most effective method for reducing methylmercury loads (LWA 2018a). The DVI found that the facility's existing tertiary wastewater treatment, which includes biological nutrient removal, filtration, and ultraviolet disinfection, effectively removed methylmercury and total mercury (GHD 2018). The CVWCA found that higher levels of treatment beyond secondary alone, such as secondary treatment with nitrification, secondary treatment with nitrification and denitrification, or tertiary with nitrification and denitrification, did not improve the methylmercury removal efficiency in the effluent versus the influent (Gies *et al*. 2018). However, secondary treatment with nitrification and denitrification had lower effluent methylmercury concentrations than secondary treatment alone and secondary treatment with only nitrification. Tertiary treatment with nitrification and denitrification did not have a notably lower median effluent concentration than secondary treatment with nitrification and denitrification. The results of these studies suggest that primary controls such as implementing LID controls may be an effective method to reduce methylmercury loads for CSSs, implementing treatment methods beyond secondary treatment with nitrification and denitrification may not be effective and feasible control methods, and reducing flow may be an effective method to reduce loads.

3.8 Key Points

- Board staff reviewed the information provided in the 2010 TMDL Staff Report Section 3 and maintains that it continues to be accurate and relevant.

- Board staff provided updated information to several sections of the 2010 TMDL Staff Report to include findings from more recent studies, including results from the DMCP Phase 1 characterization and control studies:
    - Implementing LID features, such as basins, and implementing sediment control measures upland of LID features may be effective at reducing sediment mercury and methylmercury loads from urban storm water runoff to Delta waterways.
    - Reducing agricultural discharge volumes and removing unnecessary vegetation may reduce methylmercury production.
    - Holding dredged slurry water within DMPSs after placement allowed for particle settling and sedimentation of mercury, and releasing water from DMPSs within one to three days after placement may be ideal for reducing methylmercury production.
    - Tidal wetland habitats may be net sinks of aqueous methylmercury.
    - The use of basins to allow sedimentation of mercury and subsequent removal of mercury contaminated sediment may be a viable control option.
    - Limiting turbidity, vegetation coverage, and DOM in aquatic environments may better allow the photodegradation of methylmercury.
    - Tertiary level wastewater treatment with nitrification and denitrification does not reduce methylmercury more than secondary treatment with nitrification and denitrification.
- Implementation and monitoring of potentially controllable methylation processes should be evaluated on a site-specific basis, optimize water and solids retention times to prevent methylmercury production, and investigate mercury concentrations in resident aquatic biota.

4 NUMERIC TARGETS

Sections 4.1 through 4.6 of the 2010 TMDL Staff Report were not changed for the DMCP Review. These sections included defining a numeric target and the calculation of fish tissue targets. The calculated fish tissue targets estimate methylmercury concentrations in Delta fish tissue protective for consumption by wildlife and humans based on species specific consumption rates. The 2010 TMDL Staff Report synonymously uses the terms “fish tissue targets”, “TMDL targets”, “wildlife health targets”, “human health targets”, “methylmercury targets”, and “trophic level food group targets”. This report uses the term “trophic level group (TLG) targets” to indicate that the calculated targets in fish tissue are based on trophic level and grouped by size range.

The 2010 TMDL Staff Report recommends three of the TLG targets as numeric targets for methylmercury in fish tissue to protect human and piscivorous wildlife health:

- 0.24 milligrams (mg) methylmercury per kilogram (kg), wet weight, in filets of TL4 fish sized 150-500 mm, such as bass and catfish
- 0.08 mg methylmercury per kg, wet weight, in filets of TL3 fish sized 150-500mm, such as carp and salmon
- 0.03 mg methylmercury per kg, wet weight, in whole TL2 and TL3 fish less than 50 mm in length

The first two targets are protective of humans eating 32 grams per day (g/day) (i.e., approximately eight ounces per week) of uncooked fish that are commonly consumed, and are also protective of large fish and all wildlife species that consume large fish. The target for small TL2 and TL3 fish is protective of wildlife species that consume small fish. These targets were not changed as part of the DMCP Review and Board staff recommends no changes to the WQO currently in the Basin Plan.

While the numeric targets are for methylmercury, 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 TL4 fish (Becker and Bigham 1995; Nichols *et al*. 1999; Slotton *et al.* 2004). Ackerman and Eagles-Smith (2010) estimate that methylmercury accounts for 94.3% of the total mercury in fish. Therefore, the 2010 TMDL Staff Report assumed that all the mercury measured as total mercury in Delta fish was methylmercury (see Sections 2.1.4 and 4.2.1 of the 2010 TMDL Staff Report). This DMCP Review makes the same assumption for the purpose of linking mercury concentrations in fish with aqueous methylmercury concentrations. However, this DMCP Review refers to “mercury concentrations in fish” rather than “methylmercury concentrations in fish”, as done in the 2010 TMDL Staff Report, to be clear that mercury was the measured analyte and will be the analyte used to determine compliance with the numeric targets.

The TLG targets calculated in the 2010 TMDL Staff Report (Table 4.9 in the 2010 TMDL Staff Report) were used in the DMCP Review TLG evaluation (Section 4.1) and the black bass evaluation (Section 4.2).

4.1 Trophic Level Group Evaluation

The 2010 TMDL Staff Report referred to this section and associated analysis as "trophic level food group evaluation". For the DMCP Review, Board staff shortened the term to "trophic level group evaluation" or "TLG evaluation".

This section reexamines the TLG evaluation performed in the 2010 TMDL Staff Report. The TLG evaluation investigated whether there was a relationship between the TL4 group sized 150 – 500 mm and the other trophic level groups. The same methods used in the 2010 TMDL Staff Report were used while incorporating new data. The updated TLG evaluation confirmed that the proposed numeric targets (2010 TMDL Staff Report Sections 4.1 – 4.6) for the protection of humans remain to be protective of other wildlife species that consume the same trophic group, or smaller and lower trophic level fish.

4.1.1 Data Used in Trophic Level Group Evaluation

Data used in the 2010 TMDL Staff report were collected between 1998 and 2001. For the DMCP Review, Board staff compiled fish tissue mercury data from years 1998 to 2019 (Appendix A.1). After evaluating different year ranges, Board staff selected fish data from 2002 to 2019 because it provided the lowest average SER of regression models used to evaluate the relationship between total mercury average weighted concentrations in TLGs and total mercury average weighted concentrations in standardized 350 mm black bass (Appendix B).

The updated average[1] fish tissue mercury concentrations for each TLG and Delta TMDL subarea are presented in Table 4.1. The average concentrations are weighted by the number of individual fish in composite samples, consistent with 2010 TMDL Staff Report methods. The weighted averages are the result of analyzing 6,908 composite samples of 7,068 fish from 17 species in the Delta. Board staff rounded the averages shown in Table 4.1 to three decimal places because analytical methods provide that level of accuracy, and the majority of compiled data were reported to three decimal places. Weighted averages for TLG TL3 < 50 mm are not included in Table 4.1 because data for this TLG were not available for the selected year range of 2002 to 2019 and were only collected in 1998 and 1999. However, these data were considered in the evaluation of different year ranges as discussed in Appendix B. Figure 4.1 illustrates the fish monitoring locations for data used in the trophic level group evaluation.

The 2010 TMDL Staff Report excluded the limited samples of migratory species due to a lack of available data and habitat range. Migratory species include salmon, American shad, steelhead, sturgeon, and striped bass. Methylmercury concentrations in migratory fish may not be representative of Delta mercury dynamics because most of their lives are lived outside of the Delta MeHg TMDL Boundary. Therefore, even though more migratory fish data were available, Board staff also removed migratory species samples from the DMCP Review due to their habitat range.

[1] "Average" in this Report is the arithmetic mean, unless otherwise stated.

To be consistent with the 2010 TMDL Staff Report and Statewide Mercury Provisions, Board staff excluded fish samples with lengths greater than 500 mm from the reevaluation. In addition, to be consistent with the 2010 TMDL Staff Report, Board staff only used fillet data for the human and bald eagle trophic level group analyses. The 2010 TMDL Staff Report only included whole body data for the other trophic level groups. However, there were no whole-body data collected for these TLGs during the 2002 to 2019 analysis. Therefore, Board staff included fillet data for these TLGs in the DMCP Review.

The Marsh Creek subarea was not included in the trophic level group analysis due to a lack of mercury fish data, which was also the case with the 2010 TMDL Staff Report. However, fish mercury data were available for the Yolo Bypass - North and South subareas, which were not available for the 2010 TMDL Staff Report trophic level group analysis. Table 4.2 shows the lowest calculated TLG target for each TLG and the relative percent reduction needed by each Delta TMDL subarea to reduce the weighted average fish tissue mercury concentration in Table 4.1 to the listed TLG target. Consistent with the 2010 TMDL Staff Report, this comparison indicates that the Central and West Delta subareas are the closest to meeting recommended wildlife and human targets.

4.1.2 Trophic Level Group Relationships

The TLG TL4 150-500 mm weighted average tissue mercury concentrations in Table 4.1 were regressed against the other TLG weighted average tissue mercury concentrations using linear, power, exponential, NLS, GAM (using a smoothing dimension term 1, 2, 3, or 4), and logarithmic models. The regression model with the lowest SER was selected as the final model. SER provides an absolute measure of the typical distance that the data points fall from the regression line and is in the units of the dependent variable (e.g., mg of total mercury per kg of fish tissue). The lower the SER, the better the goodness of fit of the regression model. SER was chosen to measure goodness of fit because R^2 has been shown as an inadequate model selection criterion (Spiess and Neumeyer 2010; Jenkins and Quintana-Ascencio 2020). The final regressions support the findings of the 2010 TMDL Staff Report that there are predictable relationships between mercury concentrations in TLG TL4 150-500 mm fish and other TLGs in the Delta.

Table 4.3 updates Table 4.9 from the 2010 TMDL Staff Report and shows the predicted protective fish tissue mercury concentrations for each TLG and piscivorous species in terms of TL4 150-500 mm fish. The predicted TL4 150-500 mm fish concentration ranges from 0.124 mg/kg in TL3 150-500 mm fish for humans to 0.403 mg/kg in TL4 150-350 mm for river otters. The lowest predicted TL4 150-500 mm fish concentration (i.e., 0.124 mg/kg) corresponds to the numeric target of 0.08 mg/kg in TL3 150-500 mm fish. The proposed numeric target of 0.24 mg/kg in TL4 150-500 mm fish corresponds to the lowest predicted TL4 150-500 mm fish concentration of all other TL4 TLGs. This indicates that the recommended numeric targets for 150-500 mm TL3 and TL4 fish developed for the protection of humans are most likely protective of wildlife species that consume smaller or lower trophic level fish. Figure 4.2 illustrates the use of regression to convert the lowest TLG target for each TLG shown in Table 4.3 to the predicted TL4 Fish (150-500 mm) protective mercury concentration. For each graph in Figure 4.2(A-E), the x-axis value arrow indicates the lowest TLG target for that TLG, and the y-axis value indicates the conversion to the predicted TL4 Fish (150-500 mm) protective mercury concentration using the regression model.

Table 4.3 also shows the predicted standardized 350 mm black bass protective mercury concentrations. The results and methodology to standardize black bass methylmercury concentrations to 350 mm are described in Section 4.2.

As proposed in the 2010 TMDL Staff Report, Board staff recommends 0.03 mg/kg in TL2 and TL3 fish less than 50 mm as an additional numeric target. This target represents a protective fish tissue mercury concentration for consumption by the California least tern, an endangered species listed by the federal government, and is also expected to protect the Western snowy plover and other species that consume small fish.

Table 4.1: Weighted Average Fish Tissue Total Mercury Concentrations (mg/kg) by Trophic Level Group and Delta TMDL Subarea from 2002-2019

Trophic Level Group	Central Delta	Mokelumne/ Cosumnes Rivers	Sacramento River	San Joaquin River	West Delta	Yolo Bypass - North	Yolo Bypass - South
TL4 Fish (150-500 mm)	0.220	1.056	0.474	0.342	0.259	0.660	0.372
TL4 Fish (150-350 mm)	0.182	1.028	0.365	0.321	0.223	0.660	0.324
TL3 Fish (150-500 mm)	0.089	0.383	0.212	0.181	0.114	0.535	0.224
TL3 Fish (150-350 mm)	0.086	0.412	0.156	0.108	0.072	0.535	0.214
TL3 Fish (50 - <150 mm)	0.052	0.312	0.142	0.077	0.050	0.239	0.198
TL3 Fish (<50 mm)	NA	NA	NA	NA	NA	NA	NA

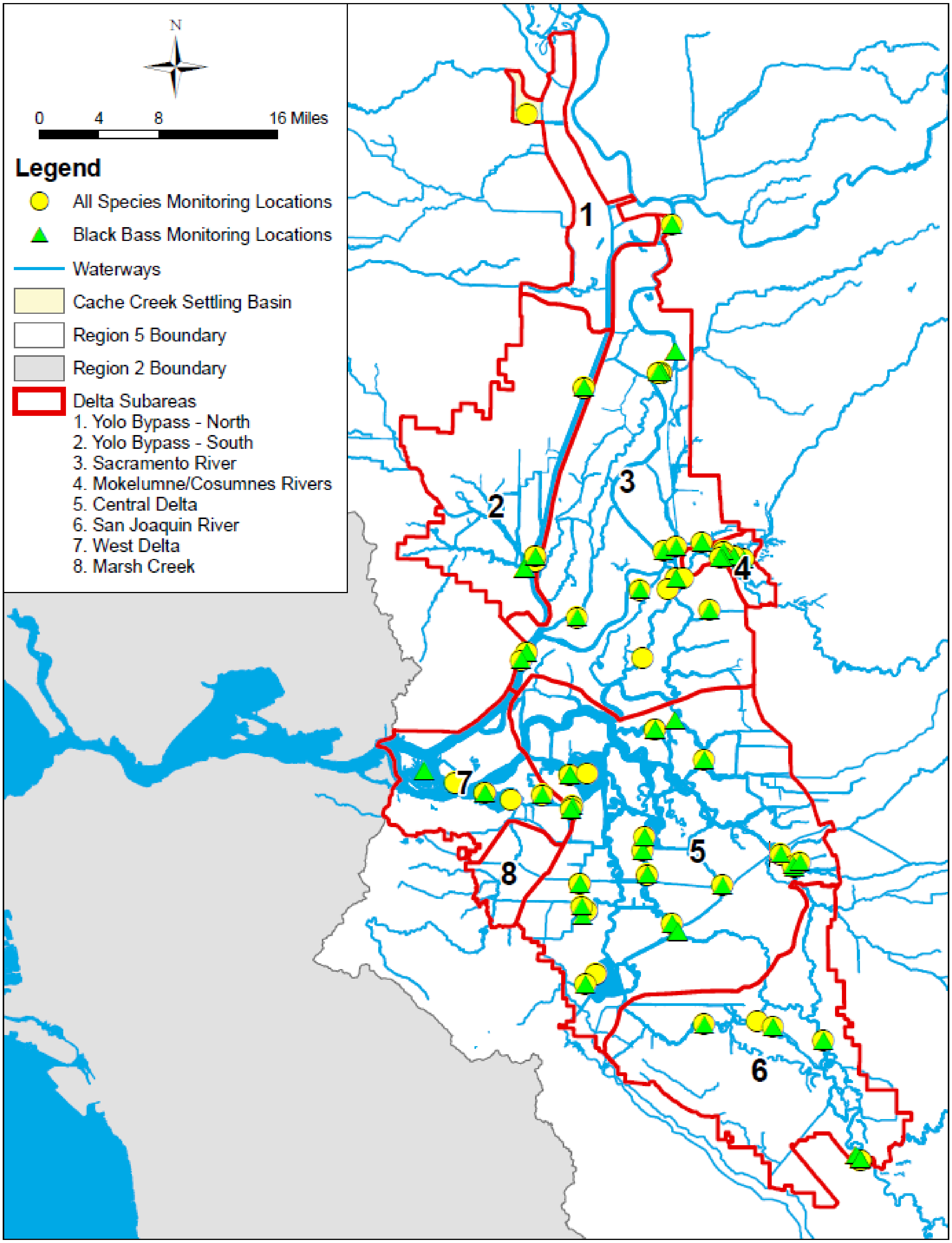

Figure 4.1: Monitoring Locations Included in the Trophic Level Group Evaluation (All Species and Black Bass) and Black Bass Evaluation (Black Bass Only)

Table 4.2: Percent Reductions Needed in Fish Tissue Mercury Concentrations to Meet TLG Targets

Trophic Level Group	Target Species	TLG Target (mg/kg)	Central Delta	Moke./ Cos. Rivers	Sac. River	San Joaquin River	West Delta	Yolo Bypass - North	Yolo Bypass - South
TL4 Fish (150-500 mm)	Human	0.24	0%	77%	49%	30%	7%	64%	36%
TL4 Fish (150-350 mm)	Osprey	0.26	0%	75%	29%	19%	0%	61%	20%
TL3 Fish (150-500 mm)	Human	0.08	10%	79%	62%	56%	30%	85%	64%
TL3 Fish (150-350 mm)	Grebe	0.08	7%	81%	49%	26%	0%	85%	63%
TL3 Fish (50 - <150 mm)	River Otter	0.04	23%	87%	72%	48%	21%	83%	80%
TL3 Fish (<50 mm)	California Least Tern	0.03	NA	NA	NA	NA	NA	NA	NA

Table 4.3: Predicted Methylmercury Concentrations in 150-500 mm TL4 Fish and Standard 350 mm Black Bass Corresponding to TLG Targets for the Protection of Piscivorous Species

Trophic Level Group	Species	TLG Target (mg/kg)	Predicted TL4 Fish (150-500 mm) Protective Hg Concentration[2] (mg/kg)	Predicted Standard 350 mm Black Bass Protective Hg Concentration[3] (mg/kg)
TL4 Fish (150-500 mm)	Human	0.24	0.24	0.290
TL4 Fish (150-500 mm)	Bald Eagle	0.31	0.31	0.376
TL4 Fish (150-350 mm)	Osprey	0.26	0.307	0.343
TL4 Fish (150-350 mm)	River Otter	0.36	0.403	0.526
TL3 Fish (150-500 mm)	Human	0.08	0.124	0.258
TL3 Fish (150-500 mm)	Bald Eagle	0.11	0.243	0.298
TL3 Fish (150-350 mm)	Western Grebe	0.08	0.238	0.324
TL3 Fish (150-350 mm)	Common Merganser & Osprey	0.09	0.275	0.336
TL3 Fish (50 - <150 mm)	River otter	0.04	0.230	0.293
TL3 Fish (50 - <150 mm)	Kingfisher	0.05	0.253	0.307
TL3 Fish (50 - <150 mm)	Mink	0.08	0.317	0.353
TL3 Fish (50 - <150 mm)	Double-crested Cormorant	0.09	0.336	0.370
TL3 Fish (<50 mm)	California Least Tern	0.03	NA	NA
TL3 Fish (<50 mm)	Western Snowy Plover	0.10	NA	NA

[2] This column is titled “Predicted 150-500 mm TL4 Fish Safe Level” in the 2010 TMDL Staff Report.

[3] This column is titled “Predicted Standard 350 mm Black Bass Safe Level” in the 2010 TMDL Staff Report.

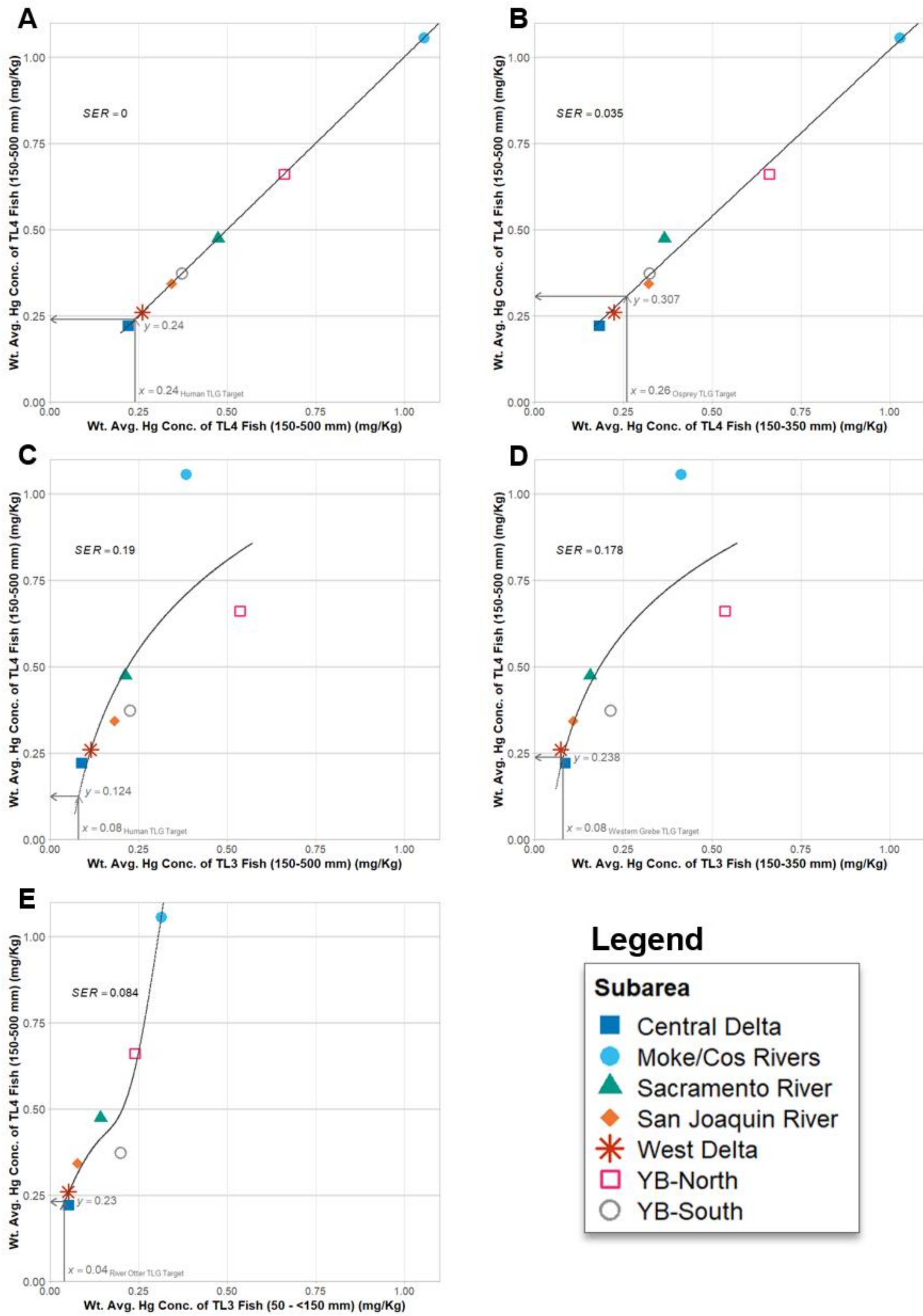

Figure 4.2: Regression models used to determine the predicted TL4 Fish (150-500 mm) protective mercury concentration shown in Table 4.3 for each TLG. Weighted average mercury concentration of TL4 Fish (150-500 mm) (y-axis) vs weighted average mercury concentration of each TLG (x-axis) as follows: **(A)** TL4 Fish (150-500 mm), a 1:1 relationship; **(B)** TL4 Fish (150-350 mm); **(C)** TL3 Fish (150-500 mm); **(D)** TL3 Fish (150-350 mm); and **(E)** TL3 Fish (50 - <150 mm).

4.2 Black Bass Evaluation

This section reevaluates the relationship between TLGs and black bass. The evaluation performed in the 2010 TMDL Staff Report developed a largemouth bass implementation goal of 0.24 mg/kg (fillet wet weight) based on a standardized length of 350 mm for largemouth bass collected in the year 2000. The DMCP Review developed a black bass implementation goal of 0.258 mg/kg (fillet wet weight) also based on a standardized length of 350 mm. Black bass (*Micropterus*) is a genus of fish that includes several bass species. The species included in this reevaluation were spotted bass (*M. punctulatus*), smallmouth bass (*M. dolomieu*), and largemouth bass (*M. salmoides*).

Based on the data compiled from various sources (Appendix A.1), largemouth bass have not been sampled in the Sacramento River subarea since 2007. Restricting data to only largemouth bass would limit mercury fish data and result in excluding the Sacramento River subarea from the linkage analysis, which develops an aqueous MeHg implementation goal (Section 5) using the black bass implementation goal described in this section. Black bass, other than largemouth bass, were observed in the Sacramento River subarea in 2001, 2005-2007, 2011, and 2016-2019, and in the Mokelumne River subarea in 2006. In order to keep the Sacramento subarea in the linkage analysis, Board staff decided to use data for all available black bass species: largemouth bass, smallmouth bass, and spotted bass. The black bass species are a top predator that tend to accumulate relatively high concentrations of mercury. Additionally, as with largemouth bass, black bass have been demonstrated to be indicator species that are representative of conditions in the waterbody where they are collected and yield comparable data across waterbodies and over time (Davis and Bonnema 2021). Therefore, Board staff does not consider the inclusion of all black bass for all Delta TMDL subareas to be a substantial change from methods used in the 2010 TMDL Staff Report.

For the DMCP Review, the relationship between 350 mm standardized black bass total mercury concentrations and TLG total mercury concentrations were evaluated using the following options (see Appendix B for more detail):

- Methods to calculate the 350 mm standardized black bass mercury concentration for each subarea (i.e., pooling data or the annual weighted average)
- Data year ranges (i.e., 1998-2019, 1998-2001, or 2002-2019 for TLGs and 2000-2019, 2000, or 2002-2019 for black bass)
- Regression models (i.e., linear, exponential, logarithmic, power, NLS, or GAM)

After evaluating the above options, Board staff determined that using the annual weighted average 350 mm standardized black bass total mercury concentration and the 2002-2019 data period provided regression models between 350 mm standardized black bass total mercury concentrations and TLG total mercury concentration with the lowest average SER. Section 4.2.1 describes the data and methods Board staff used to standardize black bass total mercury concentrations to 350 mm. Section 4.2.2 describes the data and methods used to determine the black bass implementation goal using the relationship between 350 mm standardized black bass total mercury concentrations and TLG total mercury concentrations.

4.2.1 Data Used in Black Bass Evaluation & Standardization

To develop the largemouth bass implementation goal in the 2010 TMDL Staff Report, Board staff used one black bass species, largemouth bass, and standardized fillet total mercury concentrations collected in 2000 to a fish length of 350 mm. For the DMCP Review, Board staff attempted to remain as consistent as possible with the methods used in the 2010 TMDL Staff Report with the following exceptions:

- Using black bass (largemouth, smallmouth, and spotted) fillet mercury concentrations rather than only largemouth bass
- Using black bass fillet mercury concentration data from years 2002 through 2019 rather than one year of data
- Using GAM with a smoothing dimension term of 1, 2, 3, or 4 and NLS regression models in addition to those used in the 2010 TMDL Staff Report (linear, exponential, logarithmic, and power models) to standardize fillet mercury concentrations to a fish length of 350 mm

Regressions were used to standardize each year of black bass mercury concentrations to 350 mm, consistent with the 2010 TMDL Staff Report. In each case, the model that provided the lowest SER was selected. Occasionally, Board staff selected a model with a higher SER if the model with lowest SER was not appropriate. For example, GAM models often had the lowest SER, but portions of the model had a negative slope, which does not correspond with the general understanding of methylmercury concentrations increasing with the size of the fish, also known as bioaccumulation.

Table 4.4 shows black bass sampled by subarea and year and the corresponding size range, number of samples, 350 mm standardized black bass mercury concentrations, whether the standardized concentration was interpolated or extrapolated, and whether the standardized concentration was included or excluded from the black bass evaluation. An interpolated concentration means that the black bass length of 350 mm was within the range of sampled black bass lengths; an extrapolated concentration means that a black bass length of 350 mm was not within the range of sampled black bass lengths. The 350 mm standardized black bass mercury concentration needed to be extrapolated for four of the years.

If the extrapolated 350 mm standardized black bass mercury concentration was not within the subarea's range of interpolated concentrations as shown in Figure 4.3, Board staff determined the extrapolated concentration was not representative of the subarea. For example, the black bass collected in 2017 for the Sacramento River subarea ranged from 208 mm to 340 mm. Therefore, the standardization needed to be extrapolated by 10 mm. The resulting extrapolated 350 mm standardized mercury concentration remained in the black bass evaluation because it was within the range of interpolated 350 mm standardized mercury concentrations for the Sacramento River subarea

(Figure 4.3). However, the extrapolated 350 mm standardized mercury concentrations for 2002 in the Sacramento River subarea (not shown in Figure 4.3), 2003 in the Yolo Bypass - North subarea, and 2018 in the San Joaquin River subarea were excluded from the black bass evaluation. For 2002, the Sacramento River subarea only had two black bass mercury concentrations. The 350 mm standardization needed to be extrapolated by 42.4 mm resulting in a negative mercury concentration that was not within the range of Sacramento River subarea interpolated concentrations. A negative concentration is not feasible and the lowest total mercury concentration detectable in fish tissue by current scientific methods is 0.003 mg/kg. Therefore, this extrapolated concentration was excluded from the black bass evaluation.

The Yolo Bypass - North subarea only had data for the year of 2003 with just two black bass mercury concentrations available. In this case, the 350 mm standardization needed to be extrapolated by 120 mm. Since the 350 mm standardized mercury concentration was extrapolated and data were limited, the Yolo Bypass - North subarea was removed from the black bass evaluation. The 2010 TMDL Staff Report also excluded the Yolo Bypass from the largemouth bass evaluation due to a lack of data.

The 350 mm standardized mercury concentration for 2018 in the San Joaquin River subarea needed to be extrapolated by 70 mm and was excluded from the black bass evaluation because the extrapolated concentration was not within the range of interpolated concentrations (Figure 4.3).

4.2.2 Relationship of Black Bass & TLG Mercury Concentrations

For the DMCP Review, Board staff reevaluated the relationship between 350 mm standardized black bass total mercury concentrations and TLG total mercury concentrations to determine a black bass implementation goal for use in the linkage analysis (Section 5).

To reevaluate the relationship, Board staff first averaged the 350 mm standardized black bass total mercury concentrations calculated in Section 4.2.1 (Table 4.4) for each subarea and weighted the average by the annual sample size. Then the annual average 350 mm standardized black bass total mercury concentrations (Table 4.5) were regressed on the weighted average total mercury concentrations for each TLG (Table 4.1). Lastly, Board staff used linear, exponential, logarithmic, power, NLS, and GAM regression models and selected the model that provided the lowest SER, the same methods that were used to standardize black bass to 350 mm. The selected regressions were used to predict the protective mercury concentration for each TLG target in terms of standardized 350 mm black bass (Table 4.3). Figure 4.4 illustrates the conversion of the lowest TLG target for each TLG shown in Table 4.3 to the predicted standardized 350 mm black bass protective mercury concentration. For each graph in Figure 4.4(A-E), the x-axis value arrow indicates the lowest TLG target for that TLG, and the y-axis value indicates the conversion to the predicted standardized 350 mm black bass protective mercury concentration using the regression model. Figure 4.5 specifically illustrates Figure 4.4(C), which shows the regression that resulted in the lowest predicted standard 350 mm black bass protective mercury concentration of 0.258

mg/kg. This value corresponds to the TLG target of 0.08 mg/kg for humans in 150-500 mm TL3 fish and is the most conservative of all the predicted standard 350 mm black bass protective mercury concentrations.

When 0.258 mg/kg or less of total mercury is achieved in standardized 350 mm black bass, Board staff expect that the TLG targets in Table 4.3 will also be achieved and that fish consumption in the Delta will be protective of wildlife and human health. Thus, Board staff recommends that 0.258 mg/kg wet weight in a standard 350 mm black bass fillet be used as the black bass implementation goal in the linkage analysis (Section 5) to determine the aqueous MeHg implementation goal (Section 5.3).

Table 4.5 lists the percent reductions in standardized 350 mm black bass mercury levels necessary to meet the recommended black bass implementation goal. The reduction needed ranges between 2% and 77%, which is similar to the 0% to 77% reduction range shown in Table 4.11 of the 2010 TMDL Staff Report. Excluding the addition of the Yolo Bypass - South subarea, the order of percent reduction needed hasn’t changed for the Delta TMDL subareas. The San Joaquin River subarea has reduced the most, from 65% to 38%, and the Central Delta subarea is the only one to increase, from 0% to 2%. Consistent with the 2010 TMDL Staff Report, Board staff expects the reduction required to meet the black bass implementation goal will also translate to a reduction in other aquatic organisms. As with the 2010 TMDL Staff Report, Board staff continues to recommend monitoring all trophic level groups to verify TLG targets continue to be met once the black bass implementation goal is attained.

Table 4.4: Summary of Standardized 350 mm Black Bass Mercury Concentrations by Subarea and Year

Delta TMDL Subarea	Year	Length Range (mm)	Sample Size	Std. 350 mm THg (mg/kg)	Prediction Type	Difference of Length to 350 mm (mm)	Status
Sacramento River	2002	392.4 - 392.6	2	-8.399	Extrapolated	-42.4	Excluded
San Joaquin River	2018	200 - 280	10	1.246	Extrapolated	70	Excluded
Yolo Bypass - North	2003	160 - 230	2	0.958	Extrapolated	120	Excluded
Central Delta	2005	204 - 579	135	0.218	Interpolated	0	Included
Central Delta	2007	202 - 549	63	0.298	Interpolated	0	Included
Central Delta	2011	205 - 580	22	0.211	Interpolated	0	Included
Central Delta	2016	205 - 548	22	0.204	Interpolated	0	Included
Central Delta	2017	211 - 460	33	0.289	Interpolated	0	Included
Central Delta	2018	203 - 573	33	0.344	Interpolated	0	Included
Central Delta	2019	200 - 483	33	0.335	Interpolated	0	Included
Mokelumne/ Cosumnes Rivers	2005	269 - 474	18	0.610	Interpolated	0	Included
Mokelumne/ Cosumnes Rivers	2006	240 - 477	18	1.359	Interpolated	0	Included
Mokelumne/ Cosumnes Rivers	2007	195 - 475	27	1.272	Interpolated	0	Included
Mokelumne/ Cosumnes Rivers	2011	203 - 506	11	0.651	Interpolated	0	Included
Mokelumne/ Cosumnes Rivers	2016	236 - 408	11	0.568	Interpolated	0	Included
Mokelumne/ Cosumnes Rivers	2017	218 - 541	18	1.353	Interpolated	0	Included
Mokelumne/ Cosumnes Rivers	2018	238 - 525	16	1.440	Interpolated	0	Included
Mokelumne/ Cosumnes Rivers	2019	221 - 500	17	1.387	Interpolated	0	Included
Sacramento River	2003	347 - 408	3	0.706	Interpolated	0	Included
Sacramento River	2005	180 - 540	61	0.502	Interpolated	0	Included

Delta TMDL Subarea	Year	Length Range (mm)	Sample Size	Std. 350 mm THg (mg/kg)	Prediction Type	Difference of Length to 350 mm (mm)	Status
Sacramento River	2006	217 - 472	49	0.557	Interpolated	0	Included
Sacramento River	2007	203 - 614	50	0.503	Interpolated	0	Included
Sacramento River	2011	202 - 420	11	0.716	Interpolated	0	Included
Sacramento River	2016	200 - 365	11	0.631	Interpolated	0	Included
Sacramento River	2017	208 - 340	17	0.537	Extrapolated	10	Included
Sacramento River	2018	212 - 377	17	0.599	Interpolated	0	Included
Sacramento River	2019	201 - 395	17	0.618	Interpolated	0	Included
San Joaquin River	2005	200 - 574	43	0.256	Interpolated	0	Included
San Joaquin River	2007	214 - 557	13	0.706	Interpolated	0	Included
San Joaquin River	2011	215 - 461	11	0.370	Interpolated	0	Included
San Joaquin River	2016	206 - 408	11	0.227	Interpolated	0	Included
San Joaquin River	2017	203 - 445	16	0.533	Interpolated	0	Included
San Joaquin River	2019	193 - 462	17	0.639	Interpolated	0	Included
West Delta	2005	202 - 465	32	0.236	Interpolated	0	Included
West Delta	2007	234 - 502	12	0.227	Interpolated	0	Included
West Delta	2018	215 - 515	17	0.397	Interpolated	0	Included
West Delta	2019	174 - 400	17	0.456	Interpolated	0	Included
Yolo Bypass - South	2005	261 - 368	8	0.334	Interpolated	0	Included
Yolo Bypass - South	2006	213 - 467	17	0.429	Interpolated	0	Included
Yolo Bypass - South	2007	200 - 454	24	0.366	Interpolated	0	Included
Yolo Bypass - South	2016	223 - 443	11	0.383	Interpolated	0	Included
Yolo Bypass - South	2017	225 - 508	17	0.483	Interpolated	0	Included
Yolo Bypass - South	2018	193 - 474	18	0.584	Interpolated	0	Included
Yolo Bypass - South	2019	220 - 451	17	0.494	Interpolated	0	Included

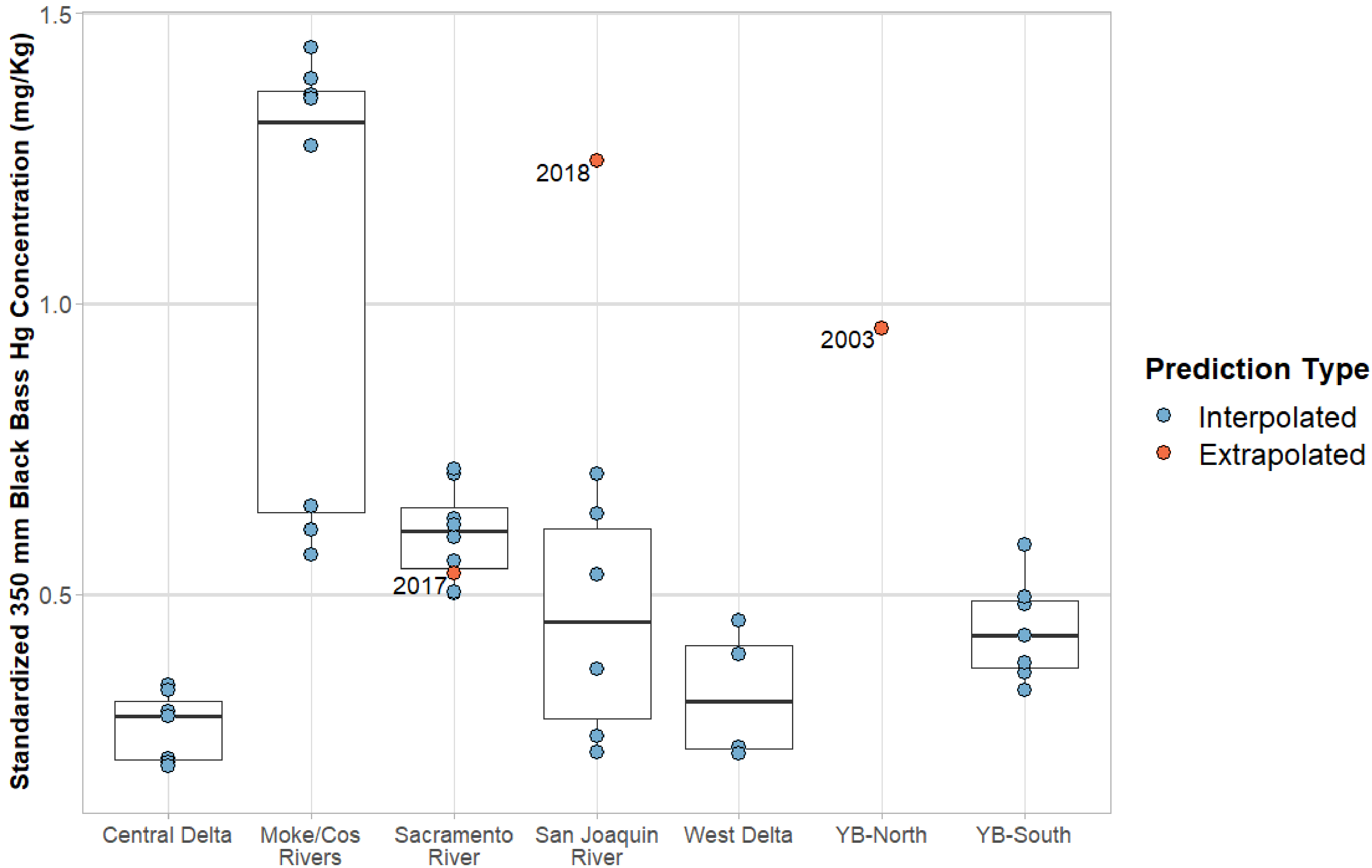

Figure 4.3: Boxplot of Interpolated Standardized 350 mm Black Bass Mercury Concentrations with Extrapolated Data Points Labeled by Sample Year

Table 4.5: Average Total Mercury Concentrations in Standard 350 mm Black Bass Weighted by Annual Sample Size (2002-2019) and Percent Reductions Needed to Meet the Recommended Fish Tissue Implementation Goal of 0.258 mg/kg in Each Delta TMDL Subarea

Delta TMDL Subarea	Wt. Avg. Std. 350 mm Black Bass THg[4] (mg/kg)	DMCP Review Percent Reduction	2010 TMDL Staff Report Percent Reduction
Central Delta	0.262	2%	0%
Mokelumne/ Cosumnes Rivers	1.130	77%	77%
Sacramento River	0.558	54%	67%
San Joaquin River	0.416	38%	65%
West Delta	0.317	19%	23%
Yolo Bypass - South	0.447	42%	NA

[4] Average weighted by total number of fish collected annually.

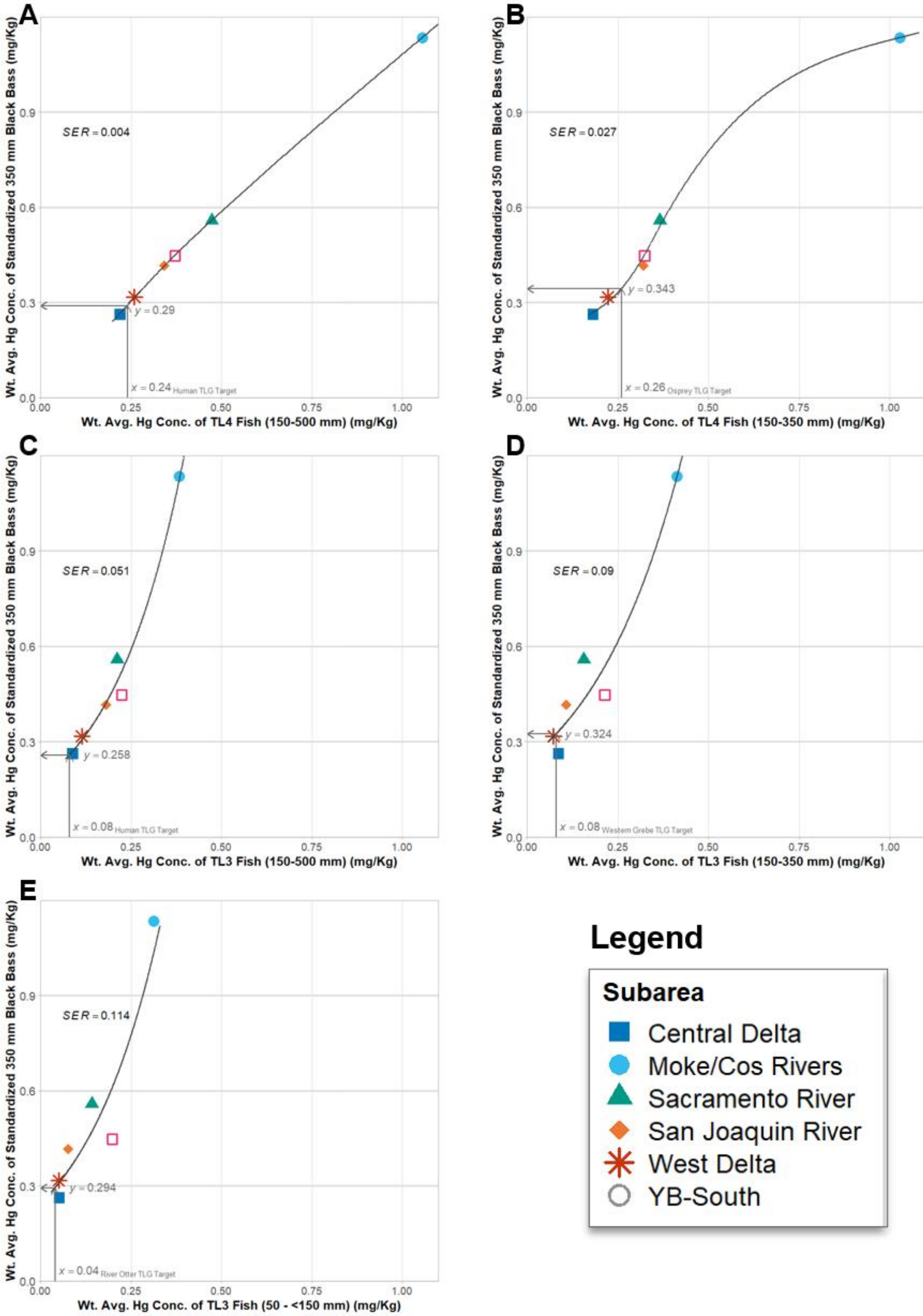

Figure 4.4: Regression models used to determine the predicted standardized 350 mm black bass protective mercury concentration shown in Table 4.3 for each TLG. Weighted average mercury concentration of standardized 350 mm black bass (y-axis) vs weighted average mercury concentration of each TLG (x-axis) as follows: **(A)** TL4 Fish (150-500 mm); **(B)** TL4 Fish (150-350 mm); **(C)** TL3 Fish (150-500 mm); **(D)** TL3 Fish (150-350 mm); and **(E)** TL3 Fish (50 - <150 mm).

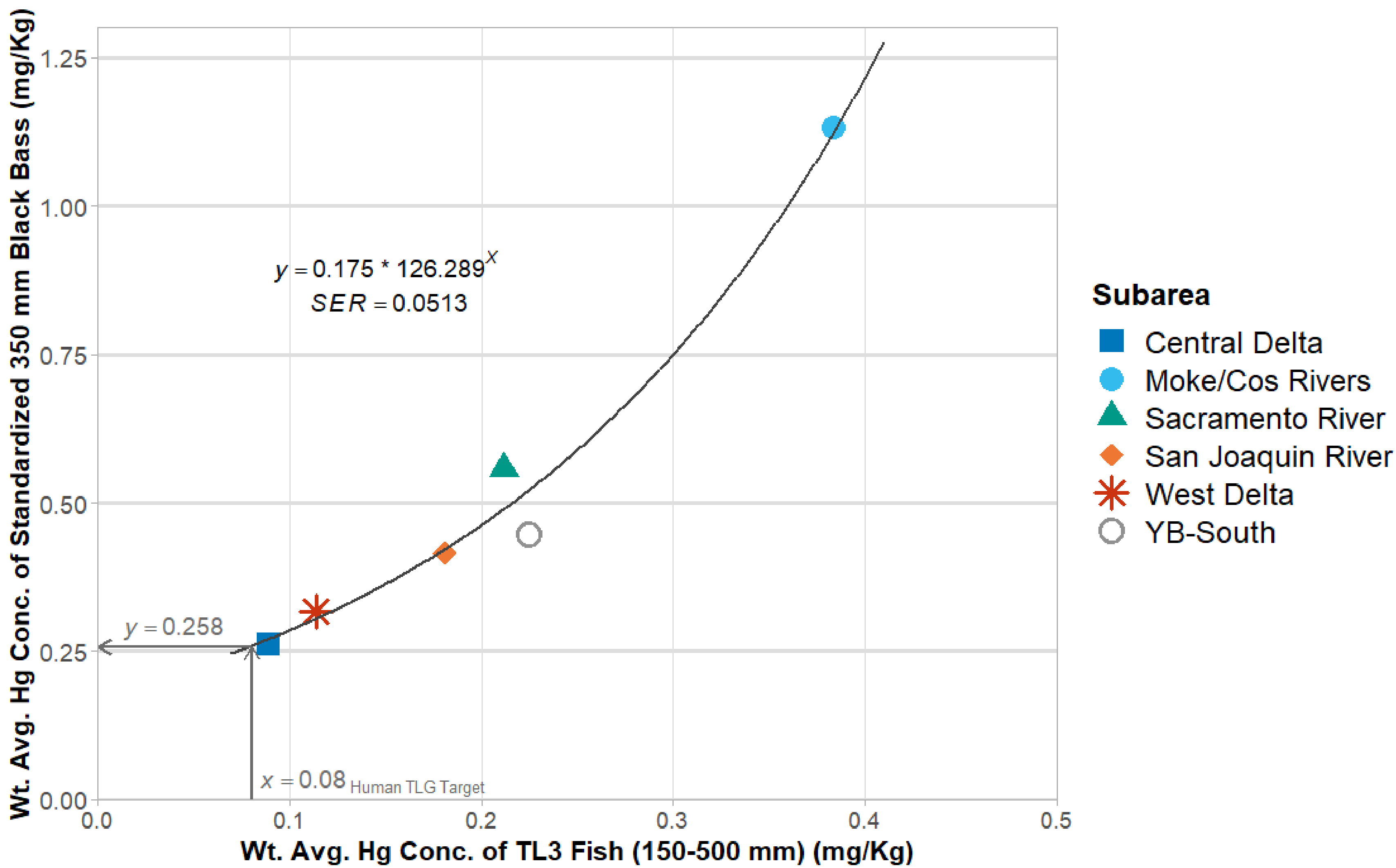

Figure 4.5: Relationship of Mercury Concentrations between TL3 150-500 mm Fish and Standardized 350 mm Black Bass

4.3 Key Points

- Board staff maintained the recommended TLG targets from the 2010 TMDL Staff Report, which are the following:
    - 0.24 mg/kg wet weight in muscle tissue of 150-500 mm TL4 fish, such as bass
    - 0.08 mg/kg wet weight in muscle tissue of 150-500 mm TL3 fish, such as salmon
    - 0.03 mg/kg mercury in less than 50 mm TL2 and TL3 fish.
- These targets are expected to be protective of humans eating 32 g/day (1 meal per week) of commonly consumed large fish, and all wildlife species that consume fish.
- Consistent with the 2010 TMDL Staff Report, black bass was used as an indicator species for mercury contamination in the Delta because it is a strong indicator of mercury bioaccumulation.
    - The 2010 TMDL Staff Report evaluated one species of black bass, largemouth bass.
    - For the DMCP Review, Board staff used all available species of black bass to include the Sacramento River subarea.
- Recent data were used to reevaluate the relationship between 350 mm standardized black bass and TLG mercury concentrations.
    - The resulting mercury concentration of 0.258 mg/kg (fillet, wet weight) in 350 mm standardized black bass was the most conservative value and expected to protect humans and piscivorous wildlife health.
- Board staff propose using 0.258 mg/kg as the black bass implementation goal for use in the linkage analysis and determination of the aqueous methylmercury implementation goal.
- Board staff observed elevated fish tissue mercury concentrations still occur in subareas closest to the foothill tributaries (e.g., Mokelumne/Cosumnes Rivers and Sacramento River subareas), while lower fish tissue mercury concentrations were measured in the Central Delta and West Delta subareas. The reevaluated percent reductions of mercury concentrations in black bass to meet TLG targets for wildlife and human health protection in all Delta TMDL subareas range from 2% to 77%.

5 LINKAGE ANALYSIS

Consistent with the 2010 TMDL Staff Report, the linkage analysis focuses on the Delta-specific quantitative relationship between mercury concentrations in bass and unfiltered, aqueous methylmercury concentrations. This relationship, along with the black bass implementation goal determined in Section 4, is used to predict an aqueous methylmercury concentration expected to result in fish tissue mercury concentrations protective for both human and wildlife consumption. An aqueous MeHg implementation goal was determined using the predicted aqueous methylmercury concentration and accounting for data and prediction variability. The aqueous MeHg implementation goal is used to allocate methylmercury reductions for within-Delta and tributary sources (Section 8).

The linkage analysis has three sections. The sections are as follows:

- Section 5.1 describes the available black bass mercury and aqueous methylmercury data
- Section 5.2 describes the mathematical relationship or "linkage" between mercury concentrations in black bass and unfiltered aqueous methylmercury concentrations
- Section 5.3 describes the random resampling methodology used to determine the aqueous MeHg implementation goal and margin of safety

The DMCP Review linkage analysis results in a protective aqueous methylmercury concentration of 0.061 ng/L expected to result in the recommended numeric targets for fish tissue (Section 4) for protection of human and wildlife health when consuming Delta fish. The probability distribution of the protective aqueous methylmercury concentration was determined using random resampling of the linkage analysis data. The 5th percentile of the probability distribution, 0.059 ng/L, was set as the aqueous MeHg implementation goal, which equates to a margin of safety of 3.3%.

5.1 Data Used in Linkage Analysis

The 2010 TMDL Staff Report relied on data from one black bass species, largemouth bass, in the linkage analysis. The DMCP Review used largemouth bass and the black bass species of smallmouth bass and spotted bass to develop the black bass implementation goal. Section 4.2 describes the reasoning for using multiple black bass species instead of only largemouth bass. Consistent with these reasons, black bass data were used for the DMCP Review linkage analysis.

The 2010 TMDL Staff Report conducted the linkage analysis using aqueous methylmercury data and largemouth bass mercury data sampled in the year 2000. The year 2000 was chosen because it was the year with the greatest overlap of available aqueous and fish data. For the DMCP Review, Board staff compiled fish data from years 1998 to 2019 and aqueous data from years 1992 to 2019 (Appendix A.1). After evaluating different year ranges (Appendix C), Board staff selected aqueous and black bass data from 2016 to 2019 because it provided a regression model with the lowest SER. A lower SER means the regression line better predicts observed values, with a less complex model having more weight. The data from these years were collected by the Delta RMP, which sampled black bass mercury and aqueous methylmercury concentrations at locations determined to be representative of Delta TMDL subareas (Figure 5.1). Appendix A.1 lists the fish and aqueous data sources used in the linkage.

5.2 Aqueous Methylmercury Versus Black Bass Total Mercury Regressions

Consistent with the 2010 TMDL Staff Report, the DMCP Review performs an analysis to link the relationship between aqueous unfiltered methylmercury concentrations in ambient water and mercury concentrations in standardized 350 mm black bass. The 2010 TMDL Staff Report used one black bass species as there was only tissue mercury concentrations for largemouth bass at the time. After adoption of the DMCP, subsequent fish monitoring focused on largemouth bass, but only smallmouth and spotted bass tissue mercury data were available for some years in the Sacramento River subarea. Other Delta TMDL subareas had largemouth bass data but little or no spotted bass or smallmouth bass data (Figure C.1). Therefore, the DMCP Review linkage analysis uses the black bass species of largemouth bass, spotted bass, and smallmouth bass to include data for the Sacramento subarea.

The 2010 TMDL Staff Report, regressed median and mean annual aqueous methylmercury concentrations against standardized 350 mm largemouth bass mercury concentrations using linear, exponential, logarithmic, and power regression models. In total, eight potential linkage models were evaluated. The final linkage model was selected based on the best R^2 value, which used mean annual aqueous methylmercury concentrations and a logarithmic regression model.

For the DMCP Review, the relationship between aqueous methylmercury and standardized 350 mm black bass mercury concentrations were evaluated using the following options (see Appendix C for more detail):

- Data year ranges (i.e., 2002-2019, 2012-2019, or 2016-2019)
- Methods to pair aqueous methylmercury data with standardized 350 mm black bass mercury concentrations (i.e., by year and Delta TMDL subarea or by subarea only)
- Summary statistics to measure central tendency (i.e., arithmetic mean, weighted mean, geomean, or median)
- Methods to group aqueous data (i.e., pooling or by year)
- Regression models (i.e., linear, exponential, logarithmic, power, NLS, or GAM)

In total, 405 potential linkage models were evaluated. The model that provided the lowest SER was selected as the final linkage model to represent the relationship between aqueous methylmercury and black bass mercury concentrations. The final linkage model uses the following data selection and analysis steps:

1. **1.** Selecting black bass and aqueous methylmercury Delta RMP data from 2016 through 2019.
    a. Black bass mercury data were selected based on calendar year
    b. Aqueous methylmercury data were selected based on a seasonal year that extends from 1 November to 31 October. For example, the 2017 seasonal year started on 1 November 2016 and ended on 31 October 2017
2. **2.** Standardizing each year of black bass mercury concentrations to 350 mm (Section 4.2.1).
3. **3.** Calculating the median of the standardized 350 mm black bass mercury concentrations for each Delta TMDL subarea (Table 5.1).
4. **4.** Calculating the median aqueous methylmercury concentration for each Delta TMDL subarea that had black bass mercury data (Table 5.1)[5].
    a. A median aqueous methylmercury concentration was calculated by pooling aqueous methylmercury data by seasonal years preceding and including each year a standardized 350 mm black bass concentration was available. For instance, if black bass data were available in year 2018, the median aqueous methylmercury concentration was calculated by pooling data from seasonal years 2016 through 2018. Similarly, if black bass data were available in year 2019, the median aqueous methylmercury concentration was calculated by pooling data from seasonal years 2016 through 2019 This method of calculating a median aqueous methylmercury concentration provided up to four seasonal years of aqueous methylmercury data coinciding with the lifespan of the sampled black bass.
    b. The median of these pooled aqueous methylmercury concentration medians was calculated and is the value reported in the second column of Table 5.1 for the Central Delta, Mokelumne/Cosumnes Rivers, Sacramento River, San Joaquin River, and West Delta subareas.
5. **5.** Plotting the median aqueous methylmercury concentration with the median standardized 350 mm black bass mercury concentration.
6. **6.** Regressing the data points from step 5 using a logarithmic model provided the lowest SER of all the other considered linkage models and was chosen for the DMCP Review linkage model.

Figure 5.2 shows the proposed DMCP Review linkage model, which results in a protective aqueous methylmercury concentration of 0.061 ng/L in unfiltered water using the recommended black bass implementation goal of 0.258 mg/kg (wet weight). Figure 5.3 shows the proposed DMCP Review linkage model in comparison to the linkage

[5] The Yolo Bypass - South subarea has black bass mercury data but was excluded from the linkage model because it is hydrologically unique compared to the other subareas.

model shown in Figure 5.2A of the 2010 TMDL Staff Report. Notably, Figure 5.3 shows the linkage graph coordinates flipped in comparison to Figure 5.2A of the 2010 TMDL Staff Report so that the protective aqueous methylmercury concentration could be determined by solving for y, which is consistent with Section 4 of the 2010 TMDL Staff Report, and standard modeling methods. As a result, a slightly different protective aqueous methylmercury concentration was determined than in the 2010 TMDL Staff Report (i.e., 0.069 ng/L in Figure 5.3 versus 0.066 ng/L in Figure 5.2A of the 2010 TMDL Staff Report).

The Marsh Creek, Yolo Bypass - North, and Yolo Bypass - South subareas were not included in the proposed linkage model. The Marsh Creek subarea was not included because it did not have available fish data. The Yolo Bypass - North subarea was not included because it was removed during the development of the black bass implementation goal (Section 4.2.1). While the Yolo Bypass - South subarea contained sufficient data, the entire Yolo Bypass was not included in the linkage model because it is hydrologically unique compared to the other Delta TMDL subareas. Unlike the rest of the Delta, the Yolo Bypass receives source water intermittently from flood events when weirs overspill or from regulated gate openings. There are periods where either or both Yolo Bypass subareas are completely dry, which is unlike other subareas. This also likely results different mercury cycling processes compared to the other subareas. It also means that fish have different residence times in the Yolo Bypass than the rest of the Delta. Board staff attributes these characteristics to the Yolo Bypass - South showing higher aqueous and lower fish mercury concentrations relative to other subareas. Ultimately, removing the entire Yolo Bypass from the linkage model is consistent with the 2010 TMDL Staff Report, which also excluded the Yolo Bypass and Marsh Creek from the linkage model due to a lack of data.

The median aqueous methylmercury concentration for the Marsh Creek, Yolo Bypass - North, and Yolo Bypass - South subareas was calculated using a similar method for the subareas used in the linkage model (Step 4, above) and is shown in the second column of Table 5.1. First, the five most recent seasonal years of available data from 2010 through 2019 were selected. Next, the median aqueous methylmercury concentration was calculated for the earliest seasonal year, then a seasonal year of data were sequentially added to the data pool to calculate another median. This resulted in five pooled medians, each using a different number of seasonal years of aqueous methylmercury data. Finally, the median of the 5 pooled medians was calculated.

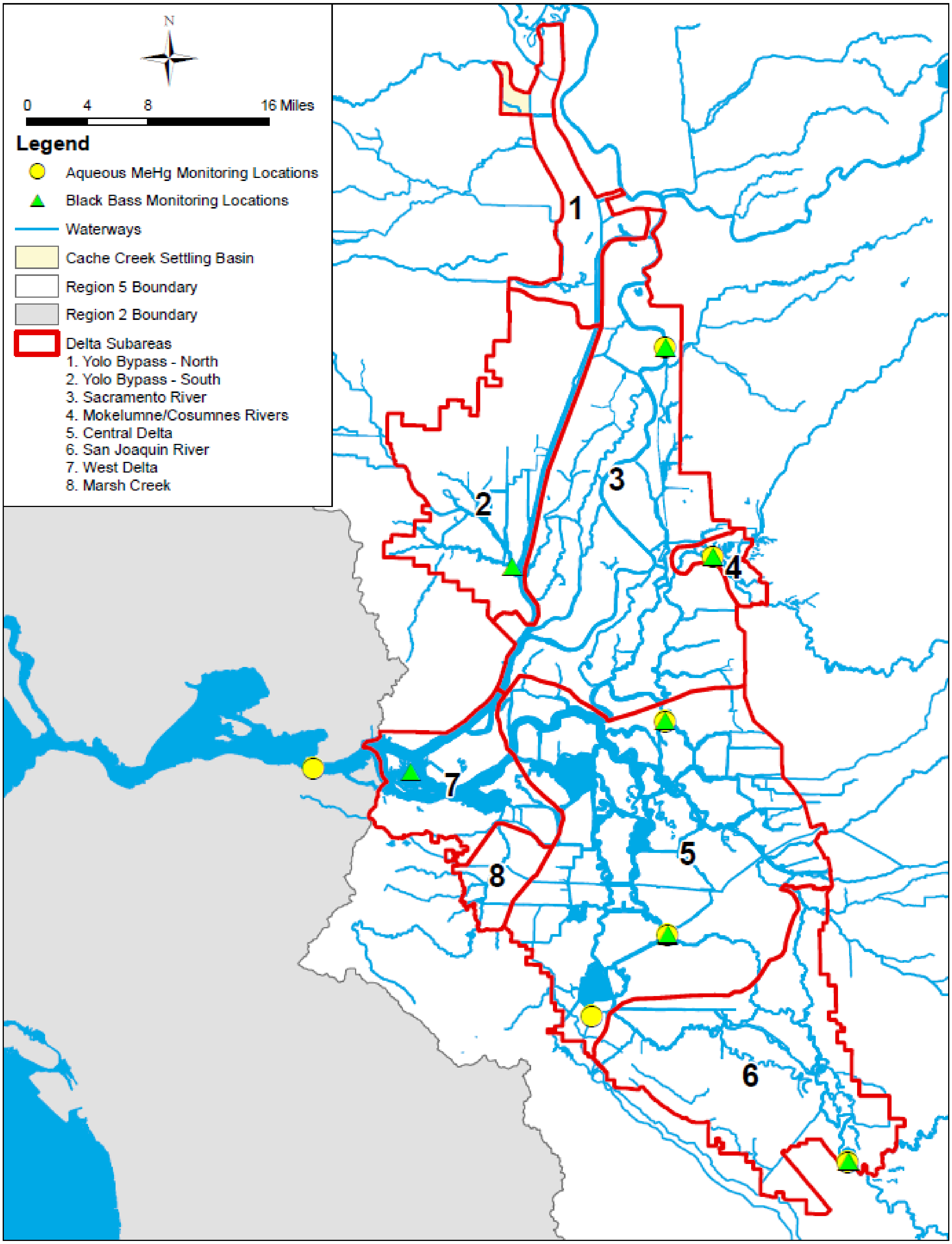

Figure 5.1: Monitoring Locations of Aqueous Methylmercury and Black Bass Data Used in the Linkage Analysis

Table 5.1: Median Mercury Concentrations in Standard 350 mm Black Bass and Median Aqueous Methylmercury Concentrations with Respective Percent Reductions Needed to Meet the Recommended Aqueous MeHg Implementation Goal of 0.059 ng/L in Each Delta TMDL Subarea

Delta TMDL Subarea	Median Std. 350 mm Black Bass Hg Conc. (mg/kg)[6]	Median Aqueous MeHg Conc. (ng/L)[7]	Regression Aqueous MeHg Conc. (ng/L)[8]	Percent Reduction[9]
Central Delta	0.312	0.067	0.068	12.73%
Mokelumne/ Cosumnes Rivers	1.388	0.118	0.120	50.85%
Sacramento River	0.609	0.079	0.091	35.23%
San Joaquin River	0.533	0.115	0.086	31.73%
West Delta	0.426	0.065	0.079	24.93%
Marsh Creek		0.237		75.11%
Yolo Bypass - North (includes CCSB)		0.185		68.02%
CCSB only		0.580		89.83%
Yolo Bypass - South		0.191		69.11%
Weighted Median[10]		**0.079**		**25.10%**

[6] The median concentration of standard 350 mm black bass mercury concentrations. These values were used in the DMCP Review linkage model. Marsh Creek, Yolo Bypass - North, Cache Creek Settling Basin, and Yolo Bypass - South did not have mercury samples of 350 mm black bass mercury.

[7] The median concentration of pooled aqueous methylmercury concentration medians. The methods used to calculate these values are explained in Section 5.2. The values with a corresponding median standard 350 mm black bass mercury concentration were used in the DMCP Review linkage model.

[8] The aqueous methylmercury concentration determined from the linkage model using the median of standard 350 mm black bass mercury concentration.

[9] The percent reduction needed in aqueous methylmercury concentration in order to meet the aqueous MeHg implementation goal. For subareas with a median standard 350 mm black bass mercury concentration, the reduction is based on the regressed aqueous methylmercury concentration. For subareas without a median standard 350 mm black bass concentration, the reduction is based on the values in the column "Median Aqueous MeHg Concentration (ng/L)".

[10] The median value of the column weighted by each subarea's percent area of the Delta.

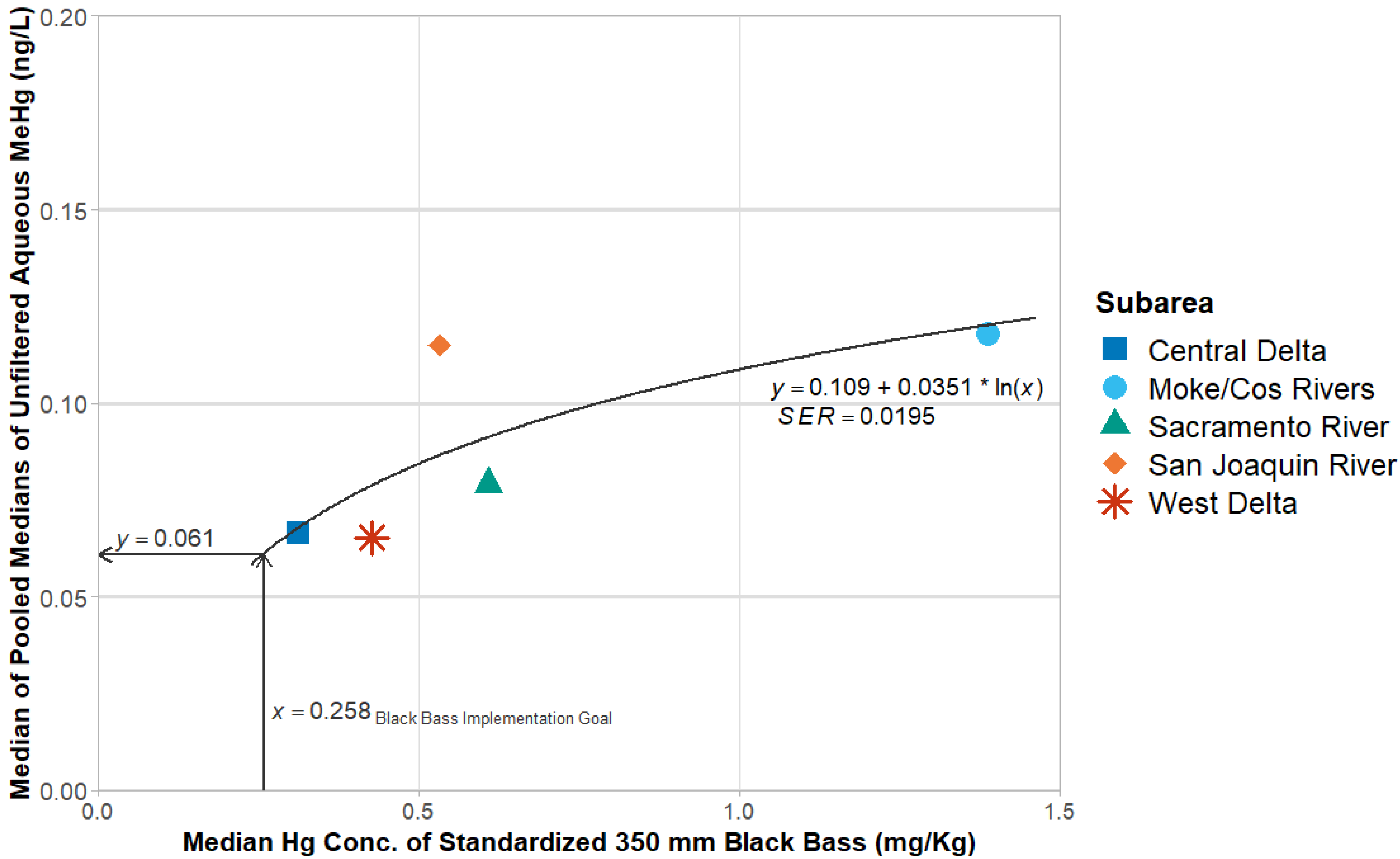

Figure 5.2: DMCP Review Proposed Linkage Model Showing the Relationship Between Standardized 350 mm Black Bass Mercury and Unfiltered Aqueous Methylmercury Concentrations

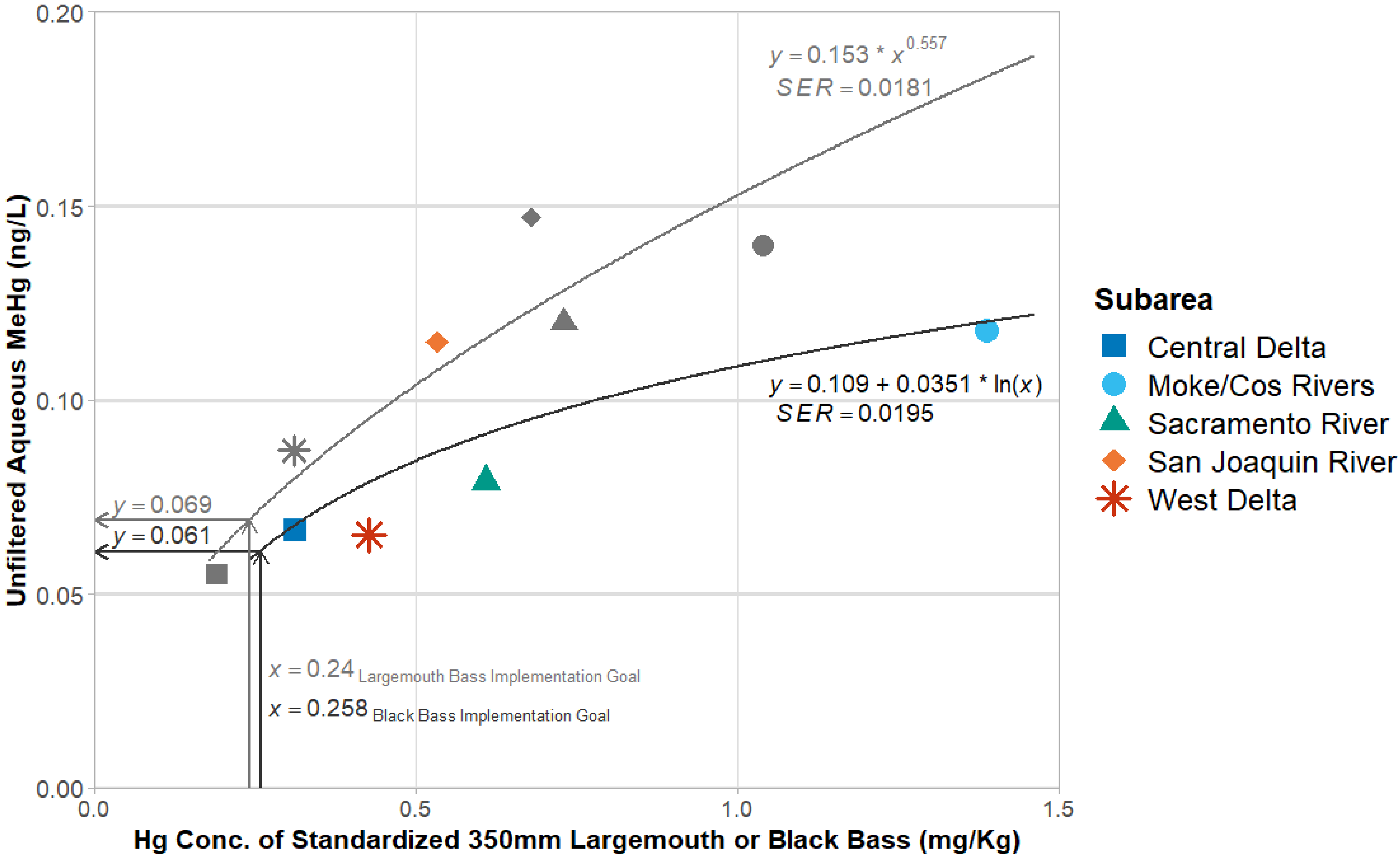

Figure 5.3: Comparison of 2010 TMDL Staff Report Linkage Model (Gray Symbols and Line) to Proposed DMCP Review Linkage Model (Color Symbols and Black Line)

5.3 Aqueous MeHg Implementation Goal & Margin of Safety Calculation

Resampling (i.e., repetitively sampling a given dataset randomly) was used to determine the aqueous MeHg implementation goal and account for data and modeling uncertainty. Resampling mimics the randomness of aqueous and black bass monitoring and estimates the probability distribution of the predicted protective aqueous methylmercury concentration shown in Figure 5.2. Using R code, Board staff created a custom function to repetitively and randomly sample data used for the linkage model. The 5th percentile value, 0.059 ng/L, from the generated probability distribution (Figure 5.3) was set as the aqueous MeHg implementation goal, which equates to a margin of safety of 3.3%. The aqueous MeHg implementation goal of 0.059 ng/L was used to determine allocations and is predicted to protect designated beneficial uses (Section 8).

The following steps summarize the resampling technique used to generate the protective aqueous methylmercury concentration probability distribution.

1. For each combination of Delta TMDL subarea and year containing at least eight[11] black bass mercury concentration sample results:
    a. A random sample number ranging from seven to the total number of samples was selected. This number of black bass mercury concentrations were randomly selected without replacement[12].
    b. The randomly selected black bass mercury concentrations were regressed against fish length using linear, power, exponential, NLS, and logarithmic models. The regression model with the lowest SER was used to determine the standardized 350 mm black bass mercury concentration. GAM models were not used in this analysis because the models can show increasing then decreasing methylmercury concentration trends with increasing fish length, which is not expected when modeling bioaccumulation.
    c. A seasonal year of aqueous methylmercury data were randomly selected from at most five seasonal years prior to and including the selected black bass monitoring year.
    d. From the randomly selected seasonal year, five aqueous methylmercury concentrations were randomly sampled with replacement for the dry season months May through October, and seven for the wet season

[11] Board staff used a minimum sample size of eight black bass for the regressions to standardize methylmercury concentrations to 350 mm per the recommendation in Jenkins and Quintana-Ascencio (2020).

[12] Sampling with replacement (e.g., if a total of nine black bass samples were available, randomly selecting nine concentrations, with each concentration possibly being selected multiple times) resulted in abnormal regression models (e.g., regression lines with zero or negative slope) or an extrapolated standardized 350 mm black bass mercury concentration, or both. Randomly selecting the number of black bass mercury concentrations, rather than sampling with replacement, allowed for data variability and more realistic regressions when determining the standardized 350 mm black bass mercury concentration. A minimum of seven samples were selected to allow for data variability for black bass sampling events with eight samples. The minimum fish length of the random sample was required to be 360 mm or less. The maximum fish length was required to be 340 mm or more. These limits were chosen based on the extrapolation length of 10 mm that occurred in 2017 for the Sacramento River subarea and prevented random samples from requiring a large degree of extrapolation to determine the standardized 350 mm mercury concentration. Allowing a small degree of extrapolation to occur improved the data variability of random samples.

months November through April. This resulted in a total of 12 randomly selected aqueous methylmercury concentrations, representing monthly monitoring throughout the seasonal year.

  - **e.** Steps 1.c and 1.d were repeated 5 times, representing 5 seasonal years of aqueous methylmercury data preceding the black bass annual monitoring event.
  - **f.** The 60 randomly selected aqueous methylmercury concentrations were pooled and the median was calculated. Thus, each year containing black bass methylmercury data had a randomly determined standardized 350 mm black bass mercury concentration and median aqueous methylmercury concentration.

2. For each Delta TMDL subarea, the median of the standardized 350 mm black bass mercury concentrations was calculated, and the median of the median aqueous methylmercury concentrations was calculated.
3. These concentrations were regressed using the same regression models in Step 1.b, except GAM models were included. The regression with the lowest SER was selected and the black bass implementation goal of 0.258 mg/kg was plugged into the model to determine the protective aqueous methylmercury concentration.
4. Steps 1-3 were computationally repeated 10,000 times.

The resulting probability distribution of protective aqueous methylmercury concentrations is shown in Figure 5.4. The 5th percentile of the distribution, 0.059 ng/L, was considered an appropriately conservative value needed to account for data and modeling uncertainty. Thus, 0.059 ng/L was selected as the aqueous MeHg implementation goal and equates to a margin of safety of 3.3% when compared to the protective aqueous methylmercury concentration of 0.061 ng/L determined by the linkage model (Figure 5.2). Based on the data variability used in the linkage model, the 5th percentile means that there is a 5% chance that the required aqueous methylmercury concentration needed to meet the black bass implementation goal is below 0.059 ng/L. Thus, there is a 95% chance that the required aqueous methylmercury concentration is greater than 0.059 ng/L.

There is also an implicit margin of safety for wildlife species that consume Delta fish. As described in Section 4, the aqueous MeHg implementation goal corresponds to 0.08 mg/kg mercury for TL3 fish ranging in size 150 mm to 500 mm, which was calculated for the protection of humans consuming one meal per week. As shown in Table 4.3 (Section 4), the predicted TL4 150 mm to 500 mm fish mercury concentration for humans eating TL3 150 mm to 500 mm fish is 0.124 mg/kg, while the predicted TL4 150 mm to 500 mm fish mercury concentrations for wildlife range from 0.230 mg/kg, for river otter eating TL3 fish, to 0.403 mg/kg, for river otter eating TL4 fish. These values correspond to 350 mm black bass mercury concentrations of 0.293 and 0.526 mg/kg. When entered into the linkage regression model (Figure 5.2), these values translate to aqueous methylmercury concentrations of 0.065 ng/L and 0.086 ng/L, which equate to a margin of safety of 9.2% to 31%, depending on the piscivorous wildlife species.

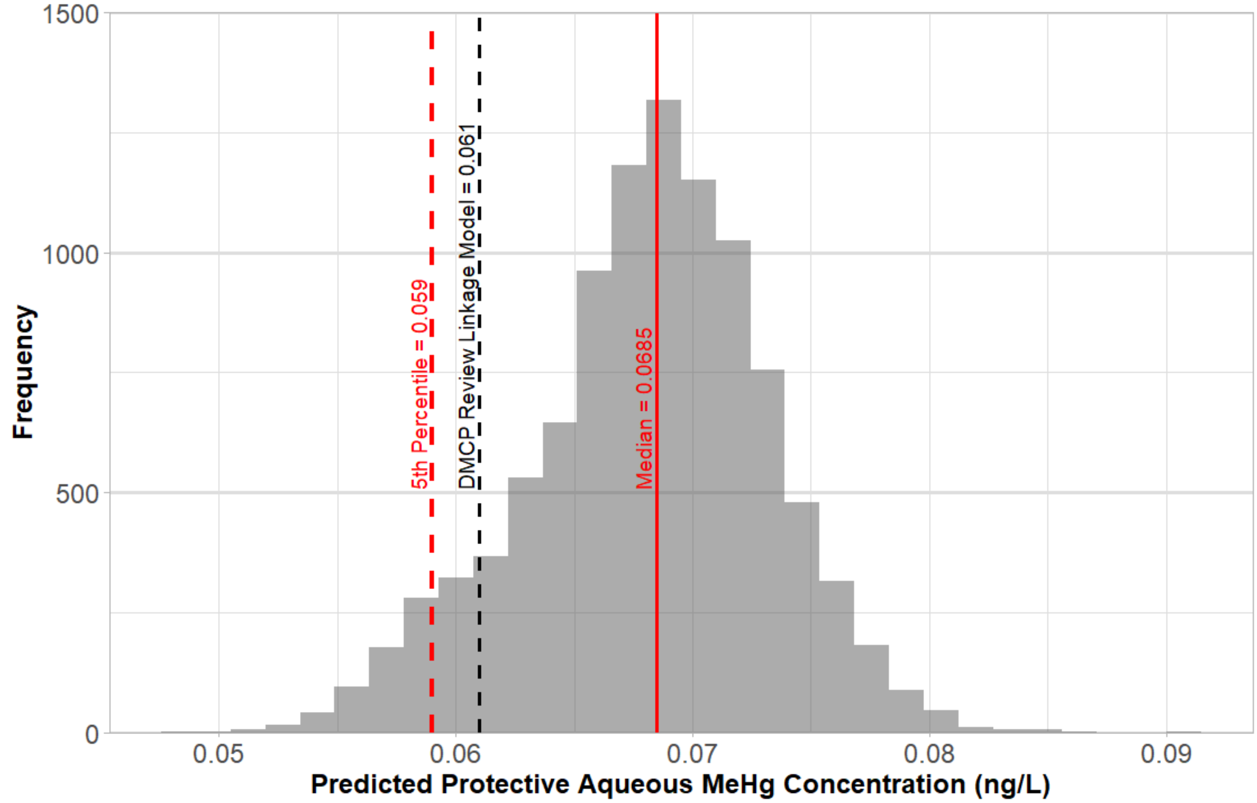

Figure 5.4: Probability Distribution of Predicted Protective Aqueous Methylmercury Concentrations from Resampling Linkage Model Data.

5.4 Key Points

- The DMCP Review linkage analysis used Delta RMP black bass mercury and unfiltered aqueous methylmercury data collected from 2016 through 2019.
- The DMCP Review linkage analysis considered 405 different regression models. The final model was selected because it had the lowest SER.
- The DMCP Review linkage regression model and black bass implementation goal resulted in a corresponding aqueous methylmercury protective concentration of 0.061 ng/L.
- The random resampling was used to determine an aqueous MeHg implementation goal of 0.059 ng/L corresponding to a margin of safety of 3.3%.

6 SOURCE ANALYSIS – METHYLMERCURY

Consistent with the 2010 TMDL Staff Report, the DMCP Review focuses on assessing the sources of methylmercury in the Delta. Sources and losses of methylmercury are described in this section. Figures and tables cited in this section are arranged at the end of each source-specific section in the order in which they are mentioned. All mass load calculations are based on Equation 6.1:

Equation 6.1: Mass Load Calculations

$$M_x = C_x \times V$$

Where:

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

To revise the methylmercury source analysis, Board staff included data from WYs 2000-2019, a period that includes a mix of wet and dry years and encompasses the methylmercury concentration data collected by dischargers and Phase 1 DMCP control study participants. Data used for the methylmercury source analysis are included in Appendix A.2. Table 6.1 summarizes the methods and land covers used to calculate sources and losses of methylmercury. Details on land cover used for each analysis are detailed in respective sections and in Appendix D. Board staff grouped land cover into five land cover classes: Agriculture, Open Space, Open Water, Urban, and Wetland and Marsh (Figure 6.1).

Section 6.1 describes the flow data and water volumes upon which the methylmercury loads are based. Sections 6.2 and 6.3 describe how the methylmercury concentration and flow data are used to calculate methylmercury loads for all major sources and losses. These two sections also describe how Board staff handled missing data and uncertainties. Section 6.4 reviews the results and potential implications of the methylmercury mass balance.

The purpose of the methylmercury source analysis is to represent the central tendency of sources and losses using normal and critical conditions over an appropriate timeframe, WYs 2000-2019. For the DMCP Review, Board staff primarily used medians as the measure of central tendency in calculating sources and losses of methylmercury, maintaining consistency with the linkage model calculation of the aqueous MeHg implementation goal (Section 5.2). Climate change is expected to create variable extremes of methylmercury concentrations and flow events (Section 6.1.13 and 6.4.1). These extremes can affect the calculated average and resulting compliance determination from one year to the next even though the central tendency of the data remains unchanged. The median is a robust statistical measure of central tendency because up to 50% of the observations can be changed without affecting the median value, while the average is heavily influenced by skewed datasets and outliers.

Table 6.1: Summary of Methods Used and Land Cover Included in Final Methylmercury Load Estimates

Source/Loss	Section	Summary of Method Used to Estimate Load	Land Cover Included in Final Load Estimate
Tributary Inflows	6.2.1	For larger tributaries, Board staff used monthly median methylmercury concentration multiplied by monthly median flow from streamflow gages to get monthly load, then summed to get annual load. For all other tributaries, used median methylmercury concentrations multiplied by estimated annual flow, either from streamflow gages or calculated wet weather runoff by tributary watershed.	All land cover categories in tributary watersheds outside of Delta MeHg TMDL Boundary for wet weather runoff estimates
Open Water Sediment Flux	6.2.2	Benthic flux chamber sediment flux rate multiplied by area.	Open water
Nontidal Wetlands	6.2.3	Monthly load rate multiplied by acreage then summed over all subareas and months.	Nontidal wetlands
Wastewater (Municipal & Non-Municipal)	6.2.4	Using data from five most recent years from 2010 to 2021, multiplied median of annual average daily flows by pooled median of reported methylmercury concentrations.	None
Agricultural Returns	6.2.5	Methylmercury concentrations in source and return waters multiplied by flow volumes from Delta Island Consumptive Use Model; net load is return load minus source load.	Agricultural lands
Urban Runoff	6.2.6	Summed wet and dry weather runoff loads per MS4 type, discharger, and subarea.	Urban
Atmospheric Deposition	6.2.7	Median of annual precipitation multiplied by runoff coefficients, acreage, and methylmercury concentration in rainfall.	All except urban
Outflow to San Francisco Bay	6.3.1	Monthly median losses summed over all months.	None

Source/Loss	Section	Summary of Method Used to Estimate Load	Land Cover Included in Final Load Estimate
Particle Settling & Update by Biota	6.3.2	Monthly median losses, summed over all months.	All area of the Delta, as defined by the 2008 California Bay-Delta Authority (State-federal program; CALFED) Mercury Project Final Report
Photodegradation	6.3.3	Monthly median losses, summed over all subareas and months.	Open water
Exports to Southern California (Delta Mendota Canal & California Aqueduct)	6.3.4	Annual median losses.	None
Dredging	6.3.5	Estimated annual methylmercury in turbid effluent discharged from dredged material placement sites subtracted by methylmercury volume removed by dredging activities.	None
Tidal Wetlands	6.3.6	Monthly load rate multiplied by acreage then summed over all subareas and months.	Tidal wetlands
Cache Creek Settling Basin	6.3.7	Used outflow and weir monthly median methylmercury concentrations multiplied by estimated monthly flow from available streamflow gage data to get monthly load, summed to get annual load, then subtracted inflow loads from Cache Creek.	None

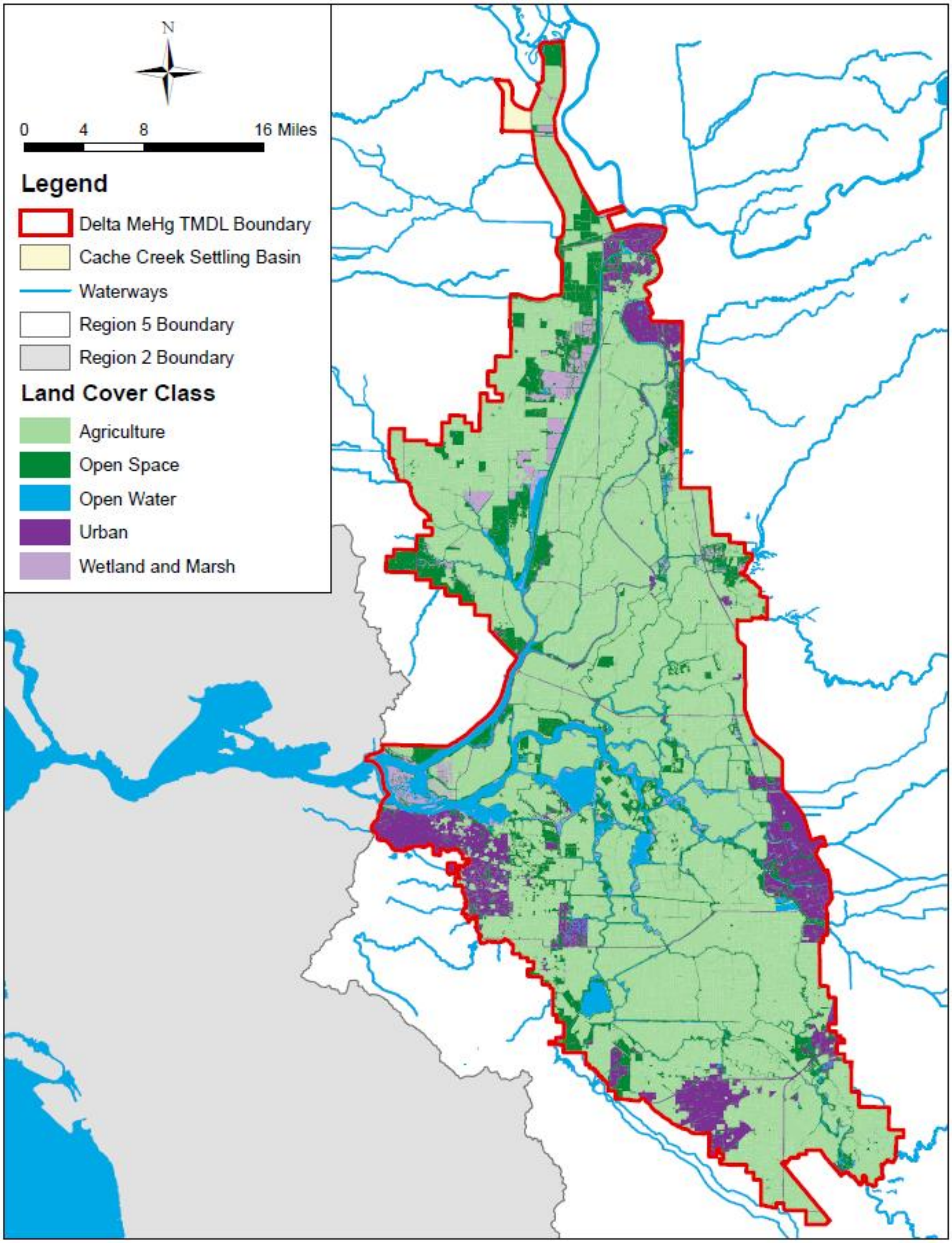

Figure 6.1: Land Cover by Classification in the Delta Methylmercury TMDL Boundary

6.1 Water Balance

The 2010 TMDL Staff Report assessed water inputs and losses for two periods: WYs 2000-2003 to match available methylmercury concentration data and determine methylmercury loads; and WYs 1984-2003 to include data from both wet and dry years and better understand long-term conditions (see Section 6.1 and Appendix E of the 2010 TMDL Staff Report).

For the DMCP Review, water inputs and losses were evaluated for WYs 2000-2019. This period includes a mix of wet and dry years and encompasses available methylmercury concentration data, which includes data used in the 2010 TMDL Staff Report and data collected by dischargers and control study participants for the DMCP (Table 6.2).

Board staff acquired WYs 2000-2019 classifications for Sacramento Valley and San Joaquin Valley from the DWR Hydrologic Classification Index (HCI). Figure 6.2 and Figure 6.3 graph each year's hydrologic classification based on 1 May runoff forecasts for the Sacramento Valley and San Joaquin Valley, respectively. As mentioned in Appendix E of the 2010 TMDL Staff Report, the DWR HCI classifies water years as "wet", "above normal", "normal", "below normal", "dry", or "critical dry" (DWR c2023). For the Sacramento Valley, normal hydrologic conditions equate to an index value of 7.8, wet is greater than or equal to 9.2, above normal is 7.8 to 9.2, below normal is 6.5 to 7.8, dry is 5.4 to 6.5, and critical dry is less than or equal to 5.4. For the San Joaquin Valley, normal hydrologic conditions equate to an index value of 3.1, wet is greater than or equal to 3.8, above normal is 3.1 to 3.8, below normal is 2.5 to 3.1, dry is 2.1 to 2.5, and critical dry is less than or equal to 2.1. For WYs 2000-2019, the Sacramento Valley has an average index of 7.59 and median index of 7 and the San Joaquin Valley has an average index of 2.95 and median index of 2.4, indicating the period for both regions had below normal rainfall.

Data sources used for the DMCP Review to estimate Delta water volume inputs and exports varied and are listed in Appendix A.2. Each water input and loss evaluation determined an annual volume and water balance ratio. Data and methods used are summarized below in order from largest input to smallest export and are described in more detail in their respective source analysis sections. Table 6.3 lists total estimated water volumes and percentage ratio for each input and export.

6.1.1 Tributary Inflows

Tributary flow volumes were determined using stream flow gage data from USGS and DWR, precipitation gage data from California Data Exchange Center (CDEC), land use acreages from multiple sources, and calculation methods similar to those in the 2010 TMDL Staff Report. Board staff prioritized using flow gages to estimate water volumes per tributary; however, not all tributary streams are gaged. To estimate ungaged stream water volumes, Board staff estimated wet weather runoff for tributary watersheds by multiplying precipitation gage medians, acreage of land cover, and land cover runoff coefficients[13]. Wet weather runoff estimates for tributaries may underestimate flow volumes because they do not include water inputs such as dry weather runoff volumes, water released from major dams and reservoirs, or groundwater discharge. Conversely, wet weather runoff estimates do not include water exports such as municipal, non-municipal, and agricultural withdrawals, evapotranspiration, or groundwater recharge. For tributary watersheds that encompassed both gaged and ungaged streams, Board staff subtracted gaged stream annual volumes from the watershed's estimated wet weather runoff volume and assigned resulting volumes to the ungaged streams. Tributary sources are estimated to annually contribute approximately 18 million acre-feet (ac-ft) of water to the Delta during the WYs 2000-2019 period. This is about 92% of all water inputs to the Delta. For more detailed information on flow volume data for tributary inputs, see Section 6.2.1.2.

6.1.2 Atmospheric Deposition

Atmospheric deposition water volume estimates relied on precipitation gage data, land use acreages, and land cover runoff coefficients within the Delta MeHg TMDL Boundary. To prevent double counting with urban runoff, Board staff estimated atmospheric deposition only over agricultural, native vegetation, open water, and wetland land covers. Approximately 1,288,141 ac-ft of water is estimated to run off from these land cover types annually in the Delta. This is approximately 6.55% of all water inputs in the Delta. See Section 6.2.7 for a detailed description of atmospheric deposition flow volumes.

6.1.3 Wastewater (Municipal & Non-Municipal)

To estimate discharge volumes for municipal and on-municipal wastewater, facility data were acquired from the electronic Self-Monitoring and Reporting (eSMR) Program, except for the City of Lathrop Consolidated Treatment Facility (CTF)[14]. Board staff used the five most recent calendar years of facility flow data from 2010 through 2021 to calculate the median annual flow per facility and only account for recent facility upgrades. The range of years for each facility varies because of data availability, but most had discharge data available from 2017 to 2021. Daily flow volumes were summed by year; then the median of the yearly flow volumes was used to estimate the annual flow for each facility discharge location. For WWTFs with multiple discharge locations, the median of all discharge locations estimated annual discharge volume was used. This analysis estimated that NPDES WWTFs contribute approximately 200,781 ac-ft of water annually to the Delta during the WYs 2000-2019 period, which is about 1.02% of all water inputs. For more detailed information on discharge volume estimates for municipal and non-municipal wastewater, see Section 6.2.4.

[13] Board staff used the same runoff coefficients for land cover in the 2010 TMDL Staff Report, which were adapted from Lindeburg (1992).

[14] Since no discharge data were available at the time of the DMCP Review for the City of Lathrop CTF, Board staff used the permitted flow volume.

6.1.4 Urban Runoff

Urban runoff volumes were calculated by summing estimates of dry and wet weather runoff, consistent with methods used in the 2010 TMDL Staff Report. To calculate dry weather urban runoff volumes, Board staff used updated urban acreage and the adapted Sacramento area dry weather runoff volume from Larry Walker Associates (LWA 2013). To estimate wet weather urban runoff volumes, Board staff used updated urban acreage, updated annual precipitation, and land cover runoff coefficients. Annual dry and wet weather runoff volumes for urban land cover within the Delta MeHg TMDL Boundary are estimated to be approximately 5,372 ac-ft and 51,776 ac-ft, respectively, totaling 57,148 ac-ft per year (ac-ft/yr) during the WYs 2000-2019 period. This is approximately 0.29% of all water inputs in the Delta. For more information on urban runoff volume estimates, see Section 6.2.6.4.

6.1.5 Cache Creek Settling Basin

The CCSB was assessed as a tributary source in the 2010 TMDL Staff Report, using a flow gage upstream of the basin and flow dependent equations to estimate outflow and weir spills into the Yolo Bypass. In the DMCP Review, Board staff propose including CCSB within the Delta MeHg TMDL Boundary and estimated flow volumes using available stream flow gage data at the outflow and weir locations. Because Cache Creek is an intermittent stream, Board staff assigned gaps in gage data as zero flow and used monthly means to estimate an annual flow volume from CCSB of about 192,236 ac-ft. Subtracting input flows from Cache Creek to the basin to remove double-counting resulted in an estimated volume of approximately 5,577 ac-ft/yr of water from CCSB, which is about 0.03% of all water inputs in the Delta. For more information on volume estimates for CCSB, see 6.3.7.2.

6.1.6 Outflows to San Francisco Bay & Diversions to Southern California

Consistent with the 2010 TMDL Staff Report, the Dayflow model was used to estimate daily outflow to San Francisco Bay, the CVP via the Delta Mendota Canal, and the SWP via the California Aqueduct. Board staff considered using summary flow values from the DSM2 provided in the DWR Open Water Report, but this model was not used because these flow values (1) were not used for the 2010 TMDL Staff Report; (2) only are provided for 1999 through 2006; and (3) are provided only as pooled averages for each export site. Annual outflows for WYs 2000-2019 from the Delta to San Francisco Bay, Delta Mendota Canal, and California Aqueduct are estimated to be approximately 13 million ac-ft of water combined, which is about 76% of all Delta water exports. See Sections 6.3.1 and 6.3.4 for more information on the estimated export volumes to San Francisco Bay and south of Delta, respectively.

6.1.7 Evaporation

The 2010 TMDL Staff Report Appendix E, Section E.2.6 included an estimated volume of approximately 300,000 ac-ft/yr water lost through evaporation from Delta water surfaces. This was calculated by multiplying the average evaporation rate for the region by the open water surface acreage. The average evaporation rates cited were approximately 73.4 inches per year (in/yr) for Brannan Island and Grizzly Island near Rio Vista (Central Valley Water Board Order R5-2002-0120, p.4, Finding No. 18), and approximately 78.43 in/yr for Oakdale Woodward Dam Station south of Stockton (Central Valley Water Board Order R5-2003-0049, p. 2, Finding No. 8). The 2010 TMDL Staff Report used 73.4 in/yr in their calculations and estimated the area of open water within the Delta to be approximately 48,600 acres.

For the DMCP Review, Board staff utilized evaporation data from Western Regional Climate Center (c2016-2023) to acquire evaporation data for the Brannan Island, Grizzly Island, Oakdale Woodward Dam Station, and Walnut Grove stations. The Brannan Island station gathered data from years 1968 through 1977, listing an average annual evaporation rate of 79.43 in/yr. The Grizzly Island station gathered data from years 1971 through 1977, listing an average annual evaporation rate of 65.79 in/yr. The Oakdale Woodward Dam station gathered data from years 1948 through 1967, listing an average annual evaporation rate of 76.09 in/yr. The Walnut Grove station gathered data from years 1953 through 1961, listing an average annual evaporation rate of 65.15 in/yr. Board staff used the median of the reported average evaporation rate of the four sites, to get an evaporation loss rate of 70.94 in/yr and the updated open water surface area of approximately 58,873 acres to estimate a total loss of about 348,040 ac-ft/yr.

Because evaporation occurs over other land cover types and precipitation over all land cover types was included in the water balance, Board staff decided to include evaporation loss on other land cover types, as well. The Western Regional Climate Center website stated the total reported evaporation rates may be overestimations of actual evaporation rates over moist natural surfaces, and that data users may choose to multiply values by 0.7 or 0.8 for natural surfaces. Board staff used a conversion factor of 0.75 with the median evaporation rate of 70.94 in/yr to get 53.205 in/yr evaporation rate for wetland, agricultural, and native vegetation land cover types.[15] Board staff multiplied the converted evaporation rate by land cover acreage to get annual loss of 143,290 ac-ft for wetlands, 2,2195,240 ac-ft for agricultural lands[16], and 382,844 ac-ft for native vegetation. Summing the evaporation loss for open water, wetland, agricultural, and native vegetation land cover types, Board staff estimates approximately 3.069 million ac-ft of water is lost through evaporation annually. This is approximately 17.98% of all water lost in the Delta.

Board staff recognizes that evaporation rates used in this update are from data gathered decades ago and that the effects of climate change on current and future evaporations rates may be different. However, a study conducted in 2019 concluded that no trends in evaporation rates due to climate variability over the years 2001 to 2017 occurred (Baldocchi *et al.* 2019). Therefore, Board staff is confident that this rate is sufficient for the DMCP Review water balance.

[15] Evaporation rate of 53.205 in/yr is comparable to the USGS 1962 report for evaporation rates in the Lower Sacramento River and San Joaquin River of 58 in/yr and 50 in/yr, respectively (Meyers and Nordenson 1962).

[16] Dayflow model accounted for evaporation rates over farmed Delta islands, which was relied on for assessing agricultural diversion source loading in Section 6.2.5.

6.1.8 Agricultural Diversions

Consistent with the 2010 TMDL Staff Report, the Delta Island Consumptive Use (DICU) Model was used to estimate Delta agricultural diversion, seepage, and return flows. The DICU Model boundary does not include the areas of the Yolo Bypass - North and Yolo Bypass - South Delta TMDL subareas north of the Legal Delta Boundary. Thus, agricultural estimated water volumes may be an underestimate for the agricultural volume within the Delta MeHg TMDL Boundary. Board staff used average monthly flow data from calendar years 2000 to 2019 that coincide with methylmercury monitoring dates. Board staff calculated the median of each month's flow data across all years to represent typical flow for each month, then summed all months to get annual total flow. Annual volumes for diversions and seepage are estimated to be approximately 1,747,105 ac-ft and return flows are approximately 781,488 ac-ft. Agricultural diversions are estimated to be a net export of about 965,617 ac-ft of water annually from the Delta, approximately 5.66% of all Delta water exports. For more information on agricultural diversions and return flows, see Section 6.2.5.3.

6.1.9 Dredging

The 2010 TMDL Staff Report included an estimate of water lost due to dredging related activities in the Delta but did not have data to estimate water released back from DMPSs. For the DMCP Review, Board staff estimated volumes of water removed from waterways and released from DMPSs, from both larger dredging activities in the DWSCs and smaller dredging activities throughout the Delta. Board staff estimates that dredging projects within the Delta MeHg TMDL Boundary remove approximately 639 ac-ft of water annually, by removing 1,593 ac-ft from waterways during dredging activities and discharging approximately 954 ac-ft of water back into the Delta from DMPSs. Dredging activities are estimated to be an overall minimal loss pathway for water in the Delta, only accounting for 0.004% of all water losses. Methods for these estimates are detailed in Section 6.3.5 for discharge volume estimates and volume removed estimates.

6.1.10 Wetlands

Consistent with the 2010 TMDL Staff Report, wetland flows are not included in the water balance. As stated in Section 6.2.3.3, water loss in wetlands is due to evapotranspiration and soil percolation. Sources of water to wetlands are from precipitation, groundwater, runoff from other wetlands, or tidal inflows. These water sources and losses are accounted for in the other sections of the water balance. Precipitation data were used to estimate per area loading from nontidal wetlands but was not used to estimate runoff over tidal wetlands. For more information on nontidal wetland and tidal wetland flows, see Sections 6.2.3.3 and 6.3.6.3.

6.1.11 Groundwater

It should be noted that this water balance does not account for groundwater intrusion or recharge.

6.1.12 Water Balance Summary

The water balance for WYs 2000-2019 balances within about 13%, which is less closely balanced than that of the 2010 TMDL Staff Report. This difference may be attributed to the general usage of median flows instead of mean flows, exclusion of municipal diversions within the Delta MeHg TMDL Boundary, or other loss pathways unknown to Board staff at the time of the DMCP Review. Major water inputs and exports identified in the 2010 TMDL Staff Report are still estimated to be the major water inputs and exports for the WYs 2000-2019 period. Specifically, the Sacramento River (including contributions from the American River and Steelhead Creek), Fremont Weir, and San Joaquin River are the primary water sources, in descending order of volume. The primary exports are still San Francisco Bay and the state and federal pumps that transport water to southern California. And lastly, seasonal export flows are still the same: most of the water in winter and spring seasons flows to San Francisco Bay, and most of the water in summer and fall seasons flows to the state and federal pumps.

Since the DMCP Review water balance uses outputs from both DICU and Dayflow, Board staff considered removing gross channel depletion[17] and precipitation from any Dayflow outputs to prevent duplicative accounting of these flow volumes. Gross channel depletion and precipitation are accounted for in DICU and cannot be removed from model outputs, whereas Dayflow also accounts for these terms but includes them as separate model outputs. Board staff assumed DICU flow model outputs accounted for precipitation over all Delta farmed islands, but were unsure if that included precipitation runoff from other land cover types within the DICU model boundary. Precipitation was accounted for as a separate source in the methylmercury source analysis to account for indirect atmospheric deposition of methylmercury over agricultural lands, not just in-situ production of methylmercury in farmed Delta islands. To prevent a misbalance, evaporation was separately accounted for over agricultural lands and gross channel depletion and precipitation were kept in Dayflow outputs. For these reasons, there may be some double counting with respect to evaporation and precipitation. However, the 2010 TMDL Staff Report used the same methods as the DMCP Review, with the exception of only accounting for evaporation over open water.

6.1.13 Future Conditions

The DMCP Review water balance and methylmercury source analysis were calculated using available data from WYs 2000-2019 to provide a snapshot of conditions for that period. Climate change, new or upcoming development projects, and upstream control programs may have substantial impacts on existing and future flows and methylmercury loads to and within the Delta.

[17] Gross channel depletion is the amount of water consumed on farmed Delta islands through evaporation, transpiration, and soil moisture storage (DWR 1995; MJA 2000).

Board staff researched anticipated effects of climate change on the water balance in the Delta and intended to include a margin of safety to account for future conditions. Due to the uncertainty and high variability of climate change impacts in the Delta in the next 100 years, Board staff was unable to incorporate a quantitative adjustment for the water balance. However, WYs 2000-2019 include multiple periods of drought followed by single flood years, similar to anticipated future conditions resulting from climate change, which is predicted to increase drought intensity and duration, with periodic heavy flooding. Examples of climate change effects in California include the 2015 rise in sea level, the increase in the number and size of wildfires, and the 2012-2016 drought period, all of which occurred within the DMCP Review's water balance period, WYs 2000-2019 (Bedsworth *et al.* 2019). Thus, Board staff expects the water balance to inherently account for climate change impacts.

Other foreseen impacts of climate change in California include: an increase in temperature, volatility of precipitation, evaporation rates, size and frequency of wildfires, in-stream temperatures, dependency on groundwater, and agricultural water needs; rise in sea level; and decline in reservoir storage and snowpack runoff (Bedsworth *et al.* 2019).

Climate change is directly related to human activities, primarily the release and accumulation of greenhouse gas emissions in the atmosphere. Initiatives to reduce greenhouse gas emissions have already been adopted by the State of California[18] and actions have been taken to implement them[19]. Successful implementation of greenhouse gas emission reduction actions should lessen climate change impacts to be less drastic than end-of-century, business-as-usual projections[20].

Current and planned projects in and around the Delta will likely change water flows and runoff volumes. New projects are being planned or have been conducted that will likely alter the water volume and methylmercury loading to and within the Delta. Such projects include, but are not limited to, the following:

- Fremont Weir Adult Fish Passage Modification Project
- Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (also known as the Big Notch Project)
- Lower Elkhorn Levee Setback Project

[18] Assembly Bill No. 32 (https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32) was approved on 27 September 2006, Senate Bill No. 535 (https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201120120SB535) was approved on 30 September 2012, and Executive Order B-55-18 (https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf) was issued on 10 September 2018.

[19] Executive Order S-3-05 (http://static1.squarespace.com/static/549885d4e4b0ba0bff5dc695/t/54d7f1e0e4b0f0798cee3010/1423438304744/California+Executive+Order+S-3-05+(June+2005).pdf) established the Climate Action Team, which implements and tracks statewide efforts to reduce emissions. More information on the Climate Action Team is available on the California Environmental Protection Agency (CalEPA) website (https://calepa.ca.gov/climate-action/). Additionally, the California Air Resource Board provides and online map of local government climate change actions on the California Climate Action Portal Map (https://webmaps.arb.ca.gov/capmap/).

[20] RCP 8.5: resulting in CO_2 atmospheric concentration of over 900 ppm by 2100 (Bedsworth *et al.* 2019).

- Sacramento Weir Widening Project
- Wallace Weir Fish Rescue Facility
- Lower Putah Creek Restoration Project
- Woodland Flood Risk Management Project
- Delta Conveyance Project

Future land cover and population changes in and around the Delta will likely occur. Many large habitat restoration projects and levee reconstruction projects in the Delta will result in shifts of land cover and change water runoff estimates. Urban growth is expected to increase, also altering land cover. Additionally, agriculture land cover, crop type, and farming methods will likely change to accommodate urban development, habitat restoration projects, and climate change. To account for such changes in the DMCP Review, land cover and population have been updated to use more recent data than was used in the 2010 TMDL Staff Report.

Tributary inflows will likely decrease overall due to the following climate change effects: longer and drier periods of drought, reduced snowpack runoff, and decline in reservoir storage. The Representative Concentration Pathway (RCP) 8.5 projects a 74% reduction in snowpack runoff by 2100 (Bedsworth *et al.* 2019) and a 29% decrease in north-of-Delta carryover storage from four reservoirs to the Sacramento River by 2060 (Wang *et al.* 2018). Future water diversion projects, such as the Delta Conveyance Project, would also reduce tributary water flows to the Delta.

Longer and drier drought periods and more intense storm systems expected with climate change should be similar to the recent dry periods observed in WYs 2001-2004, 2007-2010, and 2012-2016, followed by an extreme wet year, observed in 2005, 2011 and 2017 (Figure 6.2 and Figure 6.3). A quantified decrease or increase in California annual precipitation volumes was not known at the time of the DMCP Review (Bedsworth *et al.* 2019).

Future increases in urban land cover and population in the Delta may subsequently increase wastewater effluent volumes. However, wastewater effluent volumes also depend on facility updates and methods. For the DMCP Review, Board staff estimates an average annual reduction of approximately 68,508 ac-ft of wastewater effluent compared to the 2010 TMDL Staff Report, despite increases of urban area and population in the Delta.

Similar to wastewater effluent volumes discussed above, urban runoff volumes may increase due to expected future urban land cover and population growth in the Delta. Urban runoff volumes also depend on facility updates, methods, and precipitation. For the DMCP Review, Board staff estimates the average annual urban runoff volume is approximately 2,500 ac-ft less than the 2010 TMDL Staff Report's estimate of about 59,500 ac-ft, despite increases of urban area and population in the Delta. Annual precipitation volumes are an additional factor affecting urban runoff volumes. Climate change will likely affect precipitation rates, resulting in longer and drier drought periods and more intense storm systems that should translate into less runoff during drought periods and more runoff during flood years.

Outflows to San Francisco Bay depend largely on tributary inflows to the Delta. With the anticipated climate change conditions to Delta inflows listed above and future water diversion projects like the Delta Conveyance Project, Board staff anticipates a decrease in outflow volume to San Francisco Bay and exports to south of Delta. In addition, seasonal changes in outflow volumes to San Francisco Bay may occur with earlier melting of the snowpack and shifts in precipitation patterns. Exports to south of Delta via the SWP and CVP are expected to decrease 13% by 2060 using the RCP 8.5 projection (Wang *et al.* 2018).

Board staff expects evaporation rates to increase in the future, depending on climate change impacts on precipitation and temperature. Precipitation patterns are expected to change and become more volatile, temperatures are projected to increase by nine degrees, and soil moisture is projected to decrease by 10% in 2100 using the RCP 8.5 model (Bedsworth *et al.* 2019).

In California, climate change is expected to impact agriculture with lower crop yields due to altered weather patterns like heat waves and flooding, increased risk of heat stress on livestock, and conversion to more drought-resistant crop types. Agricultural water needs will likely increase unless adaptive management is undertaken (Bedsworth *et al.* 2019). Water rights curtailments during recent droughts have occurred, requiring decreases and halts in surface water diversions. The current statewide unsustainable dependence on groundwater will likely increase during dry and drought periods when surface water is less available. With the wide variety of potential modifications in agricultural practices and crop types, exact future agricultural return volumes are unknown.

With respect to dredging activities in the Delta, the volume of water removed from waterways depends on the amount of sediment needing to be dredged from channels. Water is allowed to evaporate, percolate, be transported offsite, and discharged back to the Delta, resulting in a net loss in the DMCP Review water balance. Dredging activities are estimated to be a minimal water loss pathway in the Delta but dredging activities may increase in the future if sea level rise and flooding cause more sediment loading to Delta waterways.

Consistent with the 2010 TMDL Staff Report, wetland water volumes were not included in the DMCP Review water balance because evaporation and precipitation are already quantified in the water balance. Wetlands in the Delta receive water from upland runoff, precipitation, groundwater, and other waterbodies. Future restoration projects in the Delta will likely result in more wetland acreage than was used in the DMCP Review. Climate change may further increase the rise of sea level and frequency of flood events, possibly resulting in more sediment loading and levee failures which may result in additional wetland habitat in the Delta. Despite this, the DMCP Review water balance would remain unchanged as Board staff does not consider wetlands as a water input or export.

As mentioned previously, statewide unsustainable groundwater dependence will likely increase, especially in dry years (Bedsworth *et al.* 2019). However, groundwater intrusion and recharge were not quantified in the water balance.

Based on the possible future changes listed in this section, Board staff anticipates changes in the water balance for the Delta. For tributary inflows, outflows to San Francisco Bay, and exports to southern California, Board staff expects a decrease in future flows. Board staff is unable to determine the future flow trends in wastewater effluent, atmospheric deposition, urban runoff, and agricultural returns in the Delta, but acknowledge volumes may be different than those in estimated in the DMCP Review. Board staff expects evaporation rates and volume of water removed by dredging activities to increase in the future.

Table 6.2: California Department of Water Resources Water Year Hydrologic Classification Indices for Water Years 2000 through 2019 for the Sacramento Valley and San Joaquin Valley (DWR c2023)

Water Year	Sacramento Valley Hydrologic Classification	San Joaquin Valley Hydrologic Classification
2000	Wet	Above Normal
2001	Dry	Dry
2002	Dry	Dry
2003	Above Normal	Below Normal
2004	Below Normal	Dry
2005	Below Normal	Wet
2006	Wet	Wet
2007	Dry	Critical
2008	Critical	Critical
2009	Dry	Dry
2010	Below Normal	Above Normal
2011	Wet	Wet
2012	Below Normal	Dry
2013	Dry	Critical
2014	Critical	Critical
2015	Critical	Critical
2016	Below Normal	Dry
2017	Wet	Wet
2018	Below Normal	Below Normal
2019	Wet	Wet

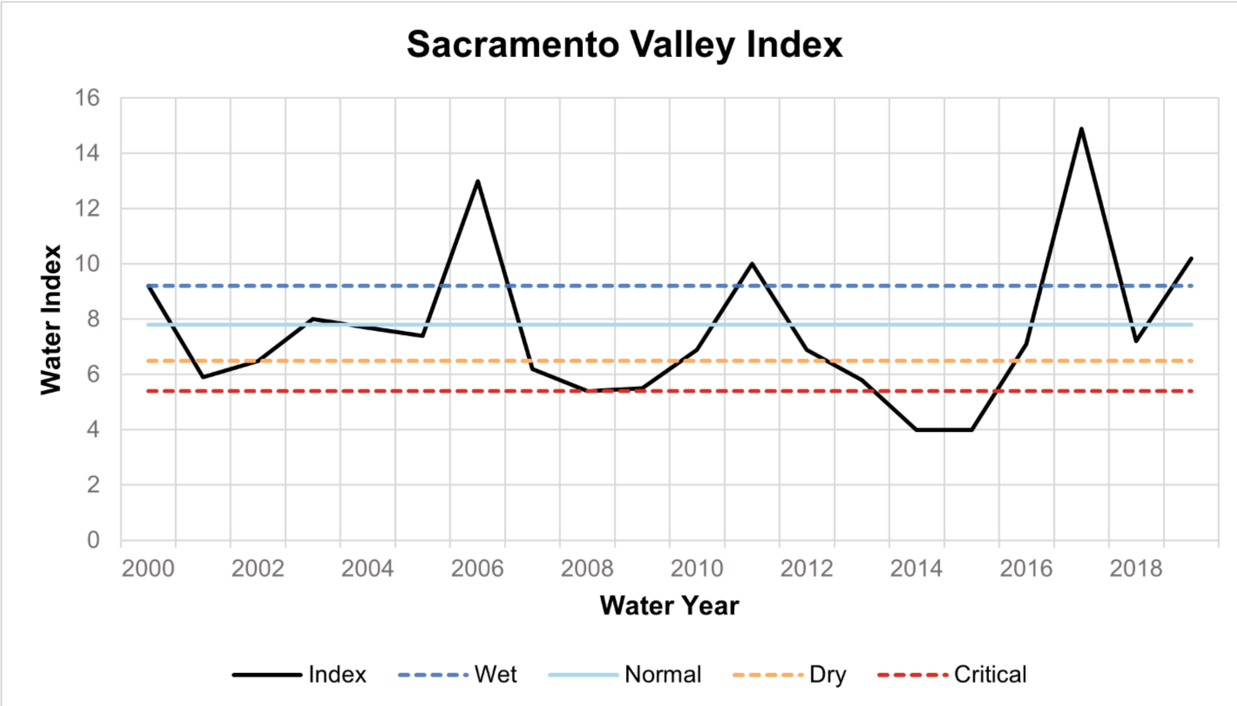

Figure 6.2: California Department of Water Resources Hydrologic Classification Indices for Water Years 2000 through 2019 for the Sacramento Valley (DWR c2023)

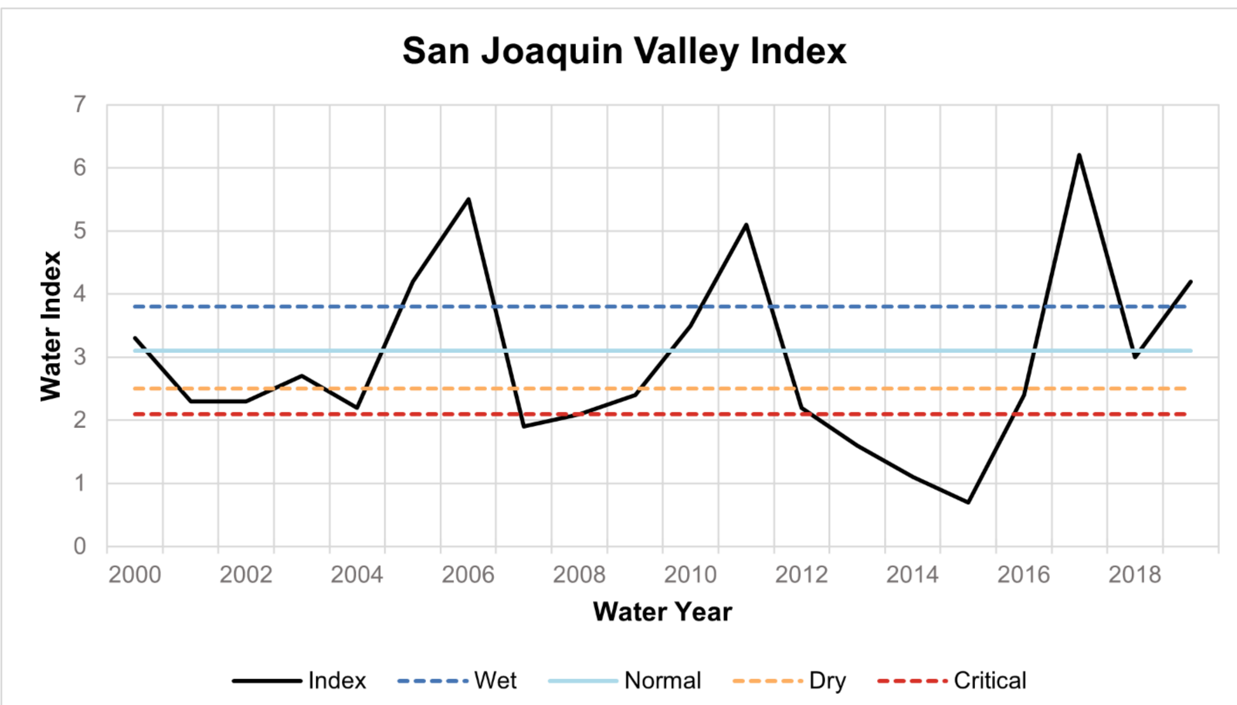

Figure 6.3: California Department of Water Resources Hydrologic Classification Indices for Water Years 2000 through 2019 for the San Joaquin Valley (DWR c2023)

Table 6.3: DMCP Review Water Balance in the Delta Methylmercury TMDL Boundary

Description	Type	Annual Water Volume (M ac-ft/yr)	Annual Water Volume (%)
Tributary Inflows	Input	18.129	92.12%
Atmospheric Deposition	Input	1.288	6.55%
Wastewater (Municipal & Non-Municipal)[21]	Input	0.201	1.02%
Urban Runoff	Input	0.057	0.29%
Cache Creek Settling Basin[22]	Input	0.006	0.03%
Sum of Inputs		**19.680**	**100.00%**
Outflow to San Francisco Bay	Export	-8.345	48.89%
California Aqueduct	Export	-2.423	14.20%
Delta Mendota Canal	Export	-2.264	13.26%
Evaporation	Export	-3.069	17.98%
Agricultural Diversions	Export	-0.966	5.66%
Dredging	Export	-0.001	0.004%
Sum of Exports		**-17.067**	**100.00%**
Water Balance		**2.614**	**86.72%**

[21] Water volume for Wastewater estimated using facilities most recent five years of reported discharge volumes from 2010 through 2021, if available, and does not include City of Lathrop permitted discharge volume because facility did not begin discharging until after WY 2019.

[22] Cache Creek Settling Basin flow volume estimated from the basin's outflow and overflow weir gages, excluding inflows from Cache Creek upstream of the basin.

6.2 Methylmercury Sources

This section illustrates the source locations; describes the available methylmercury concentration and flow data; and identifies data gaps and uncertainties associated with the load estimates. Table 6.4 lists the estimated average annual loads associated with the losses for the WYs 2000-2019 period, a representative period of wet and dry conditions that encompasses the available concentration data for the major Delta inputs and exports. Figure 6.4 shows the relative load of each source calculated in the 2010 TMDL Staff Report and DMCP Review source analyses. Figure 6.5 shows the total load of within-Delta sources calculated in the DMCP Review.

The 2010 TMDL Staff Report identified sources of methylmercury to the Delta MeHg TMDL Boundary as: tributary inflows from upstream watersheds, open water sediment flux, agricultural drainage, wetlands, municipal and non-municipal wastewater discharge, atmospheric deposition, urban runoff, and other potential sources like DMPS return slurry. Board staff re-evaluated the same sources and updated loads using available data. Differences between sources quantified include the following:

- The DMCP Review incorporates the CCSB within the Delta MeHg TMDL Boundary (Section 6.3.7), resulting in flows from Cache Creek to CCSB as a tributary source (Section 6.2.1) where the 2010 TMDL Staff Report estimated outflows from CCSB as a tributary source.
- The DMCP Review quantified dredging sources (Section 6.3.5), whereas the 2010 TMDL Staff Report did not.
- The DMCP Review separately considered loading from tidal and non-tidal wetlands (Sections 6.3.6 and 6.2.3, respectively), concluding that tidal wetlands are likely a net methylmercury sink, whereas the 2010 TMDL Staff Report only used one flux rate for all wetlands. Both the DMCP Review and 2010 TMDL Staff Report found all wetlands, cumulatively, to be an overall methylmercury source.

There are multiple methods available to measure sources of methylmercury from the various Delta land cover types. Some of the methods reviewed for the DMCP Review include the following:

- <u>Benthic flux chambers:</u> This method was used to estimate open water sediment flux loading (Section 6.2.2). Benthic flux chambers measure the sediment-water exchange flux of dissolved mercury. The flux chamber calculations measure gross dissolved methylmercury flux from sediments due to diffusion and advection and do not account for particle settling (Heim 2022; Gill *et al.* 1999; Choe *et al.* 2004). This method has the advantage of measuring the temporal dimension of flux. Benthic flux chambers can be light or dark, but Task 4B of the 2003 CALFED Report (Gill *et al.* 2003) found no clear effect of using light versus dark chambers on methylmercury flux.[23] Benthic flux chambers may

[23] More specifically, though there was often an influence of light versus dark, such influence was not always the same direction between sites. Task 4.2 of the 2008 CALFED Report (Gill 2008b) and Choe and others (2004) only used light chambers.

underestimate actual benthic flux as some mercury partitions to the solid phase as it diffuses out of sediments, which is not accounted for as dissolved flux (DiGiorgio *et al.* 2020).

- Whole-ecosystem monitoring: This method was used to estimate loads for nontidal wetlands (Section 6.2.3). Methylmercury concentrations and other biogeochemical parameters are monitored on an ecosystem scale over a period of time (e.g., a marsh's tidal cycle). Flux is measured by multiplying methylmercury concentrations by flow to get load, then dividing by surface area to get a loading rate. The load rate can then be multiplied by an area of interest to get a total load for that area. This method is applied on a larger geographical scale than the benthic flux chamber and interstitial pore water gradient methods. In marsh systems, this method is called whole-marsh tidal flushing monitoring.
- Modeling: The DMCP Review relied on models to estimate flows for agricultural returns (Section 6.2.5). Models are not a direct measurement of flux but do require monitoring data to calibrate. For example, DWR's proprietary model, DSM2-Hg, estimated net flux of methylmercury into or out of sediments in open water by modeling settling, resuspension, and diffusion (DiGiorgio *et al.* 2020). Formulas that went into this model include those for methylation, adsorption, desorption, diffusion, deposition, erosion, burial, and entrainment.

Table 6.4: Annual Methylmercury Loads to the Delta and Yolo Bypass for WYs 2000-2019

Source	Type	Annual MeHg Load (g/yr)	Annual MeHg Load (%)
Sacramento River	Tributary Inflow	1,381.211	56.15%
San Joaquin River	Tributary Inflow	260.056	10.57%
Fremont Weir	Tributary Inflow	174.201	7.08%
Mokelumne & Cosumnes Rivers	Tributary Inflow	156.614	6.37%
American River	Tributary Inflow	144.963	5.89%
Knights Landing Ridge Cut	Tributary Inflow	124.379	5.06%
Cache Creek (above Settling Basin)	Tributary Inflow	73.346	2.98%
Putah Creek	Tributary Inflow	36.199	1.47%
Steelhead Creek	Tributary Inflow	25.747	1.05%
Sacramento Weir	Tributary Inflow	18.608	0.76%
Bear/Mosher Creeks	Tributary Inflow	13.698	0.56%
French Camp Slough	Tributary Inflow	12.225	0.50%
Willow Slough	Tributary Inflow	9.825	0.40%
Ulatis Creek	Tributary Inflow	8.134	0.33%
Morrison Creek	Tributary Inflow	7.501	0.30%
Calaveras River	Tributary Inflow	7.309	0.30%
Lindsey Slough	Tributary Inflow	2.467	0.10%
Dixon Area	Tributary Inflow	2.287	0.09%
Marsh Creek	Tributary Inflow	1.231	0.05%
Other Small Drainages to Delta	Tributary Inflow	Unknown	Unknown
Sum of Tributary Sources		**2,459.999**	**74.48%**
Open Water Sediment Flux	Within-Delta	391.344	11.85%
Agricultural Returns	Within-Delta	173.212	5.24%
Atmospheric Deposition	Within-Delta	140.617	4.26%
Nontidal Wetlands	Within-Delta	92.853	2.81%
Wastewater (Municipal & Non-Municipal)	Within-Delta	34.705	1.05%
Urban Runoff	Within-Delta	10.103	0.31%
Sum of Within-Delta MeHg TMDL Boundary Sources		**842.834**	**25.52%**
Total MeHg Inputs:		**3,302.833**	**100%**

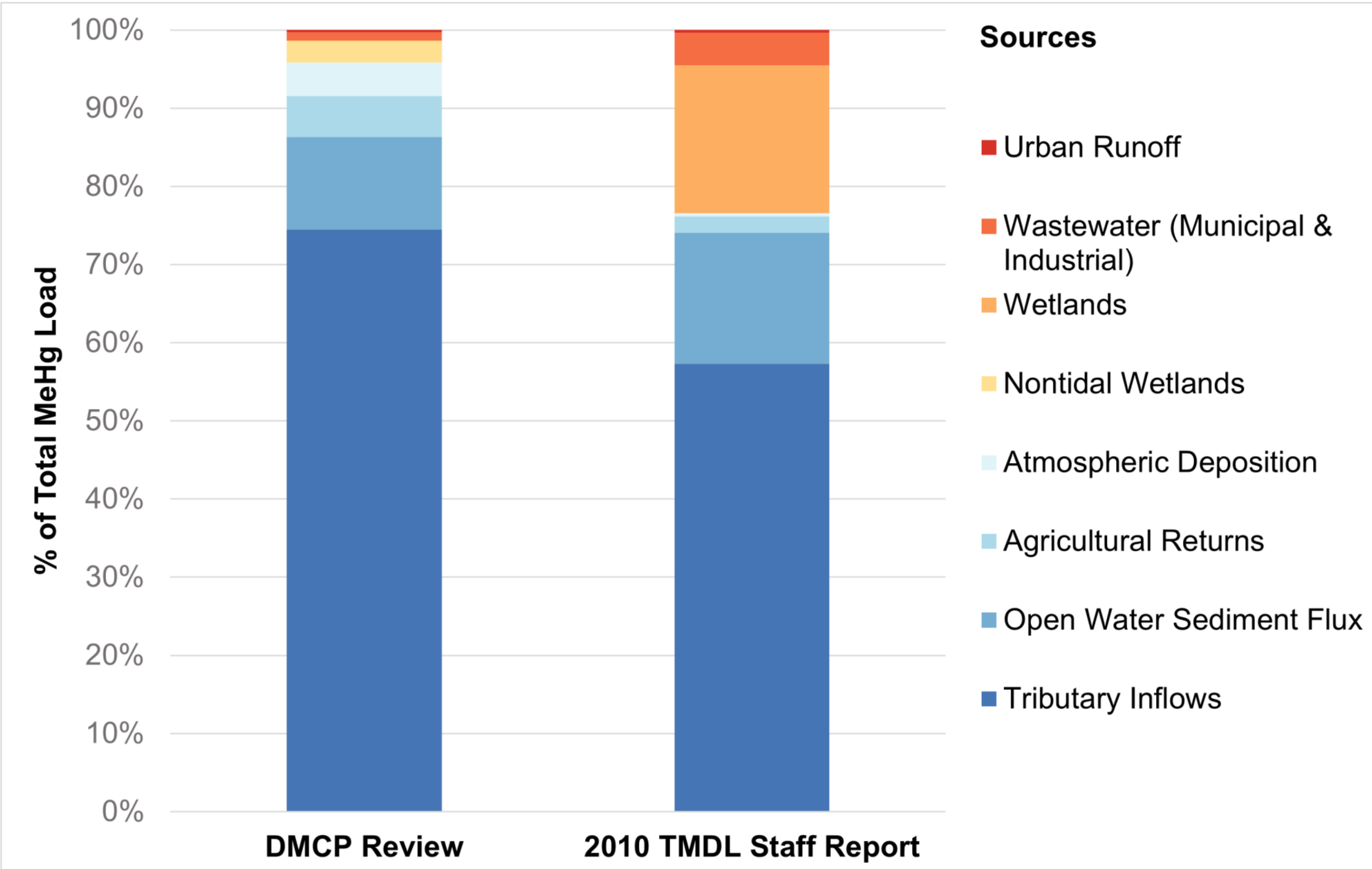

Figure 6.4: Percentage of Methylmercury Load Sources for the DMCP Review and 2010 TMDL Staff Report

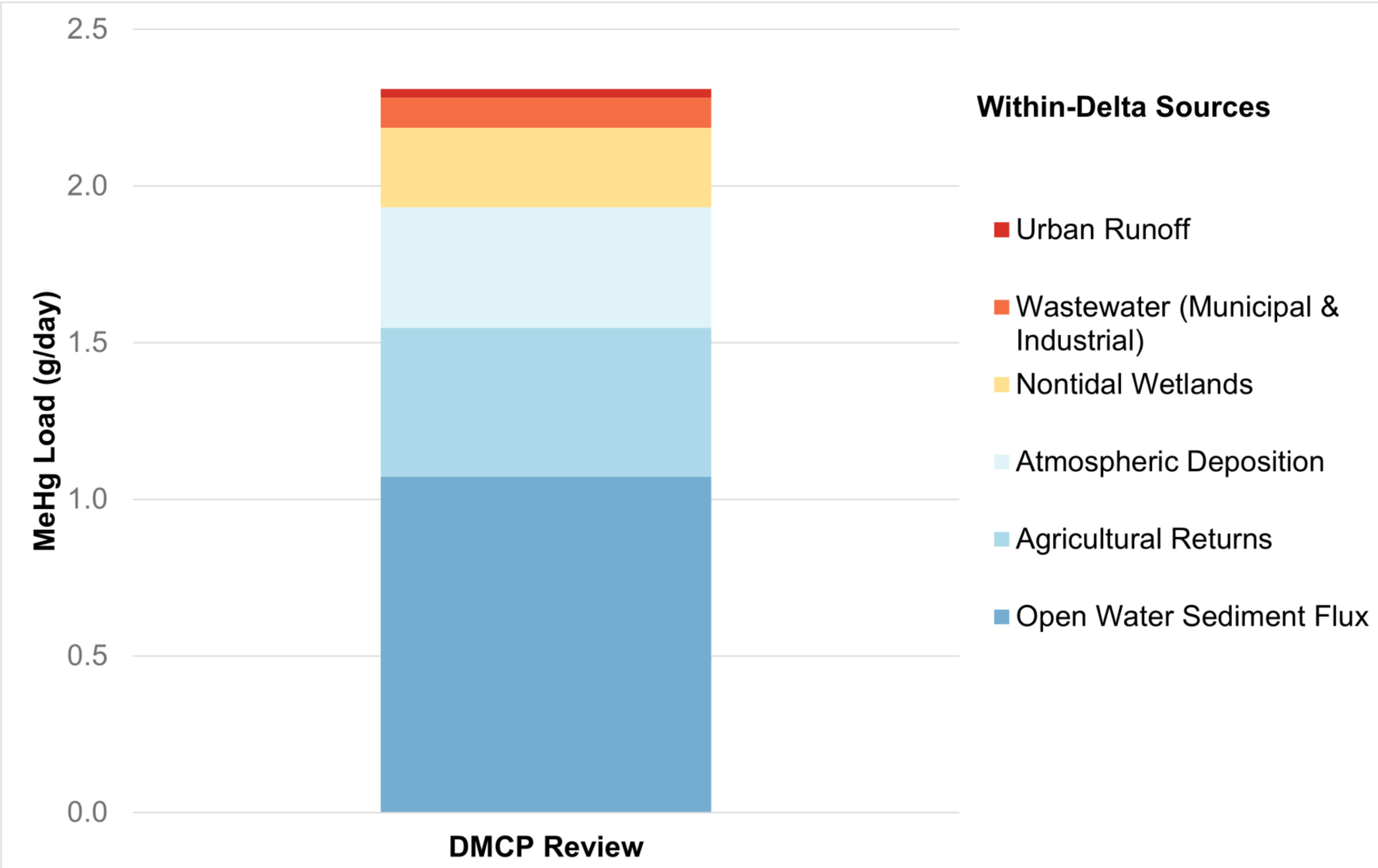

Figure 6.5: Daily Methylmercury Load of Sources Within the Delta Methylmercury TMDL Boundary for the DMCP Review

6.2.1 Tributary Inflows

The 2010 TMDL Staff Report estimated tributary loading accounted for almost 60% of Delta methylmercury sources during WYs 2000-2003. Methylmercury loading in the 2010 TMDL Staff Report was determined using precipitation runoff and stream flow gages to calculate tributary water volumes, paired with observed and estimated methylmercury concentrations. See Section 6.2.1 in the 2010 TMDL Staff Report for more details.

Board staff used the 2010 TMDL Staff Report methodology described above with available data from WYs 2000-2019 to estimate tributary water volumes, methylmercury concentrations, and loads, as detailed below. In the DMCP Review, the CCSB is considered to be within the Delta MeHg TMDL Boundary, not a tributary, as was done in the 2010 TMDL Staff Report. Flows and methylmercury loads for CCSB are described in Section 6.3.7.

6.2.1.1 Methylmercury Concentration

Methylmercury concentration estimates for each tributary were compiled by Board staff from multiple sources to ensure all available data were used for the DMCP Review. Data sources used were California Environmental Data Exchange Network (CEDEN), the 2010 TMDL Staff Report, aqueous monitoring by Board staff in 2019, and DMCP Review Linkage Analysis data compilation (see Appendix A.2). Duplicate observations in the compiled data set were removed by processing in Excel and R.

Sample locations used to represent methylmercury concentration per tributary were selected by closest geographic locations upstream of the Delta MeHg TMDL Boundary (Figure 6.6). Figure 6.7 illustrates tributary watersheds that drain directly or indirectly to the Delta used in the 2010 TMDL Staff Report as Figure 6.1. Methylmercury data were grouped by locations within each tributary branch per watershed.

Consistent with methods used in the 2010 TMDL Staff Report, the median of pooled monthly data was calculated for tributaries with monthly methylmercury data. This method was used for the Sacramento River, San Joaquin River, American River, Putah Creek, and Cache Creek (inflow to CCSB). For all other tributaries with aqueous methylmercury data, the median of pooled data respective to each tributary was calculated (Table 6.5).

The following tributaries had aqueous methylmercury sample data:

- American River
- Arcade River
- Bear Creek
- Cache Creek (inflow to CCSB)
- Calaveras River
- Cosumnes River
- Duck Creek
- Fremont Weir
- French Camp Slough
- Marsh Creek
- Mokelumne River
- Morrison Creek
- Mosher Creek
- Putah Creek
- Ridge Cut Slough (Knights Landing)
- Sacramento River
- Sacramento Weir
- San Joaquin River
- Ulatis Creek

The following tributaries did not have aqueous methylmercury sample data:

- Barker Slough
- Dixon Area
- Dry Creek
- Fivemile Creek
- Florin/ Elder Creek
- Laguna Creek
- Lindsey Slough
- Littlejohns Creek
- Natomas East Main Drain/ Steelhead Creek
- Stockton Diversion Canal
- Walker Slough
- White Slough
- Willow Slough
- Other Small Drainages to Delta (Antioch Area, Bethany Reservoir Area, Manteca-Escalon Area, Montezuma Hills Area)

For tributary systems with individual tributary branch flow volume estimates but unknown methylmercury concentrations, the closest and most hydrologically similar tributary methylmercury concentrations were assigned: Stockton Diversion Canal was assigned the methylmercury concentration of Calaveras River; Dry Creek was assigned the methylmercury concentration of Cosumnes River; both Laguna Creek and Florin/ Elder Creek were assigned the methylmercury concentration of Morrison Creek; and Natomas East Main Drain/ Steelhead Creek was assigned the methylmercury concentration of Arcade Creek.

For tributary systems with grouped watershed flow estimates and unknown individual tributary branch methylmercury concentrations, Board staff pooled all methylmercury concentration data within the tributary watershed to calculate the median of the watershed's concentration. This was done for the French Camp Slough/ Lone Tree Creek and Bear/ Mosher Creeks. Methylmercury concentration data for Duck Creek and French Camp Slough were pooled for the French Camp Slough/ Lone Tree Creek watershed since no data were available for Littlejohns Creek and Walker Slough. Methylmercury concentration data for Bear Creek and Mosher Creek were pooled for the Bear/ Mosher Creeks watershed since no data were for Fivemile Creek and White Slough.

Consistent with reasons and methods used in the 2010 TMDL Staff Report tributary source analysis, Upper Lindsey/ Cache Slough Area, Willow Slough, and Dixon Area were assigned the methylmercury concentration of Ulatis Creek. Similar to the 2010 TMDL Staff Report, no methylmercury data were available for the other small drainage areas of Manteca-Escalon, Bethany Reservoir, Antioch, and Montezuma Hills area.

6.2.1.2 Flow

Available streamflow and precipitation data were gathered from DWR's CDEC website (https://cdec.water.ca.gov/index.html) and USGS's National Water Information System website (NWIS; https://waterdata.usgs.gov/nwis) from WYs 2000-2019. Stations listed in the 2010 TMDL Staff Report were queried by Board staff; however, some stations were not found, or gages did not report complete datasets. Board staff pulled data from several additional flow gage stations that were not used in the 2010 TMDL Staff Report to provide a more accurate calculation of water volume inflows from tributaries to the Delta for the source analysis than the wet weather runoff estimates used in the 2010 TMDL Staff Report (Table 6.6).

The following tributary flows were calculated using streamflow gages:

- American River
- Arcade Creek
- Cache Creek (inflow to CCSB)
- Calaveras River
- Cosumnes River
- Fremont Weir
- Laguna Creek
- Marsh Creek
- Mokelumne River
- Morrison Creek
- Putah Creek
- Ridge Cut Slough (Knights Landing)
- Sacramento River
- Sacramento Weir
- San Joaquin River

Streamflow data outputs from NWIS and CDEC varied. Data from NWIS exported as monthly averages of daily flows in cubic feet per second (cfs), per year (e.g., October 2009 mean daily flow at the American River stream gage was 2,401 cfs). Board staff pooled monthly averages across all selected years and calculated the monthly medians to obtain representative daily flows, in cfs, for each month. Monthly medians were multiplied by the respective number of days per month and seconds per day to calculate monthly volumes in cubic feet, then volumes were converted from cubic feet to liters. CDEC outputs were not summarized by month and needed to be processed in R to determine monthly averages for each year. CDEC flow data were then processed as described above to be consistent with NWIS data flow calculations.

Cache Creek, Fremont Weir, Ridge Cut Slough (Knights Landing), and Sacramento Weir flow datasets were incomplete. Board staff requested clarification from DWR staff on missing flow data at the Fremont Weir gage and was told reasons may include no flows, low flows, or gage was turned off (Mulligan 2023). Board staff filled data gaps of monthly averages of daily flows with zero then pooled monthly averages across all selected years and calculated the monthly averages to obtain representative daily flows, in cfs, for each month. Monthly averages were multiplied by the respective number of days per month and seconds per day to calculate monthly volumes in cubic feet per month, then volumes were converted from cubic feet to liters. Board staff observed that gaps in data mostly corresponded with dry months and dry years. Many options were considered for determining representative annual flow and Board staff determined the above-mentioned methodology was the most representative of Cache Creek and Fremont Weir due to intermittent flows (Appendix F).

For tributaries that did not have flow gages, Board staff used methods consistent with the 2010 TMDL Staff Report to calculate wet weather runoff as tributary flow volumes. These calculations relied on acreage of land cover, land cover runoff coefficients, and precipitation gage data. Information on how tributary land cover acreages were determined, layers used, and the tables of runoff coefficients and total acreages are detailed in Appendix D. Board staff notes this methodology likely underestimates tributary flow because it does not include discharge from dry weather runoff, water releases from major dams and reservoirs, or groundwater discharge.

The following tributaries did not have streamflow gage data available and tributary flows were calculated using tributary watershed wet weather runoff estimates:

- Bear Creek (includes Fivemile Creek, Mosher Creek, and White Slough)
- Dixon Area
- Dry Creek (near Galt)
- Florin/ Elder Creek
- French Camp Slough (includes Duck Creek, Littlejohns Creek, Walker Slough)
- Lindsey Slough (includes Barker Slough)
- Natomas East Main Drain/ Steelhead Creek
- Stockton Diversion Channel
- Ulatis Creek
- Willow Slough
- Other Small Drainages to Delta (Antioch Area, Bethany Reservoir Area, Manteca-Escalon Area, Montezuma Hills Area)

Precipitation data were queried from CDEC and exported in several formats: monthly accumulated, daily accumulated, and hourly tipping bucket. For monthly accumulated data, monthly values were summed by water year to create total precipitation value for that water year. Daily accumulated data were first summed by month and then by water year to get the annual precipitation value for that water year. The Indian Valley precipitation station reported values by tipping bucket. After examining the data and finding no metadata details, Board staff assumed that the hourly values of tipping bucket data represented accumulated precipitation and the bucket was reset on the evening of 30 September of each year. Values reported immediately prior to the reset were assumed to be that water year's annual precipitation value. For each precipitation gage, Board staff assigned the median of pooled complete water year volumes to represent the precipitation gage's annual precipitation (Table 6.7).

The following four watersheds encompassed tributaries with flow gages and tributaries without flow gages: Calaveras River below New Hogan Lake & Mormon Slough watershed, Cosumnes River watershed, Morrison Creek watershed, and Natomas East Main Drain/ Arcade Creek watershed. Annual water volumes for the non-gaged tributaries were estimated by subtracting gaged tributary annual water volumes from the estimated annual wet weather runoff of the encompassing watershed. Stockton Diversion Canal annual water volume was estimated by subtracting the gaged Calaveras River flow from the calculated wet weather runoff volume for the Calaveras River below New Hogan Lake & Mormon Slough watershed. Dry Creek annual water volume was estimated by subtracting the gaged Cosumnes River flow from the calculated wet weather runoff volume for the Cosumnes River watershed. Florin/ Elder Creek annual water volume was estimated by subtracting the gaged Laguna Creek and Morrison Creek flows from the calculated wet weather runoff volume for the Morrison Creek watershed. Natomas East Main Drain/ Steelhead Creek annual water volume was estimated by subtracting the gaged Arcade Creek flow from the calculated wet weather runoff volume for the Natomas East Main Drain/ Arcade Creek watershed.

The estimated water volumes from tributaries total 18.068 million ac-ft/yr (Table 6.8).

6.2.1.3 Load

Annual methylmercury loads for tributaries were calculated by multiplying estimated water volumes by median methylmercury concentrations (Table 6.9). For the Sacramento River, San Joaquin River, American River, Putah Creek, and Cache Creek (inflow to CCSB), Board staff used the sum of monthly loads, determined by multiplying the monthly flow volume by monthly median methylmercury concentration, to estimate annual loading. For all other tributaries, Board staff multiplied the estimated annual water volume by the median methylmercury concentration to estimate annual loading.

As seen in Table 6.4 above, tributary loading is the primary source of aqueous methylmercury to the Delta. Tributaries are estimated to contribute approximately 2,460 grams of methylmercury per year, or about 74% of Delta methylmercury inflows during the WYs 2000-2019 period.

The DMCP Review resulted in similar conclusions to those in the 2010 TMDL Staff Report. Sacramento River is still estimated to be the main source of methylmercury to the Delta, contributing about 56% of all tributary inflows and about 42% of all sources to the Delta. It should be noted that the 2010 TMDL Staff Report included load estimates of the American River and Steelhead Creek into Sacramento River, which Board staff decided to separate for the DMCP Review. San Joaquin River and Fremont Weir were still estimated to be the second and third largest tributary contributors, respectively.

Consistent with the 2010 TMDL Staff Report, methylmercury loading from other small drainage areas were not estimated due to lack of methylmercury data, and because cumulative annual flow volume of these areas only contributes about 0.3% of all water inflows to the Delta.

A notable difference between the 2010 TMDL Staff Report and DMCP Review is that the latter did not estimate Calaveras River to be as substantial of a methylmercury source. Reasons for this are unknown but may be related to the limited timeframe of data used in the 2010 TMDL Staff Report, which used data for relatively dry water years.

The development and implementation of upstream methylmercury and inorganic mercury control programs are encouraged by Board staff in order to reduce the tributary loading of methylmercury to the Delta. Board staff recommends the analysis of a tributary's loading be completed prior to implementing any control program. Effective control program monitoring and implementation should result in the reduction of methylmercury loading from tributaries to the Delta, and thereby from the Delta to the San Francisco Bay.

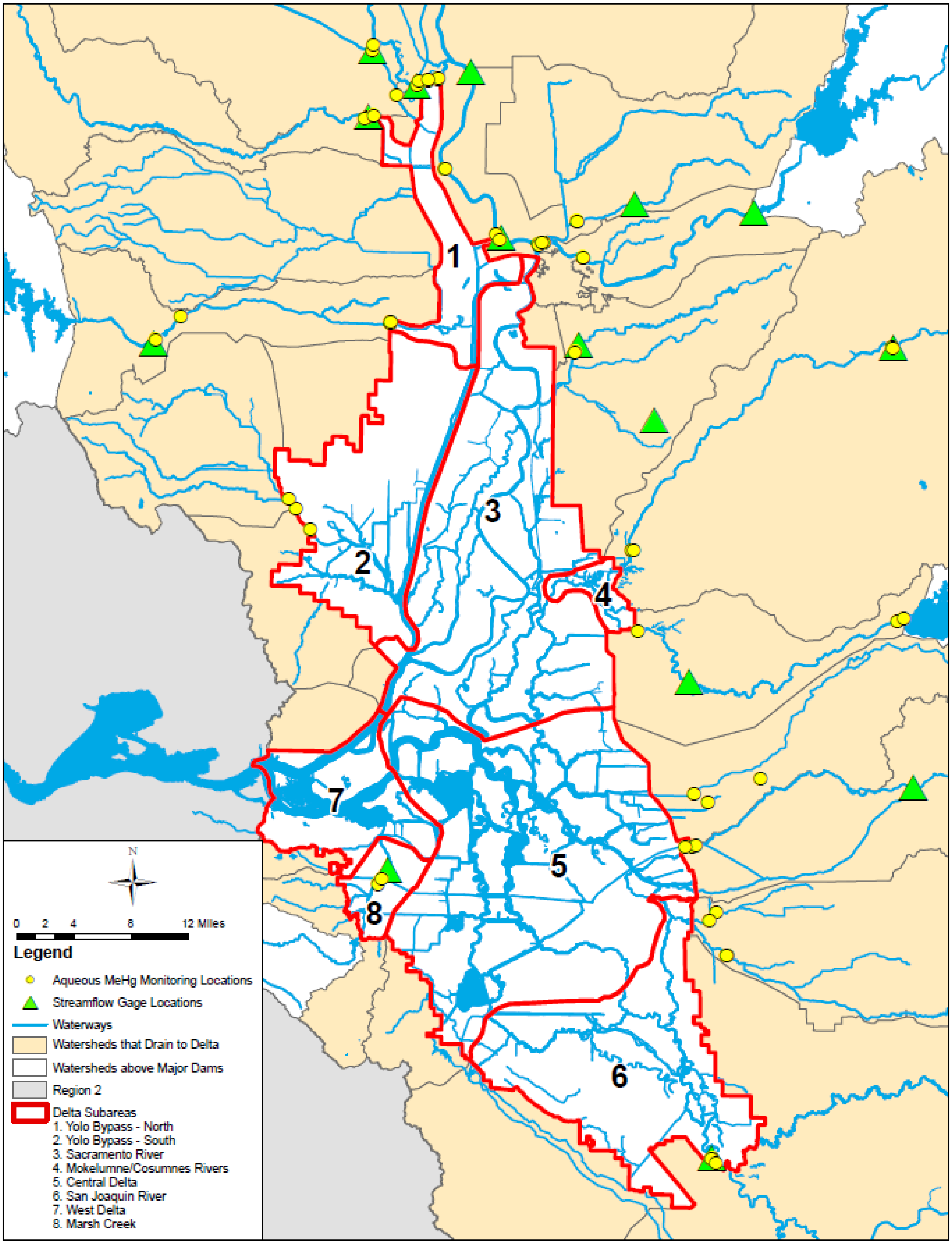

Figure 6.6: Methylmercury Concentration Sample Locations and Stream Flow Gage Locations Used to Estimate Tributary Loading

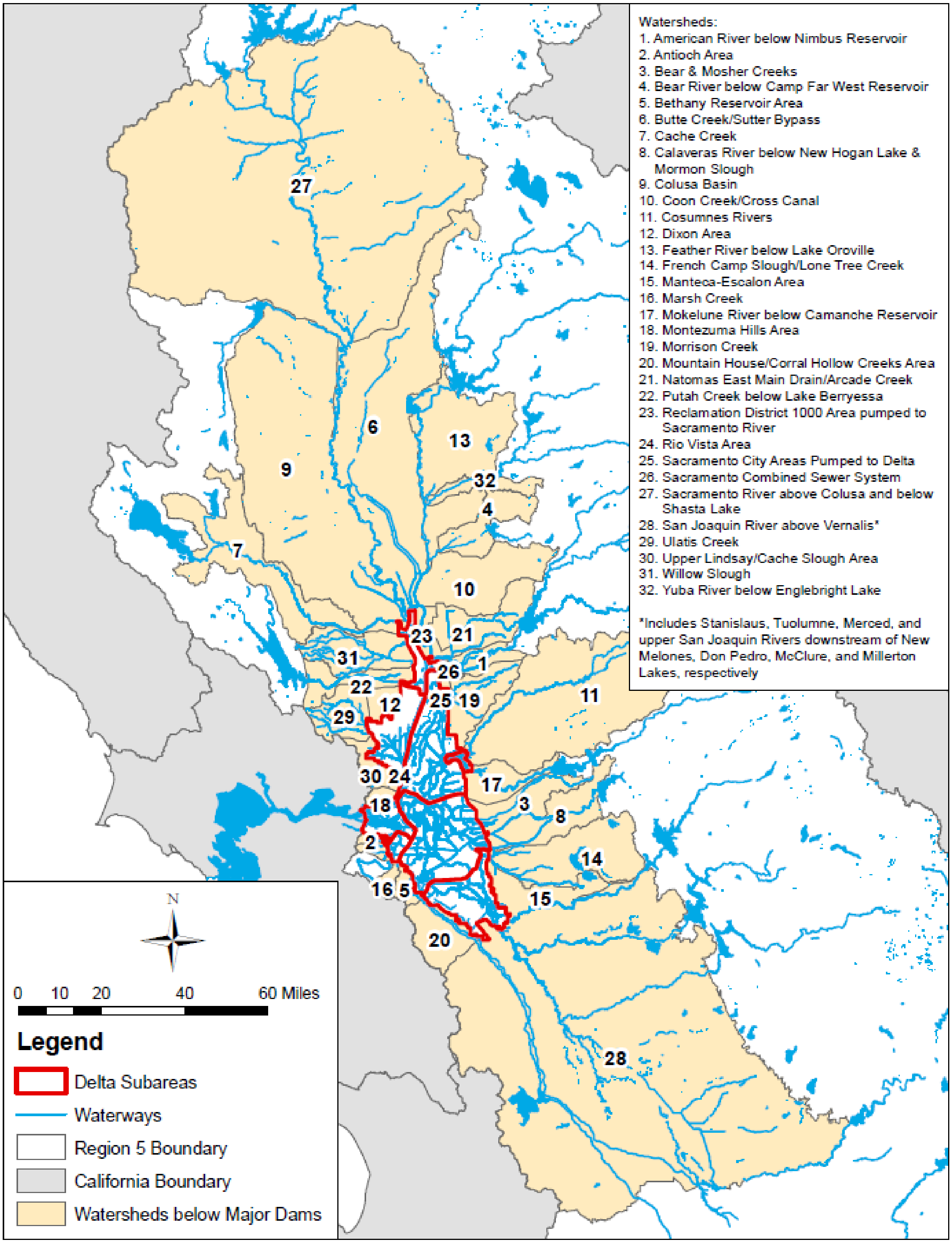

Figure 6.7: Watersheds that Drain to the Delta and Yolo Bypass, Included in the 2010 TMDL Staff Report as Figure 6.1

Table 6.5: Pooled Median Methylmercury Concentrations for Tributary Inflows

Watershed Number[24]	Watershed Name	Tributary System	Individual Tributaries	Number of Samples	Minimum MeHg Conc. (ng/L)	Maximum MeHg Conc. (ng/L)	Median MeHg Conc. (ng/L)
1	American River below Nimbus Reservoir	American River	American River	162	0.013	0.822	0.054
3	Bear & Mosher Creeks	Bear Creek	Bear Creek, Fivemile Creek, Mosher Creek, White Slough[25]	7	0.028	0.446	0.336
6	Butte Creek/ Sutter Bypass	Yolo Bypass	Fremont Weir	23	0.032	0.139	0.082
7	Cache Creek prior to Settling Basin	Cache Creek	Cache Creek	55	0.061	1.230	0.252
8	Calaveras River Below New Hogan Lake & Mormon Slough	Calaveras River	Calaveras River	7	0.090	0.301	0.127
8	Calaveras River Below New Hogan Lake & Mormon Slough	Calaveras River	Stockton Diversion Canal[26]	7	0.090	0.301	0.127
9	Colusa Basin	Yolo Bypass	Ridge Cut Slough (Knights Landing)	36	0.010	0.648	0.198
11	Cosumnes River	Mokelumne River	Cosumnes River	4	0.150	0.857	0.376

[24] See Figure 6.7 for locations of tributary watersheds with assigned numbers.

[25] No aqueous methylmercury data available for Fivemile Creek or White Slough; used pooled methylmercury data from Bear Creek and Mosher Creek.

[26] No aqueous methylmercury data available for Stockton Diversion Canal; assigned methylmercury data from Calaveras River.

Watershed Number[24]	Watershed Name	Tributary System	Individual Tributaries	Number of Samples	Minimum MeHg Conc. (ng/L)	Maximum MeHg Conc. (ng/L)	Median MeHg Conc. (ng/L)
11	Cosumnes River	Mokelumne River	Dry Creek[27]	4	0.150	0.857	0.376
12	Dixon Area	Dixon Area	Dixon Area[28]	7	0.151	0.322	0.176
14	French Camp Slough/ Lone Tree Creek	French Camp Slough	Duck Creek, French Camp Slough, Littlejohns Creek, Walker Slough[29]	9	0.054	0.193	0.139
16	Marsh Creek	Marsh Creek	Marsh Creek	7	0.090	0.323	0.237
17	Mokelumne River Below Camanche Reservoir	Mokelumne River	Mokelumne River	4	0.020	0.030	0.025
19	Morrison Creek	Morrison Creek	Laguna Creek[30]	1	0.102	0.102	0.102
19	Morrison Creek	Morrison Creek	Florin/ Elder Creek[31]	1	0.102	0.102	0.102
19	Morrison Creek	Morrison Creek	Morrison Creek	1	0.102	0.102	0.102
21	Natomas East Main Drain/ Arcade Creek	Steelhead Creek	Arcade Creek	16	0.099	1.213	0.253

[27] No aqueous methylmercury data available for Dry Creek; assigned methylmercury data from Cosumnes River.

[28] No aqueous methylmercury data available for Dixon Area; assigned methylmercury data from Ulatis Creek.

[29] No aqueous methylmercury data available for Littlejohns Creek and Walker Slough; used pooled methylmercury data from Duck Creek and French Camp Slough.

[30] No aqueous methylmercury data available for Laguna Creek; assigned methylmercury data from Morrison Creek.

[31] No aqueous methylmercury data available for Florin/Elder Creek; assigned methylmercury data from Morrison Creek.

Watershed Number[24]	Watershed Name	Tributary System	Individual Tributaries	Number of Samples	Minimum MeHg Conc. (ng/L)	Maximum MeHg Conc. (ng/L)	Median MeHg Conc. (ng/L)
21	Natomas East Main Drain/ Arcade Creek	Steelhead Creek	Natomas East Main Drain/ Steelhead Creek[32]	16	0.099	1.213	0.253
22	Putah Creek Below Lake Berryessa	Putah Creek	Putah Creek	77	0.039	1.120	0.131
27	Sacramento River above Verona	Sacramento River	Sacramento River	118	0.013	0.250	0.095
NA	Sacramento Weir	Sacramento Weir	Sacramento Weir	5	0.094	0.159	0.123
28	San Joaquin River above Vernalis	San Joaquin River	San Joaquin River	115	0.075	0.794	0.144
29	Ulatis Creek	Ulatis Creek	Ulatis Creek	7	0.151	0.322	0.176
30	Upper Lindsey/Cache Slough Area	Lindsey Slough	Barker Slough, Lindsey Slough[33]	7	0.151	0.322	0.176
31	Willow Slough	Willow Slough	Willow Slough[34]	7	0.151	0.322	0.176

[32] No aqueous methylmercury data available for Natomas East Main Drain; assigned methylmercury data from Arcade Creek.

[33] No aqueous methylmercury data available for Barker Slough or Lindsey Slough; assigned methylmercury data from Ulatis Creek.

[34] No aqueous methylmercury data available for Willow Slough; assigned methylmercury data from Ulatis Creek.

Table 6.6: Streamflow Gages Used to Estimate Tributary Water Volumes

Tributary	Station Name	Site ID	Latitude	Longitude	Data Range	Estimated Annual Water Volume (ac-ft)
American River	American River @ Fair Oaks	11446500	38.63556	-121.2267	WYs 2000-2019	1,843,112.644
Arcade Creek	Arcade Creek Nr Del Paso Height CA	11447360	38.64194	-121.3817	WYs 2000-2019	8,119.353
Cache Creek	Cache Creek Inflow to Settling Basin Near Yolo CA	11452600	38.72611	-121.7289	Oct. 2007 - Apr. 2017	186,659.090
Calaveras River	Mormon Slough at Bellota (Calaveras River)	MRS	38.054	-121.012	WYs 2000-2019	33,659.458
Cosumnes River	Cosumnes River @ Michigan Bar	11335000	38.50028	-121.0442	WYs 2000-2019	188,487.123
Fremont Weir	Sacramento R @ Fremont Weir	FRE	38.759258	-121.667274	WYs 2000-2019	1,722,280.005
Laguna Creek	Laguna C Nr Elk Grove CA	11336585	38.42333	-121.3522	WYs 2000-2018	3,200.532
Marsh Creek	Marsh Creek @ Brentwood	11337600	37.96278	-121.6864	Sept. 2000 - Sept. 2013	4,211.353
Mokelumne River	Mokelumne R A Woodbridge CA	11325500	38.15861	-121.3025	WYs 2000-2019	146,408.972
Morrison Creek	Morrison C Nr Sacramento CA	11336580	38.49861	-121.4517	Oct. 1999 - Oct. 2017	10,786.125
Putah Creek	Putah South CN NR Winters CA	11454210	38.49278	-122.0019	WYs 2000-2019	183,149.439

Tributary	Station Name	Site ID	Latitude	Longitude	Data Range	Estimated Annual Water Volume (ac-ft)
Ridge Cut Slough (Knights Landing)	Ridge Cut Slough at Knights Landing	RCS	38.793556	-121.725349	Mar. 2009 - Sept. 2019	483,911.879
Sacramento River	Sacramento R A Verona CA	11325500	38.77444	-121.5972	WYs 2000-2019	11,266,727.448
Sacramento Weir	Sacramento Weir Spill to Yolo Bypass Nr Sac CA	11426000	38.606944	-121.554167	WY2000-2019	122,649.603
San Joaquin River	San Joaquin R NR Vernalis	11303500	37.67611	-121.2653	WYs 2000-2019	1,383,246.886

Table 6.7: Precipitation Gages Used to Estimate Tributary Wet Weather Runoff Volumes

Precipitation Station	Station Code	Latitude	Longitude	WY Median Rainfall (in)[35]
Calaveras Big Trees	CVT	38.283	-120.317	47.280
Capay	CPY	38.73	-122.13	21.390
Englebright	ENG	39.239	-121.267	31.765
Fiddletown	FDD	38.533	-120.7	31.940
Folsom Dam	FLD	38.7	-121.167	20.990
Foresthill R S	FRH	39.017	-120.85	49.710
Indian Valley	IVD	39.080555	-122.535278	22.290
Los Banos	LSB	37.05	-120.867	8.440
New Exchequer-Lk McClure	EXC	37.585	-120.27	17.010
North Fork RS	NFR	37.233	-119.5	29.070
Orland	ORL	39.75	-122.2	18.180
Quincy RS	QNC	39.96	-120.95	37.540
Sacramento WB City	SCR	38.583	-121.5	16.850
Shasta Dam	SHA	40.718	-122.42	64.790
Stockton Fire Station 4	STK	38.001	-121.317	16.370
Stony Gorge Reservoir	STG	39.583	-122.533	19.485

[35] Years with incomplete datasets were excluded from annual estimation.

Table 6.8: Estimated Annual Flow Volumes for Tributary Inflows

Watershed Number	Watershed Name	Tributary System	Individual Tributaries	Method for Estimating Annual Volume	Estimated Annual Water Volume (L)[36]	Estimated Annual Water Volume (M ac-ft)
1	American River below Nimbus Reservoir	American River	American River	Flow Gage	2,273,443,710,624	1.843
2	Antioch Area	Antioch Area	Antioch Area	Wet Weather Runoff	5,733,759,165	0.005
3	Bear & Mosher Creeks	Bear Creek	Bear Creek, Fivemile Creek, Mosher Creek, White Slough	Wet Weather Runoff	40,769,009,998	0.033
5	Bethany Reservoir Area	Bethany Reservoir Area	Bethany Reservoir Area	Wet Weather Runoff	8,723,818,232	0.007
6	Butte Creek/Sutter Bypass	Yolo Bypass	Fremont Weir	Flow Gage	2,124,398,993,100	1.722
7	Cache Creek prior to Settling Basin	Cache Creek	Cache Creek	Flow Gage	230,240,367,860	0.187
8	Calaveras River Below New Hogan Lake & Mormon Slough	Calaveras River	Calaveras River	Flow Gage	41,518,289,140	0.034

[36] Median of monthly flow summed to create annual volume, except for Cache Creek, Fremont Weir, Ridge Cut Slough, and Sacramento Weir which were calculated by substituting missing data with zero and using the mean of monthly flow to best represent flow volumes in the WYs 2000-2019 period (Appendix F).

Watershed Number	Watershed Name	Tributary System	Individual Tributaries	Method for Estimating Annual Volume	Estimated Annual Water Volume (L)[36]	Estimated Annual Water Volume (M ac-ft)
8	Calaveras River Below New Hogan Lake & Mormon Slough	Calaveras River	Stockton Diversion Canal	Wet Weather Runoff[37]	16,032,004,179	0.013
9	Colusa Basin	Yolo Bypass	Ridge Cut Slough (Knights Landing)	Flow Gage	629,764,738,474	0.484
11	Cosumnes River	Mokelumne River	Cosumnes River	Flow Gage	232,495,211,162	0.188
11	Cosumnes River	Mokelumne River	Dry Creek	Wet Weather Runoff[38]	172,291,872,192	0.140
12	Dixon Area	Dixon Area	Dixon Area	Wet Weather Runoff	12,970,515,917	0.011
14	French Camp Slough/ Lone Tree Creek	French Camp Slough	Duck Creek, French Camp Slough, Littlejohns Creek, Walker Slough	Wet Weather Runoff	87,823,336,899	0.071
15	Manteca-Escalon Area	Manteca-Escalon Area	Manteca-Escalon Area	Wet Weather Runoff	52,062,750,750	0.042
16	Marsh Creek	Marsh Creek	Marsh Creek	Flow Gage	5,194,621,806	0.004

[37] Stockton Diversion Canal annual volume was estimated by subtracting the Calaveras River annual flow gage volume from the wet weather runoff volume estimated for the Calaveras River tributary system.

[38] Dry Creek annual volume was estimated by subtracting the Cosumnes River annual flow gage volume from the wet weather runoff volume estimated for the Cosumnes River tributary system.

Watershed Number	Watershed Name	Tributary System	Individual Tributaries	Method for Estimating Annual Volume	Estimated Annual Water Volume (L)[36]	Estimated Annual Water Volume (M ac-ft)
17	Mokelumne River Below Camanche Reservoir	Mokelumne River	Mokelumne River	Flow Gage	180,592,628,013	0.146
18	Montezuma Hills Area	Montezuma Hills Area	Montezuma Hills Area	Wet Weather Runoff	7,638,236,382	0.006
19	Morrison Creek	Morrison Creek	Laguna Creek	Flow Gage	3,947,793,668	0.003
19	Morrison Creek	Morrison Creek	Florin/ Elder Creek	Wet Weather Runoff[39]	56,288,729,764	0.046
19	Morrison Creek	Morrison Creek	Morrison Creek	Flow Gage	13,304,476,497	0.011
21	Natomas East Main Drain/ Arcade Creek	Steelhead Creek	Arcade Creek	Flow Gage	10,015,064,768	0.008
21	Natomas East Main Drain/ Arcade Creek	Steelhead Creek	Natomas East Main Drain/ Steelhead Creek	Wet Weather Runoff[40]	91,753,590,655	0.074
22	Putah Creek Below Lake Berryessa	Putah Creek	Putah Creek	Flow Gage	225,911,281,673	0.183

[39] Florin/ Elder Creek annual volume was estimated by subtracting the Laguna Creek and Morrison Creek annual flow gage volume from the wet weather runoff volume estimated for the Morrison Creek tributary system.

[40] Natomas East Main Drain/ Steelhead Creek annual volume was estimated by subtracting the Arcade Creek annual flow gage volume from the wet weather runoff volume estimated for the Steelhead Creek tributary system.

Watershed Number	Watershed Name	Tributary System	Individual Tributaries	Method for Estimating Annual Volume	Estimated Annual Water Volume (L)[36]	Estimated Annual Water Volume (M ac-ft)
27	Sacramento River above Verona	Sacramento River	Sacramento River	Flow Gage	13,897,289,856,154	11.267
NA	Sacramento Weir	Sacramento Weir	Sacramento Weir	Flow Gage	151,285,907,180	0.123
28	San Joaquin River above Vernalis	San Joaquin River	San Joaquin River	Flow Gage	1,706,208,213,816	1.383
29	Ulatis Creek	Ulatis Creek	Ulatis Creek	Wet Weather Runoff	46,131,355,520	0.037
30	Upper Lindsey/Cache Slough Area	Lindsey Slough	Barker Slough, Lindsey Slough	Wet Weather Runoff	13,994,048,732	0.011
31	Willow Slough	Willow Slough	Willow Slough	Wet Weather Runoff	55,722,533,093	0.045

Table 6.9: Estimated Annual Methylmercury Loads for Tributary Inflows

Watershed Number	Watershed Name	Tributary System	Individual Tributaries	Estimated Water Volume (L/yr)	Median MeHg Concentration (ng/L)	Estimated MeHg Load (g/yr)
1	American River below Nimbus Reservoir	American River	American River	2,273,443,710,624	0.054	144.963[41]
3	Bear & Mosher Creeks	Bear Creek	Bear Creek, Fivemile Creek, Mosher Creek, White Slough	40,769,009,998	0.336	13.698
6	Butte Creek/ Sutter Bypass	Yolo Bypass	Fremont Weir	2,124,398,993,100[42]	0.082	174.201
7	Cache Creek prior to Settling Basin	Cache Creek	Cache Creek	230,240,367,860[43]	0.252	73.346[44]
8	Calaveras River Below New Hogan Lake & Mormon Slough	Calaveras River	Calaveras River	41,518,289,140	0.127	5.273

[41] Annual load for American River was calculated by summing monthly load estimates, determined by multiplying monthly flow volume by monthly median methylmercury concentration, not the pooled median methylmercury concentration.

[42] Fremont Weir flow volume estimated using zeros to substitute missing data and mean of monthly flows to best represent flows during the WYs 2000-2019 period.

[43] Cache Creek flow volume estimated using zeros to substitute missing data and mean of monthly flows to best represent flows during the WYs 2000-2019 period.

[44] Annual load for Cache Creek was calculated by summing monthly load estimates, determined by multiplying monthly flow volume by monthly median methylmercury concentration, not the pooled median methylmercury concentration.

Watershed Number	Watershed Name	Tributary System	Individual Tributaries	Estimated Water Volume (L/yr)	Median MeHg Concentration (ng/L)	Estimated MeHg Load (g/yr)
8	Calaveras River Below New Hogan Lake & Mormon Slough	Calaveras River	Stockton Diversion Canal	16,032,004,179	0.127	2.036
9	Colusa Basin	Yolo Bypass	Ridge Cut Slough (Knights Landing)	596,895,920,053[45]	0.198	124.379
11	Cosumnes River	Mokelumne River	Cosumnes River	232,495,211,162	0.376	87.360
11	Cosumnes River	Mokelumne River	Dry Creek	172,291,872,192	0.376	64.739
12	Dixon Area	Dixon Area	Dixon Area	12,970,515,917	0.176	2.287
14	French Camp Slough/ Lone Tree Creek	French Camp Slough	Duck Creek, French Camp Slough, Littlejohns Creek, Walker Slough	87,823,336,899	0.139	12.225
16	Marsh Creek	Marsh Creek	Marsh Creek	5,194,621,806	0.237	1.231
17	Mokelumne River Below Camanche Reservoir	Mokelumne River	Mokelumne River	180,592,628,013	0.025	4.515

[45] Ridge Cut Slough (Knights Landing) flow volume estimated using zeros to substitute missing data and mean of monthly flows to best represent flows during the WYs 2000-2019 period.

Watershed Number	Watershed Name	Tributary System	Individual Tributaries	Estimated Water Volume (L/yr)	Median MeHg Concentration (ng/L)	Estimated MeHg Load (g/yr)
19	Morrison Creek	Morrison Creek	Laguna Creek	3,947,793,668	0.102	0.403
19	Morrison Creek	Morrison Creek	Florin/ Elder Creek	56,288,729,764	0.102	5.741
19	Morrison Creek	Morrison Creek	Morrison Creek	13,304,476,497	0.102	1.357
21	Natomas East Main Drain/ Arcade Creek	Steelhead Creek	Arcade Creek	10,015,064,768	0.253	2.534
21	Natomas East Main Drain/ Arcade Creek	Steelhead Creek	Natomas East Main Drain/ Steelhead Creek	91,753,590,655	0.253	23.214
22	Putah Creek Below Lake Berryessa	Putah Creek	Putah Creek	225,911,281,673	0.131	36.199[46]
27	Sacramento River above Verona	Sacramento River	Sacramento River	13,897,289,856,154	0.096	1,381.211[47]
NA	Sacramento Weir	Sacramento Weir	Sacramento Weir	151,285,907,180[48]	0.123	18.608

[46] Annual load for Putah Creek was calculated by summing monthly load estimates, determined by multiplying monthly flow volume by monthly median methylmercury concentration, not the pooled median methylmercury concentration.

[47] Annual load for Sacramento River was calculated by summing monthly load estimates, determined by multiplying monthly flow volume by monthly median methylmercury concentration, not the pooled median methylmercury concentration.

[48] Sacramento Weir flow volume estimated using zeros to substitute missing data and mean of monthly flows to best represent flows during the WYs 2000-2019 period.

Watershed Number	Watershed Name	Tributary System	Individual Tributaries	Estimated Water Volume (L/yr)	Median MeHg Concentration (ng/L)	Estimated MeHg Load (g/yr)
28	San Joaquin River above Vernalis	San Joaquin River	San Joaquin River	1,706,208,213,816	0.144	260.056[49]
29	Ulatis Creek	Ulatis Creek	Ulatis Creek	46,131,355,520	0.176	8.134
30	Upper Lindsey/ Cache Slough Area	Lindsey Slough	Barker Slough, Lindsey Slough	13,994,048,732	0.176	2.467
31	Willow Slough	Willow Slough	Willow Slough	55,722,533,093	0.176	9.825

[49] Annual load for San Joaquin River was calculated by summing monthly load estimates, determined by multiplying monthly flow volume by monthly median methylmercury concentration, not the pooled median methylmercury concentration.

6.2.2 Open Water Sediment Flux

Open water regions of the Delta were defined by Board staff as riverine, lake, deep water, and ponds, including any land cover defined as water by geographic sources used for the DMCP Review (Appendix D). The 2010 TMDL Staff Report used the flux rate estimated in Task 4B of the 2003 CALFED Report (Gill *et al.* 2003) to calculate aqueous methylmercury loads from open water regions of the Delta. The flux rate was estimated to be 10 nanograms per square meter per day (ng/m^2/day). Board staff updated this flux rate based on the estimate in Task 4.2 of the 2008 CALFED Mercury Project Final Report (Gill 2008b).

6.2.2.1 Acreage

In the DMCP Review, Board staff determined there were approximately 58,873 acres of open water in the Delta MeHg TMDL Boundary, excluding the CCSB, during WYs 2000-2019. Details on how open water acreage was determined for the DMCP Review can be found in Appendix D.

6.2.2.2 Methylmercury Flux

The sediment flux rate used in the 2010 TMDL Staff Report was measured using benthic flux chambers from Task 4B of the 2003 CALFED Report (Gill *et al.* 2003). Task 4.2 of the 2008 CALFED Mercury Project Final Report measured sediment flux using three different methods: benthic flux chambers, interstitial pore water gradients, and whole-marsh tidal flushing monitoring. For the DMCP Review and to maintain consistency with the methods used in the 2010 TMDL Staff Report, Board staff calculated the rate from benthic flux chamber rates[50] from Task 4.2 of the 2008 CALFED Mercury Project Final Report (Gill 2008b).

The open water flux rate calculated in Task 4B of the 2003 CALFED Report was scaled up by multiplying benthic flux chamber measurements by the surface areas of various Delta regions, then taking the median of these various rates (Gill *et al.* 2003). This median rate, 10 ng/m^2/day, was used in the 2010 TMDL Staff Report. The benthic flux chamber measurements from Task 4.2 of the 2008 CALFED Mercury Project Final Report were not scaled up using surface areas in this way, and ranged from -58 to 120 ng/m^2/day (Gill 2008b). For the DMCP Review, Board staff used the median of the 2008 CALFED Mercury Project Final Report benthic flux chamber measurements, resulting in an open water flux rate of 4.5 ng/m^2/day.[51] Board staff attributes data post-processing differences between the 2003 and 2008 CALFED reports, and the rate calculation method used in the DMCP Review, as the reasons that the DMCP Review rate is lower

[50] This rate (4.5 ng/m^2/day) is a median of all available benthic flux chamber measurements provided in Table 4.2.5 of Task 4.2 of the 2008 CALFED Mercury Project Final Report (Gill 2008b). Using a median value is consistent with how Board staff estimated other source loads.

[51] When reviewing tables in Task 4.2 of the 2008 CALFED Mercury Project Final Report, Board staff noticed a difference in median values. When Board staff calculated the median of the values in Table 4.2.2, the result was 4.35 instead of 4.5 as reported in Table 4.2.5 and in text (Gill 2008b). Board staff attributed this difference to unknown rounding in Table 4.2.2 and used the reported median that is assumed to be more accurate and less affected by rounding.

than the rate used in the 2010 TMDL Staff Report. When the rate calculation method used in the DMCP Review was applied to the Task 4B 2003 CALFED Report benthic flux chamber measurements, the result was closer to the median of Task 4.2 of the 2008 CALFED Mercury Project Final Report measurements.[52] This confirms that when DMCP Review rate calculation method is applied to Task 4B of the 2003 CALFED Report data, the results better match the rate used in the DMCP Review than does the scaled-up rate from Task 4B of the 2003 CALFED Report used in the 2010 TMDL Staff Report.

Task 4B of the 2003 CALFED Report focused on open water areas for measuring benthic flux whereas Task 4.2 of the 2008 CALFED Mercury Project Final Report measured sediment-water exchange in Delta tidal marshes and applied this flux rate to open water, but both studies used similar monitoring sites. The samples collected for Task 4.2 of the 2008 CALFED Mercury Project Final Report were not collected directly in the marsh, due to shallow water and dense emergent vegetation. Therefore, samples were collected in areas with deeper, more open water. Gill (2008a) concluded that the open water flux rates from both CALFED studies were comparable. Board staff maintained this assumption that the Task 4.2 of the 2008 CALFED Mercury Project Final Report rate is representative of open water flux.

Board staff also considered open water flux rates provided by the DWR Open Water Report. Chapter 5 of the DWR Open Water Report contains DSM2-Hg model results that show the Delta to be a net sink for methylmercury (DiGiorgio *et al.* 2020), which is consistent with the DMCP Review mass balance. At the time of analyzing data for the DMCP Review source analysis, Board staff did not have the open water acreage used in the DSM2-Hg model, which was needed to calculate flux rates in terms of ng/m^2/day. Board staff followed the methods of Task 4.2 of the 2008 CALFED Mercury Project Final Report and the 2010 TMDL Staff Report by calculating open water flux and settling rates separately. DWR's measurement of net sediment water flux is negative and considers methylmercury settling, resuspension, and diffusion (DiGiorgio *et al.* 2020). When looking only at gross methylmercury flux, the estimates in the DMCP Review and the DWR Open Water Report Chapter 5 are comparable (Table 6.10).

Technical Appendix C of the DWR Open Water Report presented two fluxes for open water, both measured at a single location in the Toe Drain of the Yolo Bypass. The diffusive flux measurement was 1.05 ng/m^2/day, and the incubated core measurement was -10.9 ng/m^2/day (DiGiorgio *et al.* 2020). Board staff does not recommend using either of these measurements within the DMCP Review because the former was a static measurement of diffusion only and both were based on measurements at only one location.

Despite the use of different methods to measure flux, the sediment flux estimates from Task 4.2 of the 2008 CALFED Mercury Project Final Report (Gill 2008b), Choe and

[52] Board staff calculated the median of benthic flux chamber measurements from Task 4B of the 2003 CALFED Report (Gill *et al.* 2003) across all sites in light and dark chambers to be 3.5 and 6.7 ng/m^2/day, respectively. Consistent with the report, to convert methylmercury values from picomole to nanogram, values were divided by 5.

others (2004), and the DWR Open Water Report (DiGiorgio *et al.* 2020) are all relatively in agreement (Table 6.10). These three studies used similar monitoring sites.

6.2.2.3 Load

To estimate subarea-specific loading, Board staff multiplied the open water flux rate by the acreage of open water in each subarea (Table 6.11). Based on the updated open water flux rate, the methylmercury sediment flux from Delta open water areas is expected to contribute approximately 391 grams per year (g/yr) within the Delta, which contributes about 12% of the overall Delta methylmercury loading (Table 6.4).

Table 6.10: Comparison of Open Water Flux Rates Considered in DMCP Review

Data Source	Open Water Flux Rate (ng/m²/day)	Delta Load Estimate (g/day)	Method(s)	Definition of Open Water in Estimating Delta Load
2010 TMDL Staff Report	10	2.4	Benthic flux chamber (Gill *et al.* 2003)	United States Fish and Wildlife (USFWS) National Wetland Inventory (NWI) map; considers tidal marshes separately; 236 km^2
DMCP Review	4.5	1.1	Benthic flux chamber (Gill 2008b)	USFWS NWI map; considers tidal marshes separately; 236 km^2
Task 4.2 2008 CALFED Report (Gill 2008b)	4.65	0.48	Average of median fluxes from benthic flux chambers (4.5 $ng/m^2/d$) and whole marsh tidal flushing (4.8 $ng/m^2/day$)	Excludes Yolo Bypass, then halves acreage (to account for sandy substrate); considers tidal marsh and open water to have the same rate; 104 km^2
Choe and others (2004)	6	1.2	Benthic flux chamber	Flux rate representative of various habitats in Central Delta: tributary streams, interconnected waterways, and open water; approx. 200 km^2 of open water (GIS estimation did not include marshes or seasonally flooded lands)
DWR Open Water Report – Chapter 5 (DiGiorgio *et al.* 2020)	1.89	0.42	DSM2-Hg Model simulation which included data from the 2003 and 2008 CALFED reports, and the 2010 TMDL Staff Report; only represents diffusion, so expected to be an underestimate	Open water channels within the legal Delta boundary; does not include temporarily flooded floodplains but does include permanently flooded wetlands; average wetted area during model simulations was 222.5 km^2

Data Source	Open Water Flux Rate (ng/m²/day)	Delta Load Estimate (g/day)	Method(s)	Definition of Open Water in Estimating Delta Load
DWR Open Water Report – Technical Appendix C (DiGiorgio *et al.* 2020)	-4.925	Unknown at time of DMCP Review	Average of average fluxes from benthic flux chamber (laboratory incubated cores; -10.9 ng/m²/day) and interstitial pore water gradients (1.05 ng/m²/day)	Cores collected from open water area of the Yolo Bypass; overlying water collected from Sacramento River; did not estimate Delta Load

Table 6.11: Methylmercury Loading from Open Water Habitats in Each Delta TMDL Subarea[53]

Delta TMDL Subarea	Open Water (ac)	Open Water (%)	Open Water (m²)	Daily Open Water MeHg Load (g/day)	Annual Open Water MeHg Load (g/yr)
Central Delta	25,772.332	43.78%	104,300,627.305	0.469	171.314
Marsh Creek	12.075	0.02%	48,868.037	0.000	0.080
Mokelumne/ Cosumnes Rivers	204.952	0.35%	829,442.070	0.004	1.362
Sacramento River	9,746.444	16.55%	39,443,859.518	0.177	64.787
San Joaquin River	3,425.668	5.82%	13,863,678.163	0.062	22.771
West Delta	12,505.682	21.24%	50,610,494.486	0.228	83.128
Yolo Bypass - North	1,349.783	2.29%	5,462,573.343	0.025	8.972
Yolo Bypass - South	5,856.544	9.95%	23,701,431.831	0.107	38.930
Total	**58,873.480**	**100.00%**	**238,260,974.752**	**1.072**	**391.344**

[53] Open water flux rate used to calculate loads is 4.5 ng/m²/day.

6.2.3 Nontidal Wetlands

Wetland aqueous methylmercury flux rates used in the 2010 TMDL Staff Report were from two experimental ponds on Twitchell Island. As a result of these studies, nontidal and tidal wetlands were estimated to input 41 ng/m^2/day during the warm season months, March through September, and 3 ng/m^2/day during the cool season months, October through February.

The 2010 TMDL Staff Report did not differentiate by wetland type in the wetland load calculation, so tidal and nontidal wetlands were grouped together as sources of methylmercury. As mentioned in Section 3.5 of the 2010 TMDL Staff Report, studies at the time determined methylmercury characteristics may vary for different wetland types. Recent studies concluded that tidal wetlands in the Delta are likely a net loss of methylmercury, but nontidal wetlands are likely a source (Fleck *et al.* 2007; Heim *et al.* 2008; Sassone *et al.* 2008; Stephenson *et al.* 2008; Marvin-DiPasquale *et al.* 2018; Lee and Manning 2020). Based on this, Board staff decided to separately analyze data from tidal and nontidal wetlands to determine which type of wetlands act as methylmercury losses and sources. The results from the DMCP Review found that tidal wetlands are a net loss of methylmercury and nontidal wetlands are a net source of methylmercury. Losses from tidal wetlands are described in Section 6.3.6.

Nontidal wetlands are evaluated separately from open water sediment flux (Section 6.2.2). Because Board staff used a whole-ecosystem monitoring approach to update wetland load estimates, these estimates are a per area measure of the net ecosystem methylmercury flux and not the gross sediment methylmercury flux. Board staff anticipates estimates of gross sediment methylmercury flux from benthic flux chambers to be higher than those of net methylmercury flux from whole-ecosystem monitoring (Section 6.2).

Data used to estimate loading from nontidal wetlands are from the BREW study[54] (Marvin-DiPasquale *et al.* 2018) and Task 5.3a at Twitchell Island of the 2008 CALFED Mercury Project Final Report (Sassone *et al.* 2008). The data from BREW and CALFED are expected to represent nontidal seasonal and permanent wetlands, respectively, within the Delta MeHg TMDL Boundary. Measured methylmercury concentrations were multiplied by associated flow data that was either measured or assumed. Flow-based methylmercury concentrations were divided by the area of the studied wetlands, then multiplied by the total area of nontidal wetlands within the Delta MeHg TMDL Boundary to determine loads. Data were pulled from each source, tidied in Excel, and loaded into RStudio for further tidying and analysis. Appendix A.2 provides references for and details on the data sources used.

6.2.3.1 Acreage

Board staff estimates a total of 32,318 acres of all wetland habitat types within the Delta MeHg TMDL Boundary, excluding the CCSB. Approximately 32,125 acres of wetlands were estimated from the USFWS NWI GIS layer (Appendix D.5). As mentioned in

[54] See Appendix E.2 for the Board staff summary of the BREW study.

Section 6.2.2 of the 2010 TMDL Staff Report, wetlands in the Delta MeHg TMDL Boundary are primarily seasonal wetlands and tidal, salt, brackish, and freshwater marshes. Appendix D.5 describes the grouping of USFWS NWI wetland map to tidal and nontidal wetlands, as shown in Figure 6.8. About 193 acres of wetlands were identified from other sources used to create the DMCP Review land cover map. Distinction on wetland type were not detailed in source files and Board staff assigned them as nontidal wetlands. In total, Board staff estimates approximately 21,755 acres of nontidal wetland habitat within the Delta MeHg TMDL Boundary, excluding the CCSB, during WYs 2000-2019.

The initiative to offset species impacts from large water diversion projects in the Delta, like the SWP, requires wildlife protection agencies to complete large habitat restoration projects within the Delta MeHg TMDL Boundary. These projects include EcoRestore projects, which largely involve converting existing agricultural lands within the Delta to complex systems of wetlands, swales, shallow channels, and habitat islands to create more and better rearing habitat for endangered and special status species. The 2010 TMDL Staff Report estimated approximately 26,576 acres of wetland habitat in the Delta MeHg TMDL Boundary, excluding the CCSB. Board staff estimates an increase of 5,742 acres of wetland habitat in the DMCP Review. As mentioned in the 2010 TMDL Staff Report Section 3.5, there was an anticipated increase of up to 90,000 acres of additional wetland habitat in the Delta. The Central Valley Water Board has received several CWA Section 401 applications for these wetland restoration projects. Board staff compiled a list of some of these projects in Appendix D.5, which shows an increase of wetland habitat in recent years (Table D.4). At the time of DMCP Review, some projects have been completed, are breaking ground, or are still in the planning stage. The ratio of tidal and nontidal wetlands in the planned projects is currently unknown, however the increase of nontidal acreages may increase methylmercury loading in the Delta.

6.2.3.2 Methylmercury Concentration

Methylmercury concentrations without associated flow data were excluded from this analysis, including those where flows could not be estimated. Further, Board staff used nontidal wetland data from within the Delta MeHg TMDL Boundary. Nontidal wetlands outside the boundary were excluded due to their geographic location not being representative of conditions within the Delta MeHg TMDL Boundary.

Board staff used the inflow and outflow methylmercury concentration monitoring data to estimate per area load. However, both studies provided very limited flow data. Therefore, assumptions about flow were made based on available information in the studies, precipitation data, and Board staff’s best judgement.

For the BREW study control pond methylmercury data (Figure 6.9), Board staff made the following assumptions:

- Because methylmercury data were not available for all months and for all wetlands, Board staff assumed the monthly median of all available methylmercury data for all years and wetlands was representative of the monthly concentration for any year and any wetland.

- Because inflow methylmercury data were not available for May in all study years, Board staff assumed the median inflow concentration in May was the same as the median inflow concentration in April.[55]
- Board staff assumed inflow monitoring occurred from the water before it reached the wetland surface.

Because the 2008 CALFED Mercury Project Final Report Task 5.3a at Twitchell Island did not have inflow or outflow methylmercury data for January and October (Figure 6.10), Board staff assumed these months are represented by the medians of the previous and subsequent monthly medians. For example, the concentration for October is assumed to be the median of the September median and November median.

6.2.3.3 Flow

The BREW study studied "control" and "treatment" nontidal, seasonal wetland cells in the Consumes River Preserve from 2014 through 2016 (Marvin-DiPasquale *et al.* 2018). The cells were constructed to mimic typical nontidal seasonal wetlands in the Delta. A fill-and-maintain strategy was employed in control wetlands except for the months of September through December 2015, when a slow flow-through strategy was temporarily employed. A similar slow flow-through strategy was maintained consistently throughout the study period in treatment wetlands. Board staff assumed the flow for control wetlands during the flow-through period was equal to the median of target outflows for treatment wetlands (Marvin-DiPasquale *et al.* 2018).

All control wetlands were drained in May and left dry throughout the summer until being refilled in September. Consequently, there was no surface water methylmercury concentration data for summer months. The drainage of the wetlands in May were in accordance with the study proponent's annual wetland operations plan, which included clearing vegetation, maintaining infrastructure, and reconstructing areas as needed. Board staff does not consider the draining of the wetlands in May to be representative of Delta nontidal wetland behavior since water loss in natural wetlands is due to evapotranspiration and soil percolation. Nontidal seasonal wetlands in the Delta receive water from precipitation (direct and indirect), groundwater, and runoff from other water sources, including other nontidal seasonal wetlands via swales during and after rain events. Board staff assumed there to be flow-through conditions during periods of precipitation, fill-and-maintain conditions during periods of no precipitation, and no wetland drainage events in May.

From these assumptions, Board staff developed representative flows for the BREW study control wetlands. Watershed precipitation data from the National Oceanic and Atmospheric Administration's (NOAA) California Nevada River Forecast Center

[55] In other cases where monthly methylmercury data were not available, Board staff assumed the concentration for the missing month was the median of the prior and following month concentration. However, this method is not possible in this case because there is no methylmercury data for consecutive months in the summer.

Observed Precipitation Monthly Data website (https://www.cnrfc.noaa.gov/) were used to classify monthly precipitation as dry, wet, or very wet. Very wet months during the study period were December through March. Wet months were September through November and April through May. Dry months were June through August. Board staff assumes the number of very wet, wet, and dry months per year will remain consistent in the future, but the months in which there is more or less flow may change with climate change. On average, the load on an annual basis is not anticipated to change.

Board staff assumed the inflow and outflow of the BREW study control ponds in very wet months was equal to the median (0.5 cfs) of target outflow for treatment wetlands. Inflow and outflow during wet months were assumed to be one quarter (i.e., 25%) of the target outflow, 0.125 cfs. Inflow and outflow during dry months were assumed to be 0 cfs (i.e., no load). In the 2010 TMDL Staff Report, concern was noted that using constant flow-through conditions to develop wetland flux rates was not representative of all nontidal wetlands. The methods used for the DMCP Review address this concern.

The 2008 CALFED Mercury Project Final Report focused on methylmercury loading in Delta-area wetlands. Of the numerous wetlands studied, only the Twitchell Island nontidal, permanent experimental ponds were within the Delta MeHg TMDL Boundary. Two Twitchell Island experimental ponds, the West and East Ponds in 2003 through 2005, were studied in Task 5.3a at Twitchell Island of the 2008 CALFED Mercury Project Final Report. At the time, both ponds consisted of native vegetation and were permanently flooded under a continuous flow regime. However, flow data were not available in the report. Since these ponds are located within Twitchell Island, nearby stream flow gage data are not applicable.

Because the Twitchell Island experimental ponds were under a flow-through regime for the entire study period, Board staff assumed this was representative of very wet months, similar to the methods described above for assuming BREW study flow.

At the time of DMCP Review, Board staff only had flow data for October through December of 2003 (Heim 2022). Board staff took the median of total inflow and outflow of both Twitchell Island experimental ponds over these months. These medians were assumed to represent the winter flow rate for nontidal permanent wetlands. Task 5.3a at Twitchell Island of the 2008 CALFED Mercury Project Final Report provided a water balance for the ponds, which Board staff incorporated the relative values from while maintaining the assumptions used for BREW study flow. The Task 5.3a at Twitchell Island of the 2008 CALFED Mercury Project Final Report water balance stated inflow in summer and winter is approximately 50% of the total balance, whereas outflow drops from 43% in winter to 32% in summer due to higher rates of evapotranspiration and seepage (Sassone *et al.* 2008). Thus, Board staff assumed the summer inflow rate was 25% of the winter inflow rate, and the summer outflow rate was 18.6%[56] of the winter

[56] Based on the Task 5.3a at Twitchell Island of the 2008 CALFED Mercury Project Final Report water balance, outflow goes from 43% in the winter to 32% in the summer. This is a 25.581% decrease, in other words 32% is 74.419% of 43%. We multiplied this decrease (0.74419) by the quarter decrease from winter to summer (0.25) to get the approximate decrease from winter outflow to summer outflow (0.186 or 18.6%).

outflow rate.[57] Because a definition of winter versus summer months was not found in the report, Board staff assessed precipitation data for the water years used in the report (2003-2005). Winter with higher precipitation was assumed to be November through April, and summer with lower precipitation was assumed to be May through October.

6.2.3.4 Load

The 2010 TMDL Staff Report used flux rates developed from studies at two Twitchell Island experimental ponds to estimate per area loading from all wetlands. The rates were calculated using the pond surface area, inflow and outflow methylmercury concentrations, and water flow measurements. The DMCP Review uses similar methods to estimate load rates from nontidal seasonal and permanent wetlands.

Board staff evaluated several options for updating the per area annual methylmercury load from nontidal wetlands in the Delta. It was assumed that the methylmercury load from nontidal wetlands is represented by the outflow load minus inflow load, which is the same method used in Sections 6.2.5 and 6.3.6. Though the 2010 TMDL Staff Report used seasonal rates, the DMCP Review used monthly rates. Board staff assumed that the median of concentrations grouped by month are representative of each month across all years.

Board staff calculated monthly flux rates for the BREW study and Task 5.3a at Twitchell Island of the 2008 CALFED Mercury Project Final Report separately. For both inflows and outflows, Board staff calculated the monthly median methylmercury concentration across all years. Board staff converted monthly flow rates in cfs to total monthly water volume in liters per day, then multiplying by the number of days in each month. Inflow and outflow loads were calculated by multiplying the monthly median methylmercury concentrations by monthly water volume. Net loads were calculated by subtracting inflow load from outflow load. For each month, the net load was divided by total area[58] and number of days in each month to get monthly rates in nanograms per square meter per day ($ng/m^2/day$). Then, Board staff calculated the median of the BREW study and Task 5.3a at Twitchell Island of the 2008 CALFED Mercury Project Final Report monthly rates to get final load rates for all nontidal wetlands in the Delta. It should be noted that this calculation assumes an equal distribution of nontidal seasonal and permanent wetland area in the Delta.

Board staff applied these per area monthly rates to the area of all nontidal wetlands in each Delta TMDL subarea. Loads for all months and subareas were summed to get the total annual methylmercury load within the Delta MeHg TMDL Boundary. Table 6.12 summarizes the loading calculations for each subarea and the entire Delta. Nontidal wetlands were determined to be a net source of approximately 93 grams of

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[57] According to the Task 5.3a at Twitchell Island of the 2008 CALFED Mercury Project Final Report, changes in methylmercury concentrations due to evaporation are negligible (Sassone *et al.* 2008). Board staff maintained this assumption.

[58] Board staff assumed that the total wetland areas listed in the reports are the wetted areas because these wetlands were under fill-and-maintain or flow-through conditions.

methylmercury per year, or about 3% of the methylmercury load to the Delta and Yolo Bypass.

The finding that nontidal wetlands are a net source of methylmercury is consistent with the results of Task 5.3a at Twitchell Island of the 2008 CALFED Mercury Project Final Report. The Task 5.3a at Twitchell Island of the 2008 CALFED Mercury Project Final Report reported the average net flux from West Pond and East Pond is 1.935 ng/m^2/day and 1.022 ng/m^2/day, respectively (Sassone *et al.* 2008). For comparison, the median of all monthly rates calculated in this update is 1.150 ng/m^2/day.

Methylmercury production rates are expected to be higher during warm months than cool months, which is reflected by the outflow methylmercury data used in the DMCP Review (Figure 6.9, Figure 6.10). Concentrations are highest in permanently flooded wetlands during spring and summer and in seasonally flooded wetlands following post-summer flooding. Discharge from all nontidal wetlands is only expected to occur during flow-through conditions from storm or flooding events. Seasonally inundated sediments may have higher rates of methylmercury production than permanently inundated sediments (Eckley *et al.* 2015). However, it is possible that seasonally flooded nontidal wetlands export less methylmercury per area than permanently flooded nontidal wetlands on an annual basis, depending on the season, duration, and amount of flooding (Stephenson *et al.* 2008).

Though the study years for Task 5.3a at Twitchell Island of the 2008 CALFED Mercury Project Final Report (WYs 2003-2005) represent a variety of conditions, those used for BREW study (WYs 2014-2016) were relatively dry. Therefore, the rates developed from the BREW study data may be an underestimate of loading. However, the assumed flow for these wetlands were based on and therefore expected to represent typical conditions.

In summary, flow is an important factor of methylmercury production and export from wetlands. Board staff recognizes that methylmercury production within Delta wetlands has been shown to be highly variable depending on a range of conditions. Further studies are recommended to characterize methylmercury production in both seasonal and permanent nontidal wetlands within the Delta MeHg TMDL Boundary. Such studies could improve understanding of monthly loads, especially after precipitation events, and methylmercury control options like invasive plant removal and limiting upstream sources of mercury. Section 3.5 further describes the conditions which affect methylmercury production in wetlands and possible controls.

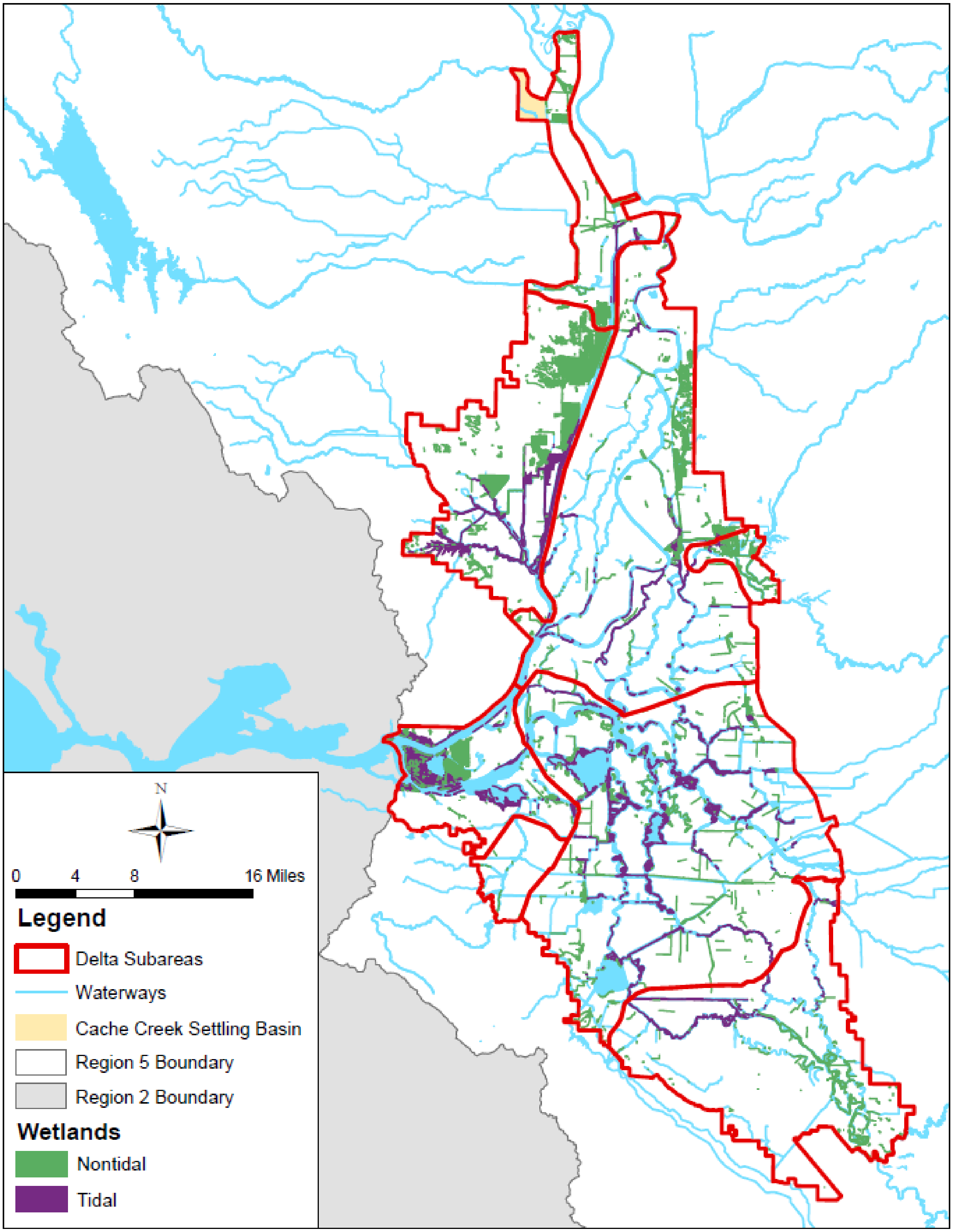

Figure 6.8: Tidal Wetlands, Nontidal Wetlands, and Open Water within the Delta Methylmercury TMDL Boundary, Not Including the Cache Creek Settling Basin

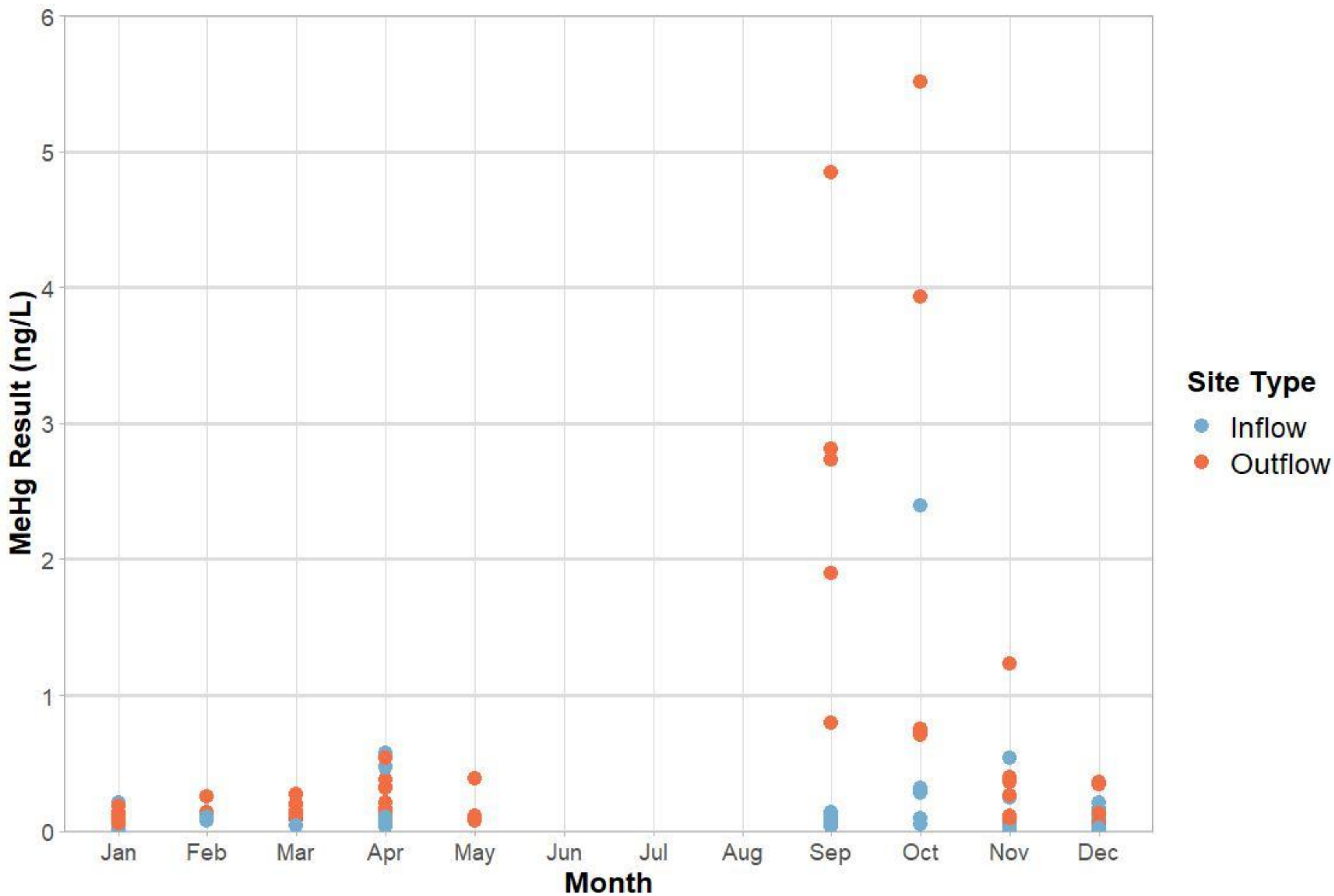

Figure 6.9: Dot Plot Monthly Summary of Raw Methylmercury Data of BREW Study Control Nontidal Seasonal Wetlands

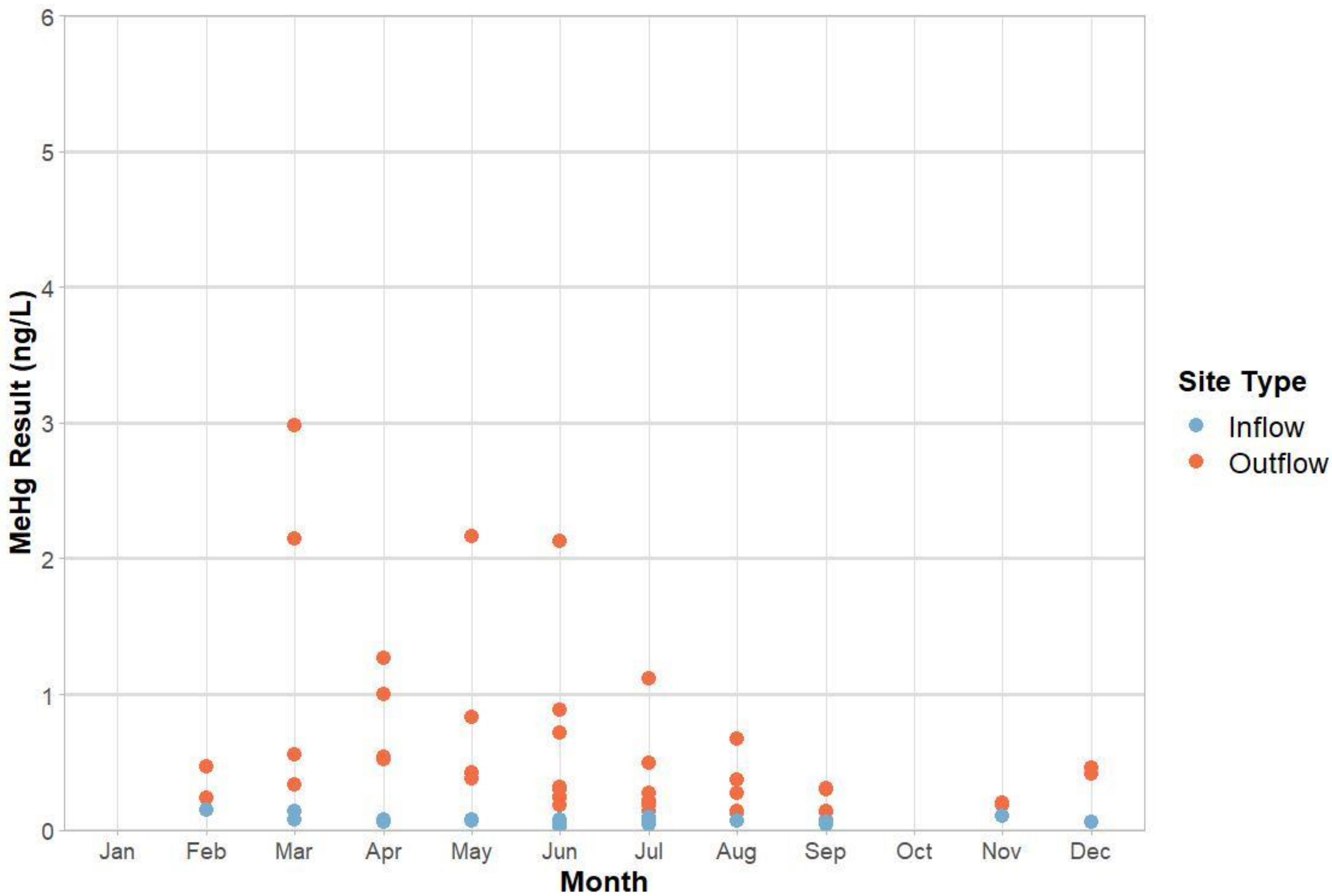

Figure 6.10: Dot Plot Monthly Summary of Raw Methylmercury Data of Twitchell Island Ponds from Task 5.3a of the 2008 CALFED Mercury Project Final Report, Nontidal Permanent Wetlands with Flow-Through Conditions

Table 6.12: Methylmercury Loading from Nontidal Wetland Habitats in Each Delta TMDL Subarea[59]

Delta TMDL Subarea	Nontidal Wetland Area (ac)	Nontidal Wetland Area (%)	Nontidal Wetland Area (m^2)	Warm Season MeHg Daily Load (g/day)	Cool Season MeHg Daily Load (g/day)	Annual MeHg Load (g/yr)
Central Delta	2,364.879	10.87%	9,570,667.033	0.033	0.020	10.094
Marsh Creek	9.227	0.04%	37,339.920	0.000	0.000	0.039
Mokelumne/ Cosumnes Rivers	1,068.907	4.91%	4,325,865.767	0.015	0.009	4.562
Sacramento River	3,056.267	14.05%	12,368,710.984	0.043	0.026	13.044
San Joaquin River	888.519	4.08%	3,595,836.426	0.012	0.007	3.792
West Delta	2,072.215	9.53%	8,386,255.294	0.029	0.017	8.844
Yolo Bypass - North	2,236.313	10.28%	9,050,359.226	0.031	0.019	9.545
Yolo Bypass - South	10,058.904	46.24%	40,708,385.927	0.141	0.084	42.932
Total	**21,755.231**	**100.00%**	**88,043,420.577**	**0.306**	**0.182**	**92.853**

[59] Warm and cool seasons are for reference only and were not used in calculating the annual loads. Warm season is defined as March through September (214 days), and cool season is defined as October through February (151 days). These definitions for warm and cool seasons are consistent with the 2010 TMDL Staff Report. Seasonal loads were calculated by adding loads for these months and dividing by the number of days in the season.

6.2.4 NPDES Municipal & Non-municipal Sources

The 2010 TMDL Staff Report evaluated effluent data from 2000 through 2003 to estimate methylmercury loading from municipal and non-municipal sources. During this time, 18 NPDES municipal facilities and 5 non-municipal facilities were active. For the DMCP Review, of the 23 facilities previously evaluated,15 municipal facilities and one non-municipal facility were active from 2010 through 2021 (Figure 6.11 and Table 6.13). Section 6.2.4.5 discusses the facilities that were evaluated in the 2010 TMDL Staff Report but no longer have an active NPDES permit and, therefore, not evaluated in the DMCP Review. The City of Lathrop CTF became an NPDES permitted municipal facility in February 2022 and was included in the DMCP Review.

In total, the DMCP Review evaluated 16 NPDES municipal facilities and one non-municipal facility, which was a groundwater treatment system (GWTS). Table 6.14 summarizes the methylmercury concentrations, flows, and calculated loads for all 17 facilities. In this report, NPDES municipal and non-municipal facilities are collectively referred to as NPDES wastewater treatment facilities (WWTFs) and do not include MS4s.

6.2.4.1 Methylmercury Concentration & Flow Data

Effluent monitoring data were obtained from the eSMR Program (https://ciwqs.waterboards.ca.gov/ciwqs/readOnly/CiwqsReportServlet?inCommand=reset&reportName=esmrAnalytical). eSMR is a module of the California Integrated Water Quality System (CIWQS) database (https://ciwqs.waterboards.ca.gov/) that allows WWTFs in the NPDES program to submit monitoring data online. Except for the City of Lathrop CTF, effluent methylmercury concentrations and flow data were pulled from eSMR between years 2010 through 2021. Effluent methylmercury data for the City of Lathrop CTF was obtained from the NPDES permit application effluent characterization study that included samples for some months in 2017, 2018, and 2020. The year range 2010 through 2021 was selected because (1) methylmercury monitoring for NPDES WWTFs did not begin until 2010 with the adoption of the 2010 DMCP requirements and (2) some municipal WWTFs had limited data prior to 2021. Effluent methylmercury data was assumed to be unfiltered per NPDES permit sampling requirements.

When reviewing data for the DMCP Review, Board staff discovered user entry errors and adjusted the reported effluent methylmercury concentrations accordingly. USEPA Method 1630 (USEPA 1998) was used for most of the reported effluent data. Therefore, Board staff relied on the Method Detection Limit (MDL) of 0.02 ng/L and Reporting Limit (RL) of 0.05 ng/L from USEPA method 1630 to identify errors. For example, if the result unit was reported as micrograms per liter (µg/L), and the MDL and RL were reported as 0.02 µg/L and 0.05 µg/L, all units were changed to ng/L.

6.2.4.2 Load

When estimating loading for municipal WWTFs with a median methylmercury concentration less than the MDL, Board staff used the median of that facility’s corrected

MDLs. In contrast, the 2010 TMDL Staff Report used the maximum reported MDL. Due to the likelihood of misreported MDLs (i.e., reported MDLs ranged from 0.0002 ng/L to 50 ng/L), Board staff was concerned that using the maximum MDL in the DMCP Review would overestimate methylmercury loading. To ensure correct methylmercury loading calculations for future compliance, Board staff urges dischargers to be diligent and ensure accuracy when self-reporting monitoring results.

The method to calculate methylmercury loading mimicked methods used in the linkage model (Section 5). Thus, the five most recent years, up to 2021, of effluent methylmercury and flow monitoring data were used to calculate the median daily effluent methylmercury concentration and median annual flow for each facility. Using the five most recent years also incorporated methylmercury effluent concentrations and flow data after recent facility upgrades and excluded data prior to any upgrades that may bias the median. The range of years varied between WWTFs, depending on data availability. Most WWTFs had flow and methylmercury data available from 2017 through 2021 (Table 6.13). Four WWTFs either had less than five years of methylmercury data or the most recent year of methylmercury monitoring was 2019.

The median effluent methylmercury concentration for each facility was determined by pooling the five most recent years of available data from 2010 through 2021 of effluent methylmercury concentrations for each sample location and then calculating the median. The median annual flow was calculated by summing the daily flow volumes by year at each sample location and then taking the median total annual flow. The median total annual flow was divided by 365 days to determine the median daily flow rate. The median effluent methylmercury concentration and median daily flow rate were multiplied together and then multiplied by 365 days to calculate the annual methylmercury load for each facility. For facilities with multiple discharge locations, the methylmercury load for each location were added together to calculate the facility's total methylmercury load shown in Table 6.14. Additionally, the median effluent methylmercury concentration and median daily flow rate shown in Table 6.14 is the median of the multiple sample locations.

The median annual methylmercury load from NPDES WWTFs account for about 1% (34.705 g/yr) of the methylmercury loading within the Delta MeHg TMDL Boundary (Table 6.4). The average annual methylmercury load was determined to be 37.626 g/yr. In comparison, the 2010 TMDL Staff Report average annual load from NPDES WWTFs was 205 g/yr (about 4%) of the total Delta methylmercury load. Thus, the annual methylmercury load for NPDES WWTFs has reduced by approximately 82% since implementation of Phase 1 of the DMCP.

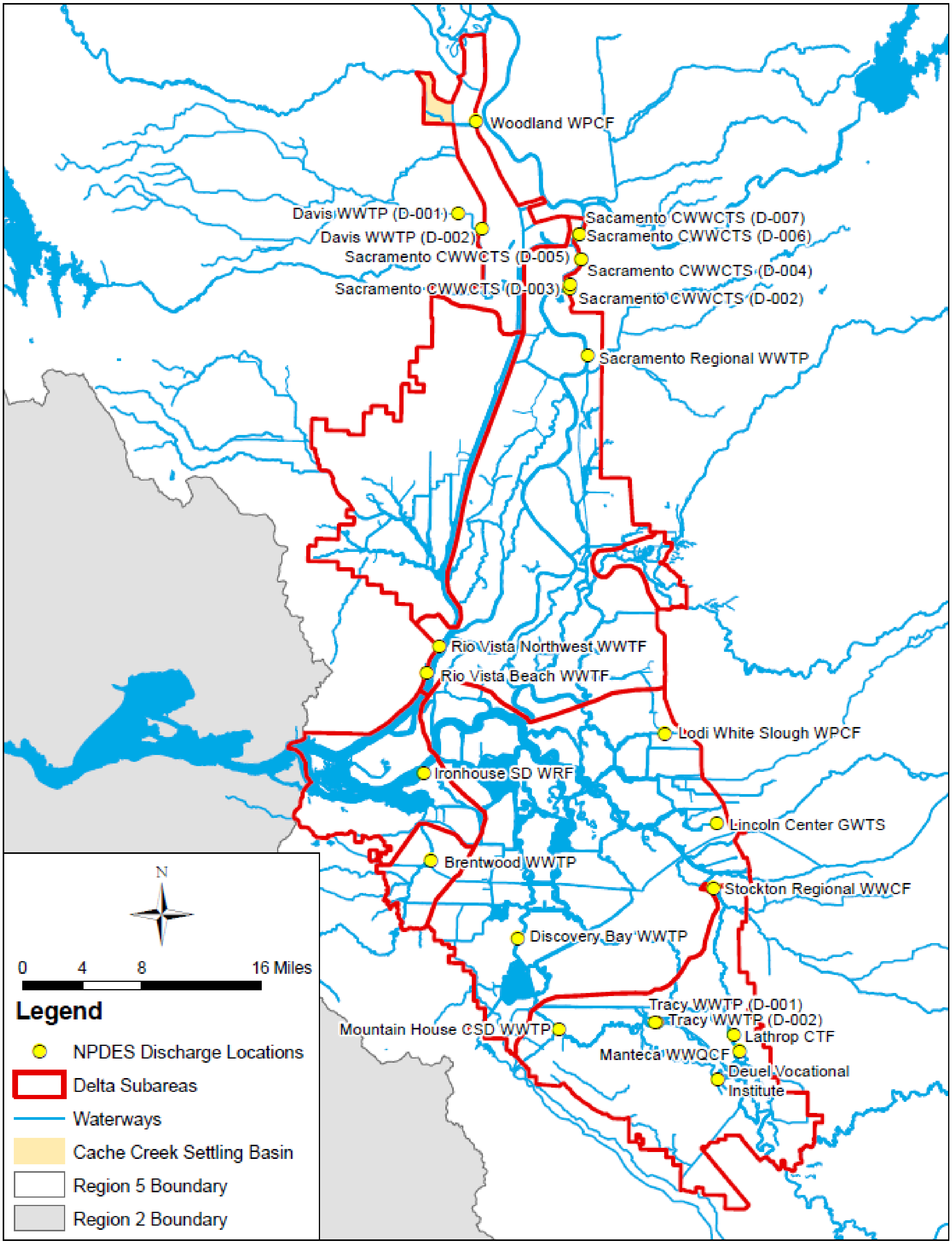

Figure 6.11: NPDES WWTF Discharge Locations

Table 6.13: Summary of NPDES WWTFs that Discharged within the Delta Methylmercury TMDL Boundary from 2010-2021

Discharger Name[60]	Facility Name	Sample Location	NPDES #[61]	Facility Type	Delta TMDL Subarea	Aqueous MeHg Data Years[62]	Flow Data Years[63]
Brentwood, City of	Wastewater Treatment Plant	EFF-001	CA0082660	Municipal Wastewater Treatment Facility	Marsh Creek	2010-2021	2010-2021
CA Dept of Corrections and Rehabilitation	Deuel Vocational Institution	EFF-001	CA0078093	Municipal Wastewater Treatment Facility	San Joaquin	2012-2021	2012-2021
Davis, City of	Wastewater Treatment Plant	EFF-002	CA0079049	Municipal Wastewater Treatment Facility	Yolo Bypass - North	2014, 2017	2011, 2013-2017, 2019
Discovery Bay Community Sanitary District, Town of	Discovery Bay Wastewater Treatment Plant	EFF-001	CA0078590	Municipal Wastewater Treatment Facility	Central Delta	2010-2021	2010-2021
Ironhouse Sanitary District	Water Recycling Facility	EFF-001	CA0085260	Municipal Wastewater Treatment Facility	West Delta	2011-2021	2011-2021
Lathrop, City of	Consolidated Treatment Facility	EFF-001	CA0085359	Municipal Wastewater Treatment Facility	San Joaquin	2017-2018, 2020	NA
Lincoln Center Environmental Remediation Trust	Groundwater Treatment System	EFF-001	CA0084255	Groundwater Treatment	Central Delta	2016-2021	2016-2021
Lodi, City of	White Slough Water Pollution Control Facility	EFF-001	CAG585001	Municipal Wastewater Treatment Facility	Central Delta	2013-2019	2013-2021

[60] Discharger Name and Facility Name cited as name listed in most recent NPDES permit as of 2022.

[61] NPDES permit numbers are the same as listed in Table 6.5 of the 2010 TMDL Staff Report, except for the City of Lodi. The City of Lodi was enrolled under Central Valley Water Board General Waste Discharge Requirements Order R5-2017-008 (NPDES No. CAG585001) in March 2019 and their NPDES permit was rescinded in October 2019. Ironhouse SD WRF and the City of Lathrop CTF were not listed in Table 6.5 of the 2010 TMDL Staff Report.

[62] Years of methylmercury concentration data available from eSMR pull, except for the City of Lathrop CTF. The City of Lathrop CTF's methylmercury data were obtained from the NPDES permit effluent characterization study.

[63] Years of flow data available from eSMR pull, except for the City of Lathrop CTF. The City of Lathrop CTF discharged to land but did not discharge to surface water during the DMCP Review analysis period. The City of Lathrop discharge to land flow data were not used for the source analysis.

Discharger Name[60]	Facility Name	Sample Location	NPDES #[61]	Facility Type	Delta TMDL Subarea	Aqueous MeHg Data Years[62]	Flow Data Years[63]
Manteca, City of	Wastewater Quality Control Facility	EFF-001	CA0081558	Municipal Wastewater Treatment Facility	San Joaquin	2010-2021	2010-2021
Mountain House Community Sanitary District	Wastewater Treatment Plant	EFF-001	CA0084271	Municipal Wastewater Treatment Facility	San Joaquin	2011-2021	2011-2021
Rio Vista, City of	Beach Wastewater Treatment Facility	EFF-001	CA0079588	Municipal Wastewater Treatment Facility	Sacramento	2010-2021	2010-2021
Rio Vista, City of	Northwest Wastewater Treatment Facility	EFF-001	CA0083771	Municipal Wastewater Treatment Facility	Sacramento	2011-2021	2011-2021
Sacramento Regional County Sanitation District	Sacramento Regional Wastewater Treatment Plant	EFF-001	CA0077682	Municipal Wastewater Treatment Facility	Sacramento	2011-2021	2011-2021
Sacramento, City of	Combined Wastewater Collection and Treatment System	EFF-002	CA0079111	Municipal Wastewater Treatment Facility	Sacramento	2011-2012, 2014, 2016-2019	2010-2012, 2014, 2016-2019, 2021
Sacramento, City of	Combined Wastewater Collection and Treatment System	EFF-003	CA0079111	Municipal Wastewater Treatment Facility	Sacramento	NA	NA
Sacramento, City of	Combined Wastewater Collection and Treatment System	EFF-004	CA0079111	Municipal Wastewater Treatment Facility	Sacramento	2012	2010, 2012, 2021
Sacramento, City of	Combined Wastewater Collection and Treatment System	EFF-005	CA0079111	Municipal Wastewater Treatment Facility	Sacramento	NA	NA
Sacramento, City of	Combined Wastewater Collection and Treatment System	EFF-006	CA0079111	Municipal Wastewater Treatment Facility	Sacramento	2010-2012, 2014-2019	2010-2012, 2014-2019, 2021

Discharger Name[60]	Facility Name	Sample Location	NPDES #[61]	Facility Type	Delta TMDL Subarea	Aqueous MeHg Data Years[62]	Flow Data Years[63]
Sacramento, City of	Combined Wastewater Collection and Treatment System	EFF-007	CA0079111	Municipal Wastewater Treatment Facility	Sacramento	NA	NA
Stockton, City of	Regional Wastewater Control Facility	EFF-001	CA0079138	Municipal Wastewater Treatment Facility	San Joaquin	2010-2021	2010-2021
Tracy, City of	Wastewater Treatment Plant	EFF-001	CA0079154	Municipal Wastewater Treatment Facility	San Joaquin	2010-2021	2010-2021
Tracy, City of	Wastewater Treatment Plant	EFF-002	CA0079154	Municipal Wastewater Treatment Facility	San Joaquin	NA	NA
Woodland, City of	Water Pollution Control Facility	EFF-001	CA0077950	Municipal Wastewater Treatment Facility	Yolo Bypass - North	2015-2021	2010-2021

Table 6.14: Summary of NPDES WWTF Median Effluent Methylmercury Concentration, Median Effluent Flow, and Methylmercury Load

Discharger Name[64]	Facility Name	Sample Locations	Delta TMDL Subarea	Aqueous MeHg Data Years	# of MeHg Monitoring Events	MeHg Conc. Range (ng/L)	# of NDs[65]	Median MeHg Conc. (ng/L)	Median Flow (MGD)	Annual MeHg Load (g/yr)
Brentwood, City of	Wastewater Treatment Plant	EFF-001	Marsh Creek	2017 - 2021	55	<0.02 - 0.47	52	<0.020	3.227	0.089
CA Dept of Corrections and Rehabilitation	Deuel Vocational Institution	EFF-001	San Joaquin	2017 - 2021	54	<0.02 - 0.065	24	0.023	0.476	0.015
Davis, City of	Wastewater Treatment Plant	EFF-002	Yolo Bypass - North	2014, 2017	5	0.35 - 0.98	0	0.760	0.585	0.614
Discovery Bay Community Sanitary District, Town of	Discovery Bay Wastewater Treatment Plant	EFF-001	Central Delta	2017 - 2021	15	<0.026 - 0.043	9	<0.026	1.107	0.040
Ironhouse Sanitary District	Water Recycling Facility	EFF-001	West Delta	2017 - 2021	50	<0.02 - 0.074	27	<0.020	2.592	0.072
Lathrop, City of	Consolidated Treatment Facility	EFF-001	San Joaquin	2017 - 2018, 2020	14	<0.02 - 0.042	11	<0.020	NA[66]	NA
Lincoln Center Environmental Remediation Trust	Groundwater Treatment System	EFF-001	Central Delta	2017 - 2021	13	<0.095 - 0.23	10	<0.095	0.052	0.007
Lodi, City of	White Slough Water Pollution Control Facility	EFF-001	Central Delta	2015 - 2019	25	<0.02 - 0.03	23	<0.020	1.561	0.043

[64] Discharger Name and Facility Name cited as name listed in most recent NPDES permit as of 2022.

[65] ND: Non-detect, below MDL.

[66] The City of Lathrop CTF discharged to land but did not discharge to surface water during the DMCP Review analysis period. The City of Lathrop CTF discharge to land flow data were not used for the source analysis to estimate the annual methylmercury load.

Discharger Name[64]	Facility Name	Sample Locations	Delta TMDL Subarea	Aqueous MeHg Data Years	# of MeHg Monitoring Events	MeHg Conc. Range (ng/L)	# of NDs[65]	Median MeHg Conc. (ng/L)	Median Flow (MGD)	Annual MeHg Load (g/yr)
Manteca, City of	Wastewater Quality Control Facility	EFF-001	San Joaquin	2017 - 2021	60	<0.02 - 0.081	51	<0.020	5.571	0.154
Mountain House Community Sanitary District	Wastewater Treatment Plant	EFF-001	San Joaquin	2017 - 2021	17	<0.02 - 1.1	11	<0.020	0.900	0.025
Rio Vista, City of	Beach Wastewater Treatment Facility	EFF-001	Sacramento	2017 - 2021	73	<0.02 - 2.39	25	0.030	0.399	0.017
Rio Vista, City of	Northwest Wastewater Treatment Facility	EFF-001	Sacramento	2017 - 2021	51	<0.02 - 0.96	36	<0.020	0.259	0.007
Sacramento Regional County Sanitation District	Sacramento Regional Wastewater Treatment Plant	EFF-001	Sacramento	2017 - 2021	79	<0.02 - 0.47	2	0.180	116.048	28.858
Sacramento, City of	Combined Wastewater Collection and Treatment System	EFF-002	Sacramento	2016 - 2019	11	0.16 - 0.39	0	0.22	1.097	0.333
Sacramento, City of	Combined Wastewater Collection and Treatment System	EFF-006	Sacramento	2015 - 2019	35	0.03 - 0.59	0	0.23	6.389	2.030
Stockton, City of	Regional Wastewater Control Facility	EFF-001	San Joaquin	2017 - 2021	45	<0.02 - 0.36	4	0.061	23.371	1.970
Tracy, City of	Wastewater Treatment Plant	EFF-001	San Joaquin	2017 - 2021	60	<0.02 - 0.05	39	<0.020	9.588	0.265

Discharger Name[64]	Facility Name	Sample Locations	Delta TMDL Subarea	Aqueous MeHg Data Years	# of MeHg Monitoring Events	MeHg Conc. Range (ng/L)	# of NDs[65]	Median MeHg Conc. (ng/L)	Median Flow (MGD)	Annual MeHg Load (g/yr)
Woodland, City of	Water Pollution Control Facility	EFF-001	Yolo Bypass - North	2017 - 2021	47	<0.02 - 0.04	27	<0.020	3.524	0.097

6.2.4.3 Active Municipal Facilities

Of the 16 municipal facilities, 15 discharged within the Delta MeHg TMDL Boundary during WYs 2010-2021. The City of Lathrop CTF did not have an NPDES permit until February 2022 and did not discharge to surface waters during the time period evaluated for the DMCP Review. Since representative flow data were not available for the City of Lathrop CTF, methylmercury loading was not estimated for the source analysis. However, the City of Lathrop was given a waste load allocation based on its permitted flow and median effluent methylmercury concentration (Section 8).

In August 2021, the Duel Vocational Institution (DVI) began a partial shutdown project. At the time of the DMCP Review, no inmates or staff are housed at DVI, and no municipal wastewater is conveyed, treated, or discharged by the sewer system or wastewater treatment plant (WWTP). All supporting activities such as kitchen, laundry, and dining, have ceased. DVI is maintained by a staff of 20 or less with domestic waste being handled by portable facilities. The sewer system and WWTP components will be drained and cleaned of all municipal waste so that the sewer system only collects water from flushing the cold and hot water piping and other incidental flows conveyed to the WWTP. After municipal waste has been cleaned out, incidental flows to the WWTP will include basement drainage, groundwater inflow and infiltration, and rainwater runoff. The effluent flow is expected to be approximately 0.059 million gallons per day (MGD). The California Department of Corrections and Rehabilitation (CDCR) requested that the DVI’s Central Valley Water Board Waste Discharge Requirements Order R5-2014-0014-01 (NPDES CA0078093) be rescinded, and the surface water discharge will be enrolled under the Central Valley Water Board Order R5-2022-0006 Waste Discharge Requirements for Limited Threat Discharges to Surface Waters General Order (NPDES CAG995002).

After Board staff addressed user entry errors, methylmercury concentrations for all facilities ranged from below the reported MDL to a maximum of 2.39 ng/L, the latter of which occurred at the City of Rio Vista Beach WWTF. The median methylmercury concentration for each facility ranged from below the MDL to a maximum of 0.76 ng/L (Table 6.15), the latter of which occurred at the City of Davis WWTP. Of the 16 municipal facilities, 10 had a median effluent methylmercury concentration less than the MDL. The reported MDLs ranged from 0.0002 ng/L to 50 ng/L. Corrected MDLs ranged from 0.012 ng/L to 0.74 ng/L with the majority of MDLs reported as 0.020 ng/L.

Twelve of the 15 municipal facilities had a median effluent methylmercury concentration less than the proposed aqueous MeHg implementation goal of 0.059 ng/L. The City of Davis WWTP, Sacramento Regional WWTP, City of Sacramento Combined Wastewater Collection and Treatment System (CWWCTS), and City of Stockton Regional Wastewater Control Facility (WWCF) each had a median effluent methylmercury concentration greater than the proposed aqueous MeHg implementation goal. The calculated annual methylmercury loads ranged from 0.007 g/yr for the City of Rio Vista Northwest WWTF to 28.858 g/yr for the Sacramento Regional WWTP.

The DMCP Review's cumulative wastewater flow and methylmercury load includes the Ironhouse Sanitary District (SD) Water Recycling Facility (WRF), which was not accounted for in the 2010 TMDL Staff Report. At the time the 2010 TMDL Staff Report was developed, methylmercury concentration data were not available for the Ironhouse SD WRF. Methylmercury concentration data for the City of Rio Vista Northwest WWTF were also not available for inclusion in the 2010 TMDL Staff Report, thus the 2010 TMDL Staff Report estimated loads for this facility using data from other wastewater plants with similar treatment processes. For the DMCP Review, the methylmercury concentrations for all dischargers were estimated using data reported by the facility.

The 2010 TMDL Staff Report states that the City of Stockton Regional WWCF only had seven monthly effluent samples available since completing upgrades to meet Title 22 tertiary requirements. The seven samples had an average methylmercury concentration of 0.08 ng/L and showed a 91% reduction in the effluent methylmercury concentration after upgrades were complete. Board staff at that time stated that more data were needed to determine if the methylmercury reduction would remain representative of the effluent and was a result of the upgrades. The data used for the DMCP Review includes 45 samples between January 2017 and April 2021 and has an average methylmercury concentration of 0.08 ng/L indicating that the upgrades have effectively helped reduce methylmercury in the effluent.

The Board staff report titled *A Review of Methylmercury and Inorganic Mercury Discharges from NPDES WWTPs in California's Central Valley* (Bosworth *et al.* 2010), states that seasonal variability in effluent methylmercury concentrations was observed at several facilities, particularly with treatment ponds. Effluent methylmercury concentrations were higher in the warm season (May through November) than the cool season. However, there was no observed trend between the type of treatment process and seasonality. The control study conducted for CVCWA evaluated whether different climatic conditions influenced effluent methylmercury concentrations for four different wastewater treatment processes[67] (Gies *et al.* 2018). The analysis did not indicate a significant difference between wet year 2017 and dry year 2016 effluent methylmercury concentrations, with the exception of tertiary wastewater treatment with nitrification and denitrification. While tertiary wastewater treatment with nitrification and denitrification had a statistically higher average effluent methylmercury concentration in wet year 2017 (0.020 ng/L) compared to dry year 2016 (0.014 ng/L), this treatment process still provided the lowest average effluent concentration of all treatment processes for both years. Overall, it does not appear that the climatic changes between these two years had a significant impact on the effluent methylmercury concentrations.

[67] Secondary wastewater treatment, secondary wastewater treatment with nitrification, tertiary wastewater treatment with nitrification, and tertiary wastewater treatment with nitrification and denitrification.

Table 6.15: Municipal Facilities Effluent Flows, Effluent Methylmercury Concentrations, and Effluent Methylmercury Loads

Discharger Name[68]	Facility Name	NPDES #[69]	Median MeHg Conc. (ng/L)	Median Flow (MGD)	Annual MeHg Load (g/yr)
Brentwood, City of	WWTP	CA0082660	<0.020	3.227	0.089
CA Dept of Corrections and Rehabilitation	Deuel Vocational Institution	CA0078093[70]	0.023	0.476	0.015
Davis, City of	WWTP	CA0079049	0.760	0.585	0.614
Discovery Bay CSD, Town of	Discovery Bay WWTP	CA0078590	<0.026	1.107	0.040
Ironhouse SD	WRF	CA0085260	<0.020	2.592	0.072
Lathrop, City of	CTF	CA0085359	<0.020	NA[71]	NA
Lodi, City of	White Slough WPCF	CAG585001	<0.020	1.561	0.043
Manteca, City of	WWQCF	CA0081558	<0.020	5.571	0.154
Mountain House CSD	WWTP	CA0084271	<0.020	0.900	0.025
Rio Vista, City of	Beach WWTF	CA0079588	0.030	0.399	0.017
Rio Vista, City of	Northwest WWTF	CA0083771	<0.020	0.259	0.007
Sacramento Regional County Sanitation District	Sacramento Regional WWTP	CA0077682	0.180	116.048	28.858
Sacramento, City of	CWWCTS	CA0079111	0.225[72]	7.603[73]	2.363[74]
Stockton, City of	Regional WWCF	CA0079138	0.061	23.371	1.970
Tracy, City of	WWTP	CA0079154	<0.020	9.588	0.265
Woodland, City of	WPCF	CA0079154	<0.020	3.524	0.097
Total				**179.311**	**34.698**

[68] Discharger Name and Facility Name cited as name listed in most recent NPDES permit as of 2022.

[69] NPDES permit numbers are the same as listed in Table 6.5 of the 2010 TMDL Staff Report, except for the City of Lodi White Slough WPCF. The City of Lodi White Slough WPCF was enrolled under the Central Valley Water Board General Waste Discharge Requirements Order R5-2017-008 (NPDES CAG585001) in March 2019 and their NPDES permit was rescinded in October 2019. Ironhouse SD WRF and the City of Lathrop CTF were not listed in Table 6.5.

[70] NPDES CA0078093 will be rescinded, and the surface water discharge will be enrolled under the Central Valley Water Board Order R5-2022-0006 Waste Discharge Requirements for Limited Threat Discharges to Surface Waters General Order (NPDES CAG995002).

[71] The City of Lathrop CTF did not discharge to surface water during the analysis period of this revision and their discharge to land flow data were not used for analysis.

[72] The median concentration from City of Sacramento CWWCTS discharge locations EFF-002 and EFF-006.

[73] The combined flow of City of Sacramento CWWCTS discharge locations EFF-002 and EFF-006 calculated based on the annual methylmercury load and median methylmercury concentration.

[74] The summed annual MeHg load from City of Sacramento CWWCTS discharge locations EFF-002 and EFF-006.

6.2.4.4 Active Non-Municipal Facilities

For the DMCP Review, the Lincoln Center GWTS was the only facility that discharged within the Delta MeHg TMDL boundary that was not a municipal facility. No methylmercury concentration data were available for this discharger at the time of the 2010 TMDL Staff Report development. The 2010 TMDL Staff Report estimated the facility's methylmercury load based on other GWTS monitoring results, which had an average methylmercury concentration below 0.03 ng/L, and the facility's average discharge volume of 0.25 MGD (see Section 6.2.3.2 of the 2010 TMDL Staff Report). Facility specific effluent data were available for the Lincoln Center GWTS from 2016 through 2018, and 2020 through 2021 in the eSMR data pull (Appendix A.2). The median methylmercury concentration was 0.095 ng/L, which was below the median of reported MDLs that ranged from 0.018 ng/L to 0.74 ng/L and the median of reported flow volumes was 0.055 MGD (Table 6.16). The facility's updated methylmercury load (0.007 g/yr) for the DMCP Review, which used medians, was similar to the 2010 TMDL Staff Report estimated load (0.010 g/yr), which used averages.

Table 6.16: Non-Municipal Facility Effluent Flows, Effluent Methylmercury Concentrations, and Effluent Methylmercury Loads

Discharger Name	Facility Name[75]	NPDES #	Median MeHg Conc. (ng/L)	Median Flow (MGD)	Annual MeHg Load (g/yr)
Lincoln Center Environmental Remediation Trust	Groundwater Treatment System	CA0084255	<0.095	0.052	0.007

[75] Discharger Name and Facility Name cited as name listed in most recent NPDES permit as of 2022.

6.2.4.5 Previously Considered Facilities No Longer Active

Facilities that were included in the 2010 TMDL Staff Report but are no longer active and not included in the DMCP Review are listed in Table 6.17 and described below.

GWF Power Systems' NPDES permit was rescinded in 2012 (Central Valley Water Board Order R5-2012-0068, p. 2, §f), after the Central Valley Water Board received a letter on 10 February 2012 that the plant ceased operations and was no longer discharging to the San Joaquin River.

The Metropolitan Stevedore Company was listed in the 2010 TMDL Staff Report as a facility that may have discharges during intense storm events. The facility was enrolled under the Central Valley Water Board NPDES Permit for Limited Threat Discharges to Surface Waters Order R5-2016-0076-007, which stated the discharge was *de minimis* and did not require effluent monitoring.

The Waste Discharge Requirement for the Mirant Delta LLC Contra Costa Power Plant, now known as AMPORTS, was rescinded in 2013 (Central Valley Water Board Order R5-2013-0142, p.1, §b) after the Central Valley Water Board received a letter on 28 June 2013 from the discharger stating the Contra Costa Generating Station ceased operations and the facility's two outfalls were no longer discharging to the San Joaquin River.

The Waste Discharge Requirement for Oakwood Lake Subdivision Mining Reclamation, formerly known as Manteca Aggregate Sand Plant, was rescinded in 2011 (Central Valley Water Board Order R5-2011-0015, p.1, §c) after the Central Valley Water Board received a letter from the discharger on 21 June 2010 that the site was graded for residential and commercial development and that discharges were discontinued in 2005.

San Joaquin County Service Area 31 Flag City WWTP ceased discharges to Highline Canal and redirected flows to Lodi White Slough Water Pollution Control Facility (WPCF) in 2008 (Central Valley Water Board Order R5-2008-0083, p.1, §3).

The Walnut Grove WWTP, owned and operated by the Sacramento Regional County Sanitation District, redirected flows to the Sacramento Regional WWTP and their NPDES permit was rescinded in 2010 (Central Valley Water Board Order R5-2010-0127, p.1. §c).

In 2009, the State of California Central Heating and Cooling Plant installed tanks and discontinued discharges to the Sacramento River and their NPDES permit was rescinded (Central Valley Water Board Order R5-2009-0125, pp.1-2).

Lastly, the West Sacramento WWTP diverted flows to the Sacramento Regional WWTP and their NPDES permit was rescinded in 2008 (Central Valley Water Board Order R5-2008-0073, p. 2).

Table 6.17: Facilities that No Longer Have an Active NPDES Permit at Time of DMCP Review

Facility Name	NPDES #	Facility Type	Delta TMDL Subarea	Year NPDES Permit Rescinded
GWF Power Systems	CA0082309	Power	West Delta	2012
Metropolitan Stevedore Company	CA0084174	Power	West Delta	NA
Mirant Delta LLC Contra Costa Power Plant (Discharge 001)	CA0004863	Power	West Delta	2013
Mirant Delta LLC Contra Costa Power Plant (Discharge 002)	CA0004863	Power	West Delta	2013
Oakwood Lake Subdivision Mining Reclamation	CA0082783	Lake Dewatering	San Joaquin River	2011
San Joaquin County Service Area 31 Flag City WWTP	CA0082848	Municipal	Central Delta	2008
Walnut Grove WWTP	CA0078794	Municipal	Sacramento River	2010
State of California Central Heating and Cooling Plan	CA0078581	Heating & Cooling	Sacramento River	2009
West Sacramento WWTP	CA0079171	Municipal	Sacramento River	2008

6.2.5 Agricultural Return Waters

In this section, "farmed Delta island" refers to any island in the Delta under agricultural production and "agricultural land" refers to all land, including islands, in the Delta under agricultural production. "Source water" refers to surface water diverted for irrigation onto farmed Delta islands, and "return water" refers to irrigation water runoff that is discharged (i.e., returned) from farmed Delta islands to surface waters.

Board staff used similar methods as the 2010 TMDL Staff Report to estimate the aqueous methylmercury loading from farmed Delta islands. The 2010 TMDL Staff Report multiplied average methylmercury concentrations by total annual return and source water flows to calculate methylmercury loads. The net methylmercury load was (1) calculated by taking the difference in return and source water loads, (2) assumed to represent loading from all agricultural land in the Delta, and (3) multiplied by the percentage of total agricultural land in each subarea to get a per-subarea load. It was assumed that available source and return water methylmercury data are representative of all farmed Delta islands.

To estimate loading from farmed Delta islands for the DMCP Review, Board staff compiled and analyzed available acreage, methylmercury concentration, and flow data from WYs 2000-2019.

6.2.5.1 Acreage

Board staff delineated approximately 495,113 acres of agricultural land within the Delta MeHg TMDL Boundary, excluding the CCSB; approximately 481,336 within the Legal Delta Boundary; and 13,777 acres outside the Legal Delta Boundary (Figure 6.12). Appendix D describes the steps Board staff took to update the acreage of agricultural land.

6.2.5.2 Methylmercury Concentration

In the 2010 TMDL Staff Report, the average methylmercury concentration of source water was estimated from monthly Sacramento River and California Aqueduct methylmercury concentrations between May and December. According to the Delta Farmed Island Study, the irrigation season in the Delta is April through September (Heim *et al.* 2009). For the DMCP Review, Board staff pulled data from the same monitoring locations between April and September.[76] Additionally, Board staff included source water methylmercury data from the *Characterization of Methylmercury Loads for Irrigated Agriculture in the Delta: Final Report*[77] (Tetra Tech 2016) and reports from Alpers and others (2014) and Eagles-Smith and others (2014). Return water methylmercury data were compiled from the 2010 TMDL Staff Report and Tetra Tech

[76] Board staff used the final linkage data for this estimation. Because the sampling location names vary, Board staff looked at geographic aqueous sampling locations in ArcMap to determine which names are associated with Sacramento River and California Aqueduct concentrations.

[77] For more information on the *Characterization of Methylmercury Loads for Irrigated Agriculture in the Delta: Final Report*, see Appendix E.1.

(2016). Appendix A.2 lists all the methylmercury data used in this analysis. The medians of available source and return water methylmercury concentrations were used to estimate annual methylmercury concentrations in all farmed Delta island source and return waters (Table 6.18). Available source water and return methylmercury data were first grouped by month to account for seasonal variation, then the medians of monthly concentrations were calculated to estimate monthly concentrations.

It should also be noted that for the purposes of this analysis, concentrations from outflows, centers, and drains were considered representative of all return waters from farmed Delta islands. Outflow is defined as tail water from an individual field, while drains contain tail water from multiple fields (Tetra Tech 2016). Field centers and outflows do not show significant differences and are grouped together in other reports (Alpers *et al.* 2014). The 2010 TMDL Staff Report only examined samples from drain water.

6.2.5.3 Flow

Consistent with the 2010 TMDL Staff Report, Board staff obtained monthly flow estimates for Delta agricultural source waters and returns from the DICU Model. DICU flow estimates were provided by DWR staff and were used to calculate methylmercury loading for all farmed Delta islands. The DICU Model is restricted to an area defined as the “Delta Service Area.” Board staff did not have the geographic information system (GIS) delineation of the Delta Service Area, but the mapped boundary appeared similar to the Legal Delta Boundary. Thus, Board staff used the Legal Delta Boundary for the DICU flow estimates. Since the Delta Service Area does not include flows for the areas of Yolo Bypass - North and Yolo Bypass - South that are outside the Legal Delta Boundary, agricultural flow estimates are likely an underestimate for within the Delta MeHg TMDL Boundary.

Consistent with the 2010 TMDL Staff Report, Board staff summed model outputs “seepage” and “diversions” to represent all source water. Flow volumes for source and return water were similar to those presented in Table 6.8 of the 2010 TMDL Staff Report. Board staff attributes any differences to variation in the DICU model outputs.

The 2010 TMDL Staff Report used one year of flow data, 1999, to estimate loads because this was the year during which most return water methylmercury data were collected. For the DMCP Review, flow data from calendar years 2000 to 2019 were pulled. To maintain consistency with the assumptions of the 2010 TMDL Staff Report, Board staff only used flow data from months and years that coincided with available methylmercury data.

The 2010 TMDL Staff Report load estimate did not include flow volumes from months when return flow was greater than source flow, so as to not pair high flow volumes with low flow methylmercury concentrations and potentially overestimate load. Because more wet weather methylmercury data were available for the DMCP Review, flow volumes from months with higher return flow than source flow were included in this analysis.

It should be noted that model outputs from DICU are given as monthly averages, not medians. After these months were selected, Board staff calculated the medians of monthly flows across the years of available data to represent a standard flow volume in ac-ft for each month (Table 6.19).

6.2.5.4 Load

For both source and return waters, monthly flow volumes were multiplied by monthly median methylmercury concentrations to calculate loads.[78] Monthly return water loads minus monthly source water loads resulted in a net monthly load. Net monthly loads were added together to estimate annual methylmercury loading for farmed Delta islands (Table 6.20).[79] The DMCP Review determined that farmed Delta islands are a net source of approximately 168 grams of methylmercury per year within the Legal Delta Boundary.

To estimate methylmercury loading from all agricultural lands within the Delta MeHg TMDL Boundary, Board staff assumed that the loading calculated based on farmed Delta island concentrations and flows can be attributed to all agricultural lands within the Legal Delta Boundary, consistent with the 2010 TMDL Staff Report. Board staff used the ratio of agricultural acreage per Delta TMDL subarea within the Legal Delta Boundary multiplied by the estimated methylmercury loading of 168 g/yr to determine loads for each Delta TMDL subarea within the Legal Delta Boundary. Dividing the load per subarea by the amount of agricultural acreage within that subarea provided a methylmercury loading rate per acre. Assuming that this rate per acre is representative of the remaining acreage within the Delta MeHg TMDL Boundary, Board staff multiplied the rate by the remaining acreage of agricultural outside the Legal Delta Boundary in Yolo Bypass - North and Yolo Bypass - South. Adding the estimated methylmercury loading within the Legal Delta Boundary and outside the Legal Delta Boundary, Board staff estimates that agricultural lands are a net source of approximately 173 grams of methylmercury per year, or about 5% of the total methylmercury load within the Delta MeHg TMDL Boundary (Table 6.21).

This estimate is higher than the 2010 TMDL Staff Report’s estimate of 123 g/yr. The higher loading estimate in the DMCP Review may be attributed to the absence of wet weather data in the 2010 TMDL Staff Report and from including the extrapolated loading estimate for agricultural acreages outside the Legal Delta Boundary in the Yolo Bypass - North and Yolo Bypass - South subareas. However, Board staff cautions the direct comparison of the two values, since the DMCP Review load was calculated using medians and the 2010 TMDL Staff Report load relied on means.

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[78] After data compilation, the month of March was missing source water methylmercury data. Board staff assumed the median of the monthly medians for remaining non-irrigation months (i.e., January, February, October, November, and December) was representative of March concentrations.

[79] Board staff chose this method of summarizing the data to account for monthly variation and maintain similarity with the methods of the 2010 TMDL Staff Report. In addition, this method allowed Board staff to only assume one month of source water methylmercury data, instead of making assumptions for all flow and methylmercury data if all monthly data were grouped into an annual median rate.

The 2010 TMDL Staff Report estimated that upland areas[80] may comprise about 20% or more of the Delta and Yolo Bypass. McCord and Heim (2015) estimate that upland irrigated lands comprise 88% (176,000 hectares) of the wetlands and irrigated farmed land uses in the Delta and Yolo Bypass. Upland farmed areas are expected to be relatively smaller contributors of methylmercury compared to farmed Delta islands because seasonal flooding, a practice typical of farmed Delta islands, appears to increase methylmercury production more than non-flooded irrigation practices (Windham-Myers *et al.* 2014a). Board staff recommends further characterization of loads from upland farmed areas upstream of the Legal Delta Boundary.

The 2010 TMDL Staff Report did not estimate methylmercury loads in rainwater runoff from farmed Delta islands because the only monitoring data available at the time was during the active irrigation season (Section 6.2.7). However, this reevaluation includes methylmercury data from non-irrigation months of the year, which estimates methylmercury loading from rainwater runoff.

In the 2010 TMDL Staff Report, peat is described as predominant in farmed Delta island soils and a good substrate for methylmercury production. Climate change may increase methylmercury production from peat soils as the water table lowers and flooding becomes more sporadic (Haynes *et al.* 2019). The DMCP Review includes data from a range of agricultural soil types, such as from mineral soils with low organic carbon content to organic, peat and carbon rich soils. Thus, the DMCP Review estimate is expected to be representative of the different soil types in farmed Delta islands.

Methylmercury loads from farmed Delta islands are highly variable, depending on a range of factors. These factors include, but are not limited to, season, temperature and the availability of DO, organic carbon, inorganic mercury, and sulfate and iron reducing bacteria (Tetra Tech 2016; Windham-Myers *et al.* 2014a). Organic soils have higher levels of, and variability in, methylmercury concentrations than mineral soils (Heim *et al.* 2009). These complexities make it challenging to characterize methylmercury cycling and loading from farmed Delta islands.

Methylmercury production also varies by field type (Bachand *et al.* 2014b). Permanently flooded wetlands generally show less variability in methylmercury concentrations and loads, and lower concentrations of methylmercury overall (Alpers *et al.* 2014; Windham-Myers *et al.* 2010). Farmed wetlands in the Yolo Bypass have been shown to contain higher methylmercury concentrations in water, biota, and sediment than non-agricultural seasonal and permanent wetlands (Windham-Myers *et al.* 2010). Additionally, it has been shown that agricultural wetlands have higher sediment methylmercury concentrations than non-agricultural wetlands (Marvin-DiPasquale *et al.* 2014). The frequent drying and wetting cycle and high availability of carbon in agricultural wetlands creates conditions for increased methylmercury production (Windham-Myers *et al*. 2014a).

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[80] Upland agricultural areas include contiguous agricultural land within the Delta MeHg TMDL Boundary that are not farmed Delta islands.

Farmed Delta islands may be a net sink for methylmercury during the summer growing season (Tetra Tech 2016), but this is not the case when accounting for transpiration as a separate hydrologic process. During summer months, evapotranspiration is a primary pathway for water loss, not flows out of the field, resulting in a decrease of methylmercury export. Instead, transpiration creates flow toward the root zone, transporting and storing methylmercury there until winter harvest and flood (Bachand *et al.* 2014b). When accounting for such flows and the methylmercury produced biogeochemically, farmed wetlands are likely a net source of methylmercury in both the summer and winter seasons (Bachand *et al.* 2014b). These studies highlight the need to separate the effects of evaporation and transpiration when characterizing loads (Bachand *et al.* 2014a).

The patterns of mercury concentrations in water and biota seem to contrast in farmed wetlands. For example, mercury concentrations are higher in fish during the summer, but aqueous methylmercury concentrations are higher during the winter (Eagles-Smith *et al.* 2014). Overall, fish have higher mercury concentrations in outlets and farmed wetlands than inlets and permanent wetlands (Ackerman and Eagles-Smith 2010). In contrast, invertebrates do not have higher mercury concentrations in farmed wetlands compared to permanent wetlands, but concentrations at outlets are higher than at inlets (Ackerman *et al.* 2010). Regardless, both fish and invertebrates in Yolo Bypass farmed wetlands were substantially above the DMCP's proposed target fish tissue mercury concentrations to protect wildlife (0.03 ppm wet weight) (Windham-Myers *et al.* 2010). These differences highlight the complexity of bioaccumulation in wetlands and emphasizes the need for characterization of exposure to higher trophic levels.

Board staff recommends continued monitoring and research to further characterize methylmercury loads and implementation of management practices to control methylmercury loads from farmed Delta islands.

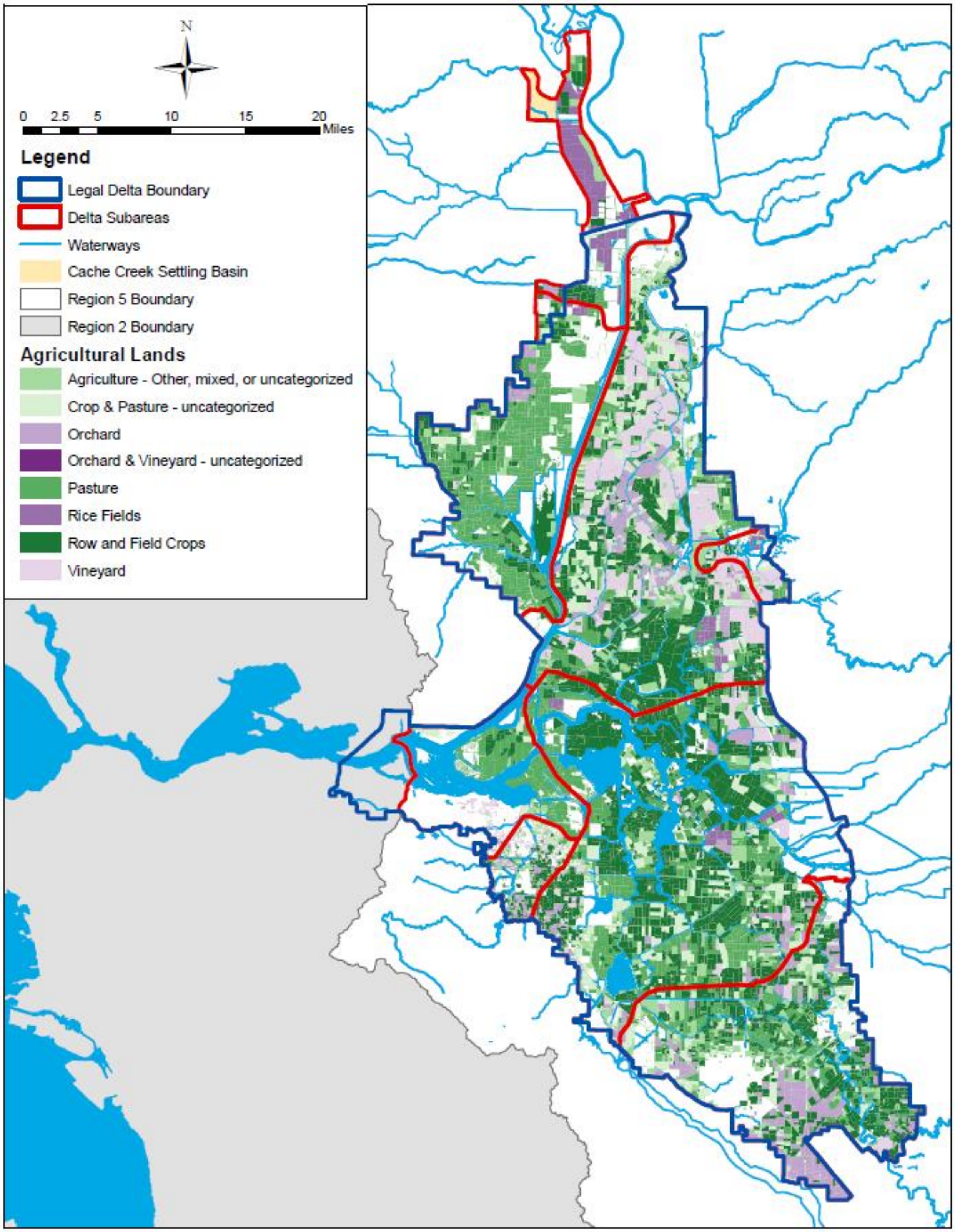

Figure 6.12: Agricultural Lands within the Delta Methylmercury TMDL Boundary, Not Including the Cache Creek Settling Basin

Table 6.18: Farmed Delta Island Monthly Median Methylmercury Concentration

Month	Source Water MeHg (ng/L)	Return Water MeHg (ng/L)
January	2.054	1.33
February	1.33	1.1
March	0.744	1.16
April	0.09	0.438
May	0.102	0.358
June	0.153	0.625
July	0.091	0.875
August	0.087	0.625
September	0.072	0.71
October	0.042	0.281
November	0.109	0.262
December	0.744	0.368

Table 6.19: Delta-wide Island Consumptive Use Model (DICU) Estimated Monthly Median Volume[81]

Month	Diversions + Seepage (ac-ft)	Return Flow (ac-ft)	Net Channel Depletion (ac-ft)
January	50,255.491	114,460.813	-64,205.322
February	46,603.419	54,483.660	-7,880.241
March	131,717.797	60,844.154	70,873.644
April	119,865.042	49,598.405	70,266.636
May	167,388.168	60,766.200	106,621.968
June	262,990.527	88,454.322	174,536.205
July	361,955.417	122,481.332	239,474.085
August	233,371.675	81,145.589	152,226.086
September	134,806.814	51,190.325	83,616.489
October	110,612.284	41,395.284	69,217.000
November	84,608.173	32,591.592	52,016.582
December	84,844.961	32,919.936	51,925.024
Annual Total	**1,789,019.767**	**790,331.612**	**998,688.155**

[81] Does not include areas of Yolo Bypass - North and Yolo Bypass - South subareas outside of the Legal Delta Boundary.

Table 6.20: Estimated Methylmercury Loads from Agricultural Lands within the Legal Delta Boundary[82]

Month	Source Water Load (g/month)	Return Water Load (g/month)	Net Load (g/month)
January	127.307	187.703	60.396
February	76.424	73.896	-2.528
March	120.832	87.024	-33.807
April	13.301	26.786	13.484
May	21.101	26.823	5.723
June	49.613	68.165	18.552
July	40.697	132.142	91.445
August	25.149	62.483	37.334
September	11.901	44.814	32.912
October	5.728	14.368	8.640
November	11.371	10.529	-0.843
December	77.833	14.917	-62.916
Annual Total	**581.257**	**749.65**	**168.392**

82 Does not include areas of Yolo Bypass - North and Yolo Bypass - South subareas outside of the Legal Delta Boundary.

Table 6.21: Agricultural Acreage and Annual Methylmercury Load Estimates by Delta TMDL Subarea

Delta TMDL Subarea	Area in Legal Delta Boundary (ac)	Area in Legal Delta Boundary (%)	Estimated MeHg Load (g/yr) in Legal Delta Boundary[83] (g/yr)	Area outside Legal Delta Boundary (ac)	MeHg Load Rate (g/yr/ac)	Extrapolated MeHg Load for Acreage outside Legal Delta Boundary (g/yr)	Estimated MeHg Load in Delta MeHg TMDL Boundary (g/yr)
Central Delta	154,929.123	32.19%	54.201	0	0.0003	0	54.201
Marsh Creek	7,288.715	1.51%	2.550	0	0.0003	0	2.550
Mokelumne/ Cosumnes Rivers	5,909.575	1.23%	2.067	0	0.0003	0	2.067
Sacramento River	145,927.342	30.32%	51.052	0	0.0003	0	51.052
San Joaquin River	87,318.495	18.14%	30.548	0	0.0003	0	30.548
West Delta	14,398.310	2.99%	5.037	0	0.0003	0	5.037
Yolo Bypass - North	5,118.495	1.06%	1.791	11,789.224	0.0003	4.124	5.915
Yolo Bypass - South	60,446.090	12.56%	21.147	1,987.512	0.0003	0.695	21.842
Total	**481,336.144**	**100.00%**	**168.392**	**13,776.736**		**4.820**	**173.212**

[83] A Delta-wide agricultural land methylmercury loading of 168.392 g/yr was estimated using the information presented in Table 6.18 through Table 6.20. Consistent with the 2010 TMDL Staff Report, the Delta-wide load was multiplied by the percentage of total agricultural acreage located in each Delta TMDL subarea to estimate the amount of loading from agricultural lands in each subarea.

6.2.6 Urban Runoff

The 2010 TMDL Staff Report estimated urban runoff from urban land cover in the Delta using land cover, precipitation gage, and methylmercury concentration data. Board staff used similar methodology in the DMCP Review to update urban runoff estimates based on available data from WYs 2000-2019, as described in detail below.

6.2.6.1 Acreage

In the 2010 TMDL Staff Report, approximately 56,000 acres of land within the Delta MeHg TMDL Boundary were classified as urban based on information from 1993 to 2003 from DWR (see Section 6.2.5 of the 2010 TMDL Staff Report). In the DMCP Review, Board staff used multiple sources to update land cover acreages (Appendix D), including urban (Figure 6.13). Data sources used to update urban land cover include individual municipalities, the Port of Stockton, DWR county land use surveys, and State highways from the Caltrans.[84] The updated urban acreage for the DMCP Review is approximately 65,237 acres within the Delta MeHg TMDL Boundary[85] (Table 6.22), an increase of 17.3% from the 2010 TMDL Staff Report.

As stated in the 2010 TMDL Staff Report, most of the urban area is regulated by NPDES wastewater discharge requirements and MS4s.[86] Consistent with the 2010 TMDL Staff Report, urban areas outside MS4 service areas were grouped into a "nonpoint source" category within each Delta TMDL subarea. This method is based on USEPA's requirements and guidance for establishing storm water source load and waste load allocations (USEPA 2002). Figure 6.14 below shows updated MS4 Phase I and Phase II service areas (see Appendix D.8 for information on layers used for urban areas).

MS4 permittees considered in the DMCP Review, and their service area acreages are listed in Table 6.23. Though MS4 service areas incorporate all land cover types within

[84] Board staff requested GIS layers from Caltrans staff on 24 November 2021, 14 December 2021, 30 November 2022, and 9 December 2022 with no response of requested data. Board staff attained a polyline GIS shapefile of state highways from the Caltrans website, which did not include acreage or width information. Board staff assigned each polyline a uniform width of 75 feet to incorporate lanes, highway medians, shoulders, and right of ways. For highways with left and right highway polylines, any overlap of the two 75-foot-wide lanes were removed.

[85] Urban land cover within the Cache Creek Settling Basin, if any, were excluded from this acreage estimate since Cache Creek Settling Basin methylmercury loading was assessed in Section 6.2.1.3.

[86] An 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 Regional Water Boards have adopted NPDES storm water permits for medium (serving between 100,000 and 250,000 people) and large (serving more 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 Water Board adopted a General Permit for the discharge of storm water from small MS4s (State Water Board WQ Order 2013-0001-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.

their boundaries, Board staff remained consistent with the 2010 TMDL Staff Report to estimate methylmercury loading from urban acreages within MS4 service areas only.

6.2.6.2 MS4 Permittees

Since the adoption of the DMCP, there have been several changes to the MS4 permitted facilities listed in Table 6.10 of the 2010 TMDL Staff Report. The County of Solano and the County of Yolo were included in the 2010 TMDL Staff Report urban runoff methylmercury loading estimate and assigned waste load allocations in the DMCP. As mentioned in Section 6.2.6.1, Board staff updated land cover acreages for the DMCP Review and MS4 jurisdictional geospatial data from State Water Board. With the updated data, no urban land cover within the Delta MeHg TMDL Boundary and MS4 jurisdictional areas for either County of Solano or County of Yolo were observed. Therefore, the County of Solano and County of Yolo are not included in the urban runoff methylmercury loading estimate for the DMCP Review.

On 23 June 2016, the Central Valley Water Board adopted the NPDES Permit and Waste Discharge Requirements General Permit for Discharges from Municipal Separate Storm Sewer Systems also known as the Region-wide MS4 Permit (Central Valley Water Board Order R5-2016-0040, NPDES No. CAS0085324). The Order became effective on 1 October 2016 and expired on 30 September 2021. The Region-wide MS4 Permit is scheduled to be revised in 2024. Per Attachment H, B.2.c:

> *Continuation of expired order. After this Order and NPDES permit expires, the terms and conditions of this Order and NPDES permit are automatically continued pending issuance of a new permit if all requirements of the federal NPDES regulations on the continuation of expires permits (40 CFR 122.6) are complied with*.

Under this Order, Phase I MS4 permittees are required to enroll under the Region-wide MS4 Permit when their current Individual permits expire. Phase II MS4 Permittees may choose to enroll under the Region-wide MS4 Permit but are not required to by the Order.

MS4s that are enrolled under the Region-wide MS4 permit at the time of the DMCP Review and are within the scope of the Delta Methylmercury TMDL are:

- City of Stockton (Phase I MS4; Central Valley Water Board Order R5-2016-0040-002)
- County of San Joaquin (Phase I & II MS4; Central Valley Water Board Order R5-2016-0040-003, amended)
- Port of Stockton (Phase I MS4; Central Valley Water Board Order R5-2016-0040-011)
- Sacramento Stormwater Quality Partnership (Phase I MS4)
    - City of Citrus Heights (Central Valley Water Board Order R5-2016-0040-004)

- City of Elk Grove (Central Valley Water Board Order R5-2016-0040-005)
- City of Folsom (Central Valley Water Board Order R5-2016-0040-006)
- City of Galt (Central Valley Water Board Order R5-2016-0040-007)
- City of Rancho Cordova (Central Valley Water Board Order R5-2016-0040-008)
- City of Sacramento (Central Valley Water Board Order R5-2016-0040-009)
- County of Sacramento (Central Valley Water Board Order R5-2016-0040-010)

On 30 April 2003, the NPDES General Permit for Waste Discharge Requirements for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems, hereafter referred to as the previous Small MS4 General Permit, was adopted by the State Water Board (State Water Board Order WQ 2003-0005-DWQ). The previous Small MS4 General Permit was replaced by the NPDES General Permit for Waste Discharge Requirements for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems (State Water Board Order WQ 2013-0001-DWQ, as amended), hereafter referred to as the current Small MS4 General Permit. The current Small MS4 General Permit was adopted by the State Water Board on 5 February 2013, became effective on 1 July 2013, and was set to expire on 30 June 2018. Per Section J of the current Small MS4 General Permit:

> *This Order expires on July 1, 2018. If this Order is not reissued or replaced prior to the expiration date, it will be automatically continued in accordance with 40 CFR 122.6 and remain in full force and effect.*

Therefore, all permit conditions and requirements of the current Small MS4 General Permit will continue to be implemented until a new permit is adopted.

Entities near and within the Delta that had active permits, as of September 2021, under the current Small MS4 General Permit include the cities of Lathrop, Lodi, Manteca, Rio Vista, Tracy, West Sacramento, and Dixon; counties of Solano, Yolo, and San Joaquin[87]; Mountain House Community Services District; California Exposition and State Fair; DVI; and Elk Grove Unified School District. As explained in Appendix D.8, Board staff removed overlap of MS4 service areas, including overlaps of Phase I and Phase II MS4s. Phase II MS4 service areas that overlapped with Phase I MS4 service areas were erased from the Phase II MS4 service area boundary and remained in the Phase I MS4 service area.

[87] The portion of San Joaquin County under the Phase II MS4 Permit is not under the Region-wide MS4 Permit as of 11 February 2022.

Phase II MS4s that are enrolled under the current Small MS4 General Permit (State Water Board Order WQ 2013-0001-DWQ, NPDES No. CAS000004) at the time of the DMCP Review and had urban land cover within the Delta MeHg TMDL Boundary are:

- City of Lathrop
- City of Lodi
- City of Manteca
- City of Rio Vista
- City of Tracy
- City of West Sacramento
- Deuel Vocational Institution
- Mountain House Community Services District

On 11 May 2022, the Waste Discharge Requirements and Municipal Regional Stormwater NPDES Permit for the discharge of storm water runoff from municipal separate storm sewer systems jurisdictions was adopted by the San Francisco Bay Water Board (San Francisco Bay Water Board Order R2-2022-0018, NPDES No. CAS612008). This permit, hereafter referred to as the San Francisco Bay Municipal Regional Stormwater Permit, includes the CCCWP, a Phase I MS4. Entities that have joined the CCCWP and have urban land cover within the Delta MeHg TMDL Boundary include:

- City of Antioch
- City of Brentwood
- City of Oakley
- City of Pittsburg
- County of Contra Costa

These entities are located in the eastern portion of Contra Costa County and are labelled in tables in this document as East Contra Costa County Permittees.

On 22 June 2022, the NPDES Statewide Stormwater Permit and Waste Discharge Requirements for State of California Department of Transportation for the discharges of storm water and non-storm water from Caltrans' municipal separate storm sewer system was adopted by State Water Board, referred to as the Caltrans Statewide Stormwater Permit (State Water Board Order WQ 2022-0033-DWQ, NPDES No. CAS000003).

6.2.6.3 Methylmercury Concentration

The 2010 TMDL Staff Report estimated methylmercury loads in urban runoff using samples collected in WYs 2000-2003 by Board staff, the City of Sacramento, and the County of Sacramento at several urban waterways in or adjacent to the Delta (see

Figure 6.9 of the 2010 TMDL Staff Report). Data were grouped into wet and dry weather concentrations: wet weather data ranged from October to May, dry weather data ranged from April to October. The data were grouped by sample site and weather type, then averaged. Then the average methylmercury concentration by weather type of all sample site averages was used for the 2010 load calculation. Both wet and dry weather loads were estimated by multiplying the weather type average methylmercury concentration by the calculated weather type runoff volume for each MS4 urban land cover acreage within a Delta TMDL subarea. Appendix E of the 2010 TMDL Staff Report details wet and dry weather urban runoff volume calculations. Dry weather urban runoff volumes used an adapted daily dry season runoff value developed by LWA for the Sacramento region (LWA 1996). Wet weather urban runoff volumes used annual precipitation, urban land cover, and land cover runoff coefficients.

For the DMCP Review, Board staff updated MS4 discharger methylmercury concentrations, urban land cover acreage in the Delta MeHg TMDL Boundary, and urban runoff volumes. Aqueous methylmercury data used for this analysis are listed in Appendix A.2 and includes newer Phase I MS4 data from CCCWP (Welsh 2021), City of Stockton and County of San Joaquin (Saini 2021), Port of Stockton (Bedore 2021), and SSQP (Laurenson 2021). Table 6.24 lists the MS4 permittee and the urban nonpoint source median methylmercury concentrations used in this analysis. Methylmercury concentration data from 2011 through 2020 was submitted by MS4 Phase I dischargers and processed by Board staff to calculate median methylmercury concentrations per discharger and weather type. Board staff was unable to find updated methylmercury concentration data representative of Phase II, Caltrans, and nonpoint source dischargers and relied upon the 2010 TMDL Staff Report dataset's median concentrations. Board staff assumed these concentrations were more representative of smaller discharges than the updated Phase I discharger concentrations standardized by acreage.

6.2.6.4 Flow

Consistent with the 2010 TMDL Staff Report, urban land cover acreage within each MS4 service area and Delta TMDL subarea was used to calculate urban runoff volumes (Table 6.25). Data sampled between 1 May and 31 October were categorized as dry weather, data sampled between 1 November and 30 April were categorized as wet weather. Dry weather (Equation 6.2) and wet weather (Equation 6.3) urban runoff volumes were calculated using the equation from the 2010 TMDL Staff Report, with updated values as necessary.

Equation 6.2: Dry Weather Runoff Volume

$$Dry\ Weather\ Runoff\ Volume = \left[\left(U_{ac} \times V_{dry}\right) \div 10^6\right] \times 3.0688833 \times N_{days}$$

Where:

U_{ac} = Urban land cover acreage within an MS4 service area and Delta TMDL Subarea (ac)

V_{dry} = Updated dry weather runoff volume for the Sacramento area (LWA 2013)

= 918 million cubic feet of dry season runoff / permit area (ac)
= 22,515,138.8852459 gallons per day (gal/day) / 255,917 acres (ac)
= 87.9782854802373 gallons per acre per day (gal/ac/day)
10^6 = Conversion factor of gallons to million gallons (million gal/gal)
3.0688833 = Conversion factor of million gallons to ac-ft (ac-ft/million gal)
N_{days} = Number of dry days a year, 305 (day)

Equation 6.3: Wet Weather Runoff Volume

$$Wet\ Weather\ Runoff\ Volume = \ MS4\ per\ Subarea \sum U_{ac} \times (P_{gage} \div 12) \times RC$$

Where:
U_{ac} = Urban land cover acreage within an MS4 service area and Delta TMDL subarea (ac)
P_{gage} = Median annual precipitation from WYs 2000-2019 per precipitation gage, in inches (in; Table 6.26)
12 = Conversion factor of inches to feet (in/ft)
RC = Urban land cover runoff coefficient (Table D.5 in Appendix D)

The updated estimates of urban runoff volumes and methylmercury loads per MS4 and Delta TMDL subarea are listed in Table 6.27. For urban land cover within the Delta MeHg TMDL Boundary, annual dry and wet weather runoff volumes are estimated to be approximately 5,372 ac-ft and 51,776 ac-ft, respectively, totaling 57,148 ac-ft per year.

6.2.6.5 Load

Methylmercury loads were determined by multiplying methylmercury concentration by flow, specific to dry or wet weather. Updated values to the dry weather load equation include urban acreage per MS4 service area and Delta TMDL subarea, methylmercury concentration for each MS4 permittee, and adapted Sacramento area dry weather runoff volume (LWA 2013). Updated values to the wet weather load equation include urban acreage per MS4 service area and Delta TMDL subarea, methylmercury concentration for each MS4 permittee, and annual precipitation estimates for WYs 2000-2019. Annual dry and wet weather methylmercury loads are estimated to be 1.162 grams and 8.941 grams, respectively, totaling 10.103 g/yr (Table 6.27).

Overall, methylmercury loading from MS4 dischargers are estimated to have decreased from the loading calculated in the 2010 TMDL Staff Report (Table 6.28). To determine if the decreased value is due to the use of median instead of average, Board staff analyzed the average methylmercury loading from MS4 dischargers to be approximately 14.532 g/yr. This value is about 26% lower than the 2010 average loading estimate of 19.689 g/yr. Therefore, the reduction is not attributed to using the median. The reduction of methylmercury loading from MS4 dischargers may be attributed to the decrease of urban runoff to the Delta by installation of LID features and drought water restrictions.

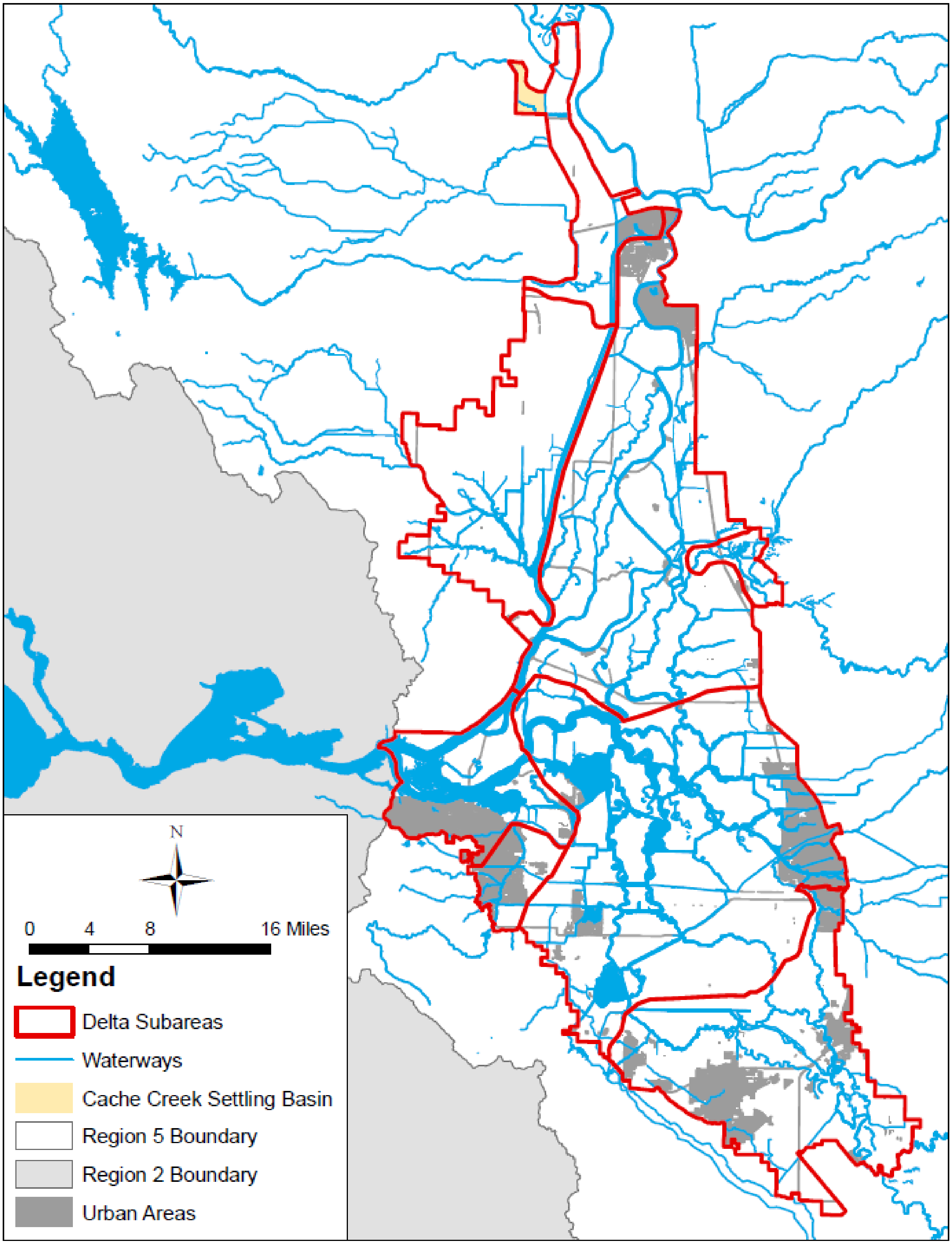

Figure 6.13: Urban Areas and State Highways in the Delta Methylmercury TMDL Boundary

Table 6.22: Urban Acreage by Land Cover and Delta TMDL Subarea

Delta TMDL Subarea	Commercial (UC)	Industrial (UI)	Residential (UR)	Transitional (UT)	Transportation, Communication, Utilities (T)	Urban unclassified (includes mixed use) (U)	Total (ac)
Central Delta	197.730	1,612.007	2,096.506	0	1,238.648	11,116.616	**16,261.507**
Marsh Creek	566.051	29.437	4,330.685	4.214	92.410	1,068.428	**6,091.224**
Mokelumne/ Cosumnes Rivers	0	37.963	13.408	0	51.460	21.267	**124.098**
Sacramento River	149.303	369.325	1,780.799	0.645	2,831.581	5,722.844	**10,854.496**
San Joaquin River	546.315	1,357.703	1,974.581	0	1,815.775	11,592.189	**17,286.562**
West Delta	1,945.405	763.065	5,442.766	91.729	507.930	2,871.792	**11,622.686**
Yolo Bypass - North	16.625	124.988	49.412	0	559.858	2,053.151	**2,804.034**
Yolo Bypass - South	0	0	9.462	0	177.921	5.352	**192.735**
Total	**3,421.428**	**4,294.487**	**15,697.619**	**96.587**	**7,275.582**	**34,451.639**	**65,237.342**

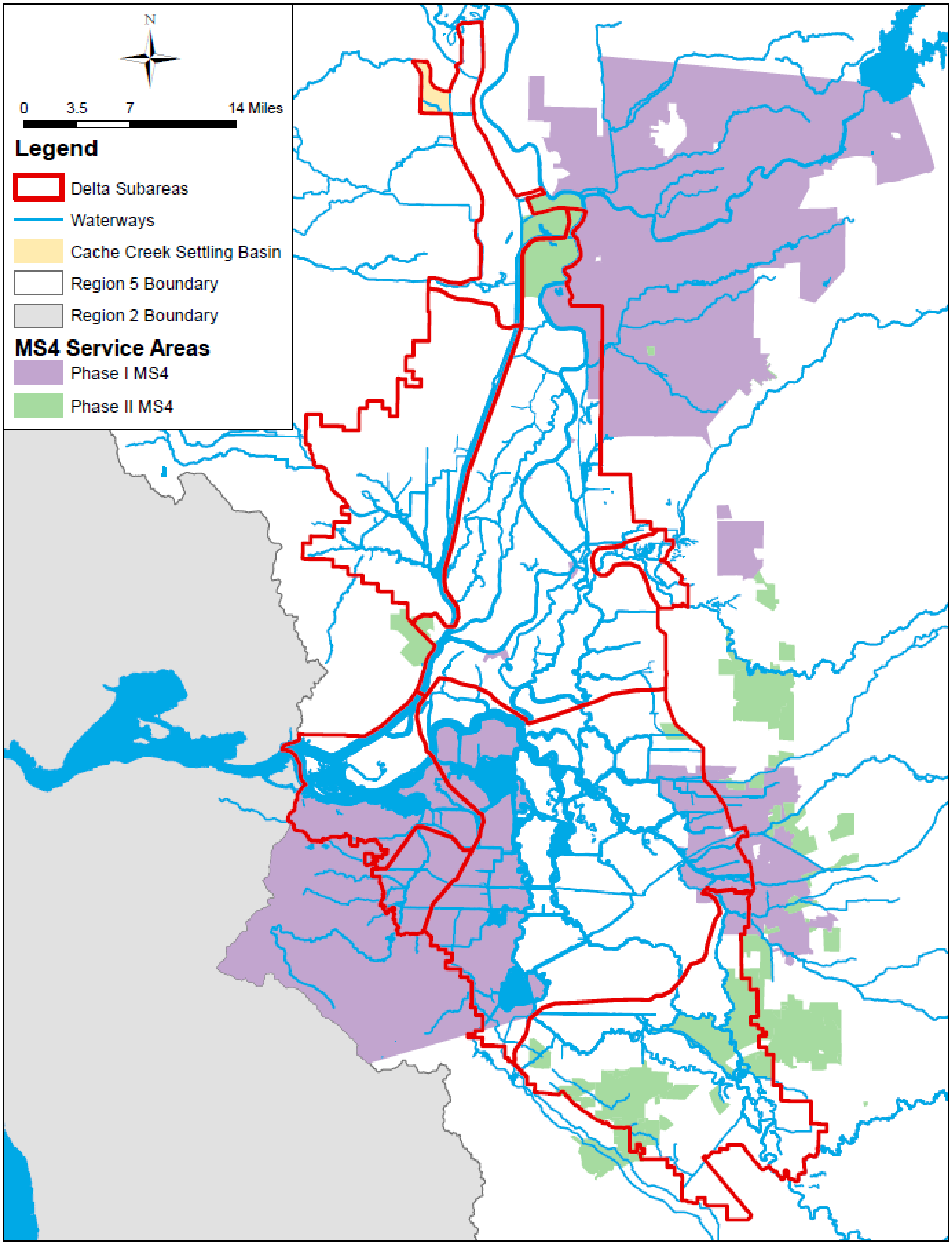

Figure 6.14: NPDES Permitted MS4 Areas in the Delta Region

Table 6.23: MS4 Permittee Information and Service Area Acreages within Delta TMDL Subareas, Delta Methylmercury TMDL Boundary, and Central Valley Water Board Boundary[88]

MS4 Permittee	MS4 Phase	Central Delta	Marsh Creek	Moke./ Cos. Rivers	Sac. River	San Joaquin River	West Delta	Yolo Bypass - North	Yolo Bypass - South	Service Area in Delta TMDL	Total Service Area in R5
Caltrans	NA	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
City of Lathrop	II	0	0	0	0	11,313	0	0	0	11,313	13,778
City of Lodi	II	956	0	0	0	0	0	0	0	956	8,835
City of Manteca	II	0	0	0	0	1,418	0	0	0	1,418	11,386
City of Rio Vista	II	0	0	0	1,102	0	0	0	83	1,186	4,571
City of Stockton/ San Joaquin County	I	17,811	0	0	0	3,353	0	0	0	21,165	50,662
City of Tracy	II	0	0	0	0	10,221	0	0	0	10,221	14,136
City of West Sacramento	II	0	0	0	7,778	0	0	4,582	0	12,360	14,688
Deuel Vocational Institution	II	0	0	0	0	771	0	0	0	771	771
East Contra Costa County Permittees	I	58,676	16,128	0	0	0	26,744	0	0	101,548	189,920
Mountain House Community Services District	II	0	0	0	0	1,435	0	0	0	1,435	1,435
Port of Stockton	I	2,135	0	0	0	26	0	0	0	2,161	2,161
Sacramento Stormwater Quality Partnership	I	0	0	0	9,452	0	0	0	0	9,452	255,269
San Joaquin County	II	0	0	0	0	4,716	0	0	0	4,716	25,339
Total (excludes Caltrans)		**79,579**	**16,128**	**0**	**18,333**	**33,253**	**26,744**	**4,582**	**83**	**178,702**	**592,950**

[88] Data from State Water Board and State Highway GIS layers. Acreage assigned by ArcMap Advanced NAD83 California Teale Alpers geometry calculations (Appendix D.4). Board staff requested delineation of jurisdictional areas from Caltrans staff several times in 2021 and 2022, with no data provided in responses.

Table 6.24: Methylmercury Concentration Data Summary for MS4 Permittees and Nonpoint Source by Weather Type

MS4 Permittee	Weather Type[89]	Median MeHg (ng/L)	Average MeHg (ng/L)	N	Maximum MeHg (ng/L)	Minimum MeHg (ng/L)
City of Stockton and San Joaquin County	Dry	0.075	0.144	23	0.330	0.020
East Contra Costa County Permittees	Dry	0.090	0.103	6	0.105	0.020
Port of Stockton	Dry	0.088	0.240	2	0.115	0.060
Sacramento Stormwater Quality Partnership	Dry	0.270	0.471	12	1.500	0.075
Caltrans, Phase 2, and Nonpoint Source	Dry	0.176	0.363	5	1.099	0.091
City of Stockton and San Joaquin County	Wet	0.090	0.120	49	0.376	0.030
East Contra Costa County Permittees	Wet	0.110	0.181	13	0.675	0.020
Port of Stockton	Wet	0.085	0.094	25	0.240	0.017
Sacramento Stormwater Quality Partnership	Wet	0.160	0.237	24	1.390	0.060
Caltrans, Phase 2, and Nonpoint Source	Wet	0.199	0.241	11	0.487	0.103
City of Stockton and San Joaquin County	Annual	0.077	0.140			
East Contra Costa County Permittees	Annual	0.093	0.116			
Port of Stockton	Annual	0.087	0.216			
Sacramento Stormwater Quality Partnership	Annual	0.252	0.433			
Caltrans, Phase 2, and Nonpoint Source	Annual	0.180	0.343			

[89] Board staff assumed wet weather occurs 60 days per year and dry weather occurs 305 days per year. Annual median and average methylmercury concentration per MS4 permittee is weighted by days in weather type.

Table 6.25: Urban Acreage per MS4 Service Area and Delta TMDL Subarea

MS4 Permittee	Central Delta	Marsh Creek	Mokelumne/ Cosumnes Rivers	Sacramento River	San Joaquin River	West Delta	Yolo Bypass - North	Yolo Bypass - South	Total (ac)
Caltrans[90]	399.141	0	36.357	1,408.880	456.226	122.041	131.967	127.169	**2,681.780**
City of Lathrop	0	0	0	0	2,022.585	0	0	0	**2,022.585**
City of Lodi	80.673	0	0	0	0	0	0	0	**80.673**
City of Manteca	0	0	0	0	77.269	0	0	0	**77.269**
City of Rio Vista	0	0	0	132.018	0	0	0	32.590	**164.608**
City of Stockton and San Joaquin County	11,431.863	0	0	0	2,337.905	0	0	0	**13,769.768**
City of Tracy	0	0	0	0	7,623.662	0	0	0	**7,623.662**
City of West Sacramento	0	0	0	3,002.418	0	0	2,615.229	0	**5,617.647**
Deuel Vocational Institution	0	0	0	0	113.857	0	0	0	**113.857**
East Contra Costa County Permittees	2,452.165	6,091.224	0	0	0	11,469.377	0	0	**20,012.767**
Mountain House Community Services District	0	0	0	0	959.750	0	0	0	**959.750**
Port of Stockton	1,412.827	0	0	0	9.497	0	0		**1,422.324**
Sacramento Combined Stormwater Sewer System	0	0	0	5,570.141	0	0	0	0	**5,570.141**
San Joaquin County	0	0	0	0	2,233.751	0	0	0	**2,233.751**
Urban Nonpoint Source[91]	484.838	0	87.741	741.040	1,452.062	31.268	56.838	32.976	**2,886.763**
Total	**16,261.507**	**6,091.224**	**124.098**	**10,854.496**	**17,286.562**	**11,622.687**	**2,804.034**	**192.735**	**65,237.343**

[90] Acreage for Caltrans are California State Highways areas not encompassed by other MS4 service areas.

[91] Urban areas not encompassed by an MS4 service area or State Highway were grouped into the “nonpoint source” category.

Table 6.26: Precipitation Stations Used to Estimate Runoff

Precipitation Station	Code	Latitude	Longitude	WYs 2000-2019 Median (in)[92]
Los Banos	LSB	37.05	-120.867	8.44
Sacramento WB City	SCR	38.583	-121.5	16.85
Stockton Fire Station	STK	38.001	-121.317	16.37

Table 6.27: Estimated Runoff Volumes and Methylmercury Loads per MS4 and Delta TMDL Subarea

Delta TMDL Subarea	MS4 Name	Urban Area (ac)	Annual Dry Weather Runoff (ac-ft)	Dry Weather Median MeHg Load (g)	Annual Wet Weather Runoff (ac-ft)	Wet Weather Median MeHg Load (g)	Annual Runoff (ac-ft)	Annual Median MeHg Load (g)
Central Delta	Caltrans	399.141	32.869	0.007	381.146	0.093	414.015	0.100
Central Delta	City of Lodi	80.673	6.643	0.001	77.036	0.019	83.679	0.020
Central Delta	City of Stockton/ San Joaquin County	11,431.863	941.397	0.313	8,886.269	0.986	9,827.666	1.299
Central Delta	East Contra Costa County Permittees	2,452.165	201.932	0.022	1,768.804	0.240	1,970.737	0.262
Central Delta	Port of Stockton	1,412.827	116.344	0.013	1,314.995	0.138	1,431.339	0.150
Central Delta	Urban Nonpoint Source	484.838	39.926	0.009	409.116	0.100	449.042	0.109
Marsh Creek	East Contra Costa County Permittees	6,091.224	501.603	0.056	4,438.726	0.602	4,940.329	0.658
Mokelumne/ Cosumnes Rivers	Caltrans	36.357	2.994	0.001	35.385	0.005	38.379	0.005
Mokelumne/ Cosumnes Rivers	Urban Nonpoint Source	87.741	7.225	0.002	76.065	0.019	83.291	0.020

92 Data from CDEC Precipitation Stations. Board staff calculated the median of the annual average precipitation volumes for WYs 2000-2019. Years without complete precipitation datasets were excluded from this analysis.

Delta TMDL Subarea	MS4 Name	Urban Area (ac)	Annual Dry Weather Runoff (ac-ft)	Dry Weather Median MeHg Load (g)	Annual Wet Weather Runoff (ac-ft)	Wet Weather Median MeHg Load (g)	Annual Runoff (ac-ft)	Annual Median MeHg Load (g)
Sacramento River	Caltrans	1,408.880	116.019	0.025	1,376.178	0.187	1,492.197	0.212
Sacramento River	City of Rio Vista	132.018	10.871	0.002	118.465	0.029	129.336	0.031
Sacramento River	City of West Sacramento	3,002.418	247.245	0.054	2,406.409	0.589	2,653.653	0.643
Sacramento River	Sacramento Stormwater Quality Partnership	5,570.141	458.693	0.152	4,504.428	0.889	4,963.121	1.041
Sacramento River	Urban Nonpoint Source	741.040	61.024	0.013	624.469	0.153	685.492	0.166
San Joaquin River	Caltrans	456.226	37.570	0.008	412.294	0.056	449.864	0.064
San Joaquin River	City of Lathrop	2,022.585	166.557	0.036	1,623.724	0.398	1,790.280	0.434
San Joaquin River	City of Manteca	77.269	6.363	0.001	56.331	0.014	62.694	0.015
San Joaquin River	City of Stockton/ San Joaquin County	2,337.905	192.523	0.064	1,894.649	0.210	2,087.172	0.274
San Joaquin River	City of Tracy	7,623.662	627.797	0.136	6,001.563	1.469	6,629.360	1.606
San Joaquin River	Deuel Vocational Institution	113.857	9.376	0.002	109.466	0.027	118.842	0.029
San Joaquin River	Mountain House Community Services District	959.750	79.034	0.017	683.244	0.167	762.278	0.184
San Joaquin River	Port of Stockton	9.497	0.782	0.000	8.938	0.001	9.720	0.001

Delta TMDL Subarea	MS4 Name	Urban Area (ac)	Annual Dry Weather Runoff (ac-ft)	Dry Weather Median MeHg Load (g)	Annual Wet Weather Runoff (ac-ft)	Wet Weather Median MeHg Load (g)	Annual Runoff (ac-ft)	Annual Median MeHg Load (g)
San Joaquin River	San Joaquin County	2,233.751	183.946	0.040	1,730.981	0.424	1,914.927	0.464
San Joaquin River	Urban Nonpoint Source	1,452.062	119.575	0.026	1,217.479	0.298	1,337.055	0.324
West Delta	Caltrans	122.041	10.050	0.002	119.607	0.016	129.657	0.018
West Delta	East Contra Costa County Permittees	11,469.377	944.486	0.105	8,947.432	1.214	9,891.918	1.319
West Delta	Urban Nonpoint Source	31.268	2.575	0.001	28.340	0.007	30.915	0.007
Yolo Bypass - North	Caltrans	131.967	10.867	0.002	129.713	0.018	140.580	0.020
Yolo Bypass - North	City of West Sacramento	2,615.229	215.360	0.047	2,153.286	0.527	2,368.646	0.574
Yolo Bypass - North	Urban Nonpoint Source	56.838	4.681	0.001	55.874	0.014	60.555	0.015
Yolo Bypass - South	Caltrans	127.169	10.472	0.002	124.996	0.017	135.468	0.019
Yolo Bypass - South	City of Rio Vista	32.590	2.684	0.001	32.033	0.008	34.717	0.008
Yolo Bypass - South	Urban Nonpoint Source	32.976	2.716	0.001	28.703	0.007	31.419	0.008
Total		**65,237.343**	**5,372.198**	**1.162**	**51,776.145**	**8.941**	**57,148.343**	**10.103**

Table 6.28: Estimated Annual Methylmercury Load in Grams from Urban Areas within Each Delta TMDL Subarea

MS4 Permittee	Central Delta	Marsh Creek	Mokelumne/ Cosumnes Rivers	Sacramento River	San Joaquin River	West Delta	Yolo Bypass - North	Yolo Bypass - South	Total (g)
Caltrans	0.100	0	0.005	0.212	0.064	0.018	0.020	0.019	0.440
City of Lathrop	0	0	0	0	0.434	0	0	0	0.434
City of Lodi	0.020	0	0	0	0	0	0	0	0.020
City of Manteca	0	0	0	0	0.015	0	0	0	0.015
City of Rio Vista	0	0	0	0.031	0	0	0	0.008	0.040
City of Stockton/ San Joaquin County	1.299	0	0	0	0.274	0	0	0	1.574
City of Tracy	0	0	0	0	1.606	0	0	0	1.606
City of West Sacramento	0	0	0	0.643	0	0	0.574	0	1.217
Deuel Vocational Institution	0	0	0	0	0.029	0	0	0	0.029
East Contra Costa County Permittees	0.262	0.658	0	0	0	1.319	0	0	2.239
Mountain House Community Services District	0	0	0	0	0.184	0	0	0	0.184
Port of Stockton	0.150	0	0	0	0.001	0	0	0	0.151
Sacramento Stormwater Quality Partnership	0	0	0	1.041	0	0	0	0	1.041
San Joaquin County	0	0	0	0	0.464	0	0	0	0.464
Urban Nonpoint Source	0.109	0	0.020	0.166	0.324	0.007	0.015	0.008	0.649
Total	**1.942**	**0.658**	**0.026**	**2.094**	**3.395**	**1.345**	**0.609**	**0.035**	**10.103**

6.2.7 Atmospheric Deposition

Mercury in the atmosphere primarily exists as elemental gaseous mercury, which has a long atmospheric residence time. Particulate and reactive gaseous mercury, though minor fractions of atmospheric mercury, are the species that are more easily deposited via rainfall or direct contact. Mechanisms for the atmospheric deposition of methylmercury is not known (Gill 2008a).

Dry deposition occurs when atmospheric mercury settles onto atmospheric particulates or terrestrial surfaces (Gill 2008a). Since the 2010 TMDL Staff Report there has been more research done on dry deposition of total mercury, but there is not new information on dry deposition of methylmercury. Consistent with the 2010 TMDL Staff Report, the DMCP Review does not include an estimate of methylmercury loading from dry deposition.

The 2010 TMDL Staff Report estimated atmospheric deposition of mercury in precipitation, known as wet deposition. Wet deposition can be direct or indirect. Direct deposition occurs when precipitation falls on open water, as defined in the Appendix D. Indirect deposition occurs when precipitation falls on land and results in storm water runoff. The 2010 TMDL Staff Report estimated direct deposition by multiplying the volume-weighted average total mercury concentration in rainfall by average precipitation volume on Delta water surfaces during water years 2000 through 2003. Indirect deposition was estimated by multiplying the same concentration by average runoff volume from non-urban areas for water years 2000 through 2003. Runoff from urban areas was not included in wet deposition estimates because methylmercury from urban runoff is accounted for in Section 6.2.6.

The 2010 TMDL Staff Report assumed total mercury in wet deposition within the Delta MeHg TMDL Boundary was equal to the volume-weighted average concentration measured at a station in the City of Martinez, chosen because it is the closest station to and typically upwind of the Delta. These data were collected between August 1999 and November 2000 and resulted in a volume-weighted average concentration of 7.4 ng/L (SFEI 2001). Based on a literature review the 2010 TMDL Staff Report assumed methylmercury was 1% of the total mercury in wet deposition, 0.074 ng/L.

Task 3 of the 2008 CALFED Mercury Project Final Report (Gill 2008a) directly measured methylmercury wet deposition between April 2004 and June 2006 in the City of Woodland. The volume-weighted methylmercury concentration from Task 3 of the 2008 CALFED Mercury Project Final Report was 0.103 ng/L, approximately 3.4% of the measured 3.7 ng/L total mercury in wet deposition (Gill 2008a). This concentration was not used in the 2010 TMDL Staff Report because the 2008 CALFED Mercury Project Final Report was published after the development of the source analysis. For the DMCP Review, Board staff used the median of the 2010 TMDL Staff Report and Task 3 of the 2008 CALFED Mercury Project Final Report concentrations, 0.0885 ng/L, as the volume-weighted concentration of methylmercury in wet deposition (Gill 2008a). In this way, Board staff used the analyses from the 2010 TMDL Staff Report while incorporating new data from different water years and locations.

To calculate total mercury loading in direct wet deposition, the 2010 TMDL Staff Report delineated open water areas by Delta TMDL subarea and precipitation gage. These areas were each multiplied by the volume-weighted average total mercury concentration and their respective average annual precipitation volume for WYs 2000-2003. The 2010 TMDL Staff Report estimated wet deposition of total mercury to be 2,300 g/yr. As 1% of total mercury, methylmercury in wet deposition was estimated to be 23 g/yr.

For the DMCP Review, Board staff maintained consistency with the 2010 TMDL Staff Report methods to estimate direct and indirect wet deposition of methylmercury. Precipitation from WYs 2000-2019 were used to match the years of the updated water balance. The median of each gage's total annual precipitation for WYs 2000-2019[93] was multiplied by the area of non-urban land cover in each subarea to get per-area precipitation volume. Volumes were multiplied by the median methylmercury concentration in wet deposition, 0.0885 ng/L, to get a methylmercury load for each Delta TMDL subarea. This resulted in a load of approximately 141 grams of methylmercury per year, or about 4% of the total methylmercury load to the Delta MeHg TMDL Boundary[94] (Table 6.29). The 2010 TMDL Staff Report divided annual water volumes by 12 to get monthly volumes but did not multiply back by 12 to get annual load. Thus, what was reported as atmospheric deposition annual load was actually monthly load and should have been 276 g/yr instead of 23 g/yr of methylmercury. With this correction accounted for, the DMCP Review estimate is about half of the 2010 TMDL Staff Report estimate, which could be accounted for by the use of medians instead of means in calculating precipitation volume and a higher relative percentage of urban land cover.

The 2010 TMDL Staff Report and Independent Scientific Review Panel's (ISRP) assessment of the DWR Open Water Report (Branfireun *et al.* 2021) both found that atmospheric deposition is a relatively insubstantial source of methylmercury in the Delta. The ISRP stated atmospheric deposition is negligible in modeling Delta methylmercury sources (Branfireun *et al.* 2021). However, the DMCP Review found that atmospheric deposition of methylmercury may be a more significant source of methylmercury than estimated in the 2010 TMDL Staff Report.

Measuring and modeling atmospheric deposition of mercury presents several challenges, ranging from a lack of data to factors that create variation in deposition and sequestration patterns (Domagalski *et al.* 2016; Eagles-Smith *et al.* 2016). The 2010 TMDL Staff Report considered using data from the Mercury Deposition Network (MDN) stations in California. However, most MDN stations do not measure methylmercury deposition (NADP c2022). In addition, the closest MDN station to the Delta is near San Jose and it has not been active since 2006. The DWR Open Water Report used data from the San Jose MDN station to model methylmercury wet deposition and an average value from San Francisco Estuary Institute (SFEI 2001) to model methylmercury dry deposition (DiGiorgio *et al.* 2020).

[93] Board staff excluded precipitation data from water years with incomplete data sets.

[94] Land cover within Cache Creek Settling Basin was not included in acreage-based methylmercury loading for the Delta MeHg TMDL Boundary because loading from Cache Creek Settling Basin is quantified in Section 6.2.1.3.

Task 3 of the 2008 CALFED Mercury Project Final Report found that variation in atmospheric deposition is highly dependent on monthly precipitation trends (Gill 2008a). Concentrations are significantly higher in rainfall in the summer, which could be because of an atmospheric "first flush" effect and smaller sample volumes. In the Central Valley, wet deposition dominates in the winter months and dry deposition dominates in the summer months, but overall deposition remains relatively constant throughout the year. Board staff recommends monitoring be conducted to improve and refine models for dry and wet atmospheric deposition of mercury and methylmercury in the Delta.

Table 6.29: Annual Methylmercury Loading from Wet Deposition

Delta TMDL Subarea	Direct precipitation Volume (ac-ft/yr)	Indirect Precipitation Volume (ac-ft/yr)	Direct MeHg Load (g/yr)	Indirect MeHg Load (g/yr)	Total MeHg Load (g/yr)
Central Delta	422,060.757	78,655.906	46.073	8.586	54.660
Marsh Creek	197.670	7,296.351	0.022	0.796	0.818
Mokelumne/Cosumnes Rivers	3,367.865	8,415.191	0.368	0.919	1.286
Sacramento River	163,176.100	47,208.678	17.813	5.153	22.966
San Joaquin River	56,059.546	31,753.877	6.120	3.466	9.586
West Delta	207,766.215	29,332.788	22.680	3.202	25.882
Yolo Bypass - North (excludes CCSB)	22,743.850	33,057.481	2.483	3.609	6.091
Yolo Bypass - South	98,682.759	78,365.582	10.773	8.555	19.327
Total	**974,054.761**	**314,085.854**	**106.331**	**34.287**	**140.617**

6.2.8 Other Potential Sources

6.2.8.1 Floodplain Flux

The 2010 TMDL Staff Report did not account for methylmercury flux from floodplains when they are inundated, for example the Yolo Bypass. For the DMCP Review, Board staff expects that this is accounted for in other source estimations like agriculture, wetland, and atmospheric deposition. Indirect precipitation and atmospheric deposition were calculated for all land use types in the Delta MeHg TMDL Boundary. Riparian vegetation was assigned the land cover of native vegetation and may include stream banks above the ordinary high-water mark that are inundated during floods (Appendix D). The tidal wetland load calculation estimated the contributing area of sediment flux, the area that is wetted and dried as the tide moves in and out. Board staff expects changes to floodplain acreages in the Delta as current and future projects in the Delta are expected to create more floodplain and wetland habitat.

6.2.8.2 Agricultural Areas in Yolo Bypass - North

As described in Section 6.2.5.3, the flow data used to calculate methylmercury loading from farmed Delta islands do not include the Yolo Bypass north of the Legal Delta Boundary or other upland agricultural areas in the Delta MeHg TMDL Boundary. However, loading was multiplied by the percentage of all agricultural land acreage in each Delta TMDL subarea to estimate a subarea specific load (Table 6.21). This methodology is consistent with the 2010 TMDL Staff Report.

The 2010 TMDL Staff Report only included runoff loading from farmed Delta islands during the active irrigation season. The DMCP Review also included runoff loading outside of the active irrigation season because of the use of wet weather flow and methylmercury data. Both the 2010 TMDL Staff Report and DMCP Review included indirect atmospheric deposition of methylmercury over agricultural lands within the Delta MeHg TMDL Boundary.

6.2.8.3 Runoff from Rangeland & Other Open Space Land Covers

Since the 2010 TMDL Staff Report was written, there has not been additional data available for storm water runoff from rangeland and other upland areas such as open recreation beyond what is included in urban, wetland, open water, and agricultural load estimates. Rangeland, a subcategory of open space, consists of mostly natural-state grasses or shrubs and was included in native vegetation land cover in the DMCP Review (Appendix D). Native vegetation comprises approximately 12% of the land cover within the Delta MeHg TMDL Boundary. Some areas observed as open recreation in the DMCP Review appeared to be non-irrigated public parks and comprise only 0.14% of all land cover within the Delta MeHg TMDL Boundary.

For the DMCP Review, Board staff retained the assumptions from the 2010 TMDL Staff Report that these lands are not expected to contribute substantially more methylmercury loading than what is in storm water runoff calculated by indirect atmospheric deposition (Section 6.2.7). Board staff recommends methylmercury loading estimates from rangeland and other upland areas be incorporated into future upstream control programs.

6.3 Methylmercury Losses

This section illustrates the loss pathways, describes the available methylmercury concentration and flow data, and identifies data gaps and uncertainties associated with the loss estimates. Table 6.30 lists the estimated average annual loads associated with the losses for the WYs 2000-2019 period, a representative period of wet and dry conditions that encompasses the available concentration data for the major Delta inputs and exports. Table 6.31 summarizes the methylmercury data for each of the Delta's major water exports. Figure 6.15 shows the relative losses calculated in the 2010 TMDL Staff Report and DMCP Review.

The 2010 TMDL Staff Report identified the following methylmercury loss pathways from the Delta: outflow to San Francisco Bay, south of Delta exports, export via dredging, and other potential loss pathways such as photodegradation and particle settling. Noteworthy changes include the following:

- The DMCP Review separately considered loading from tidal and non-tidal wetlands, concluding that tidal wetlands are likely a net methylmercury loss, whereas the 2010 TMDL Staff Report only used one flux rate for all wetlands. Both the DMCP Review and 2010 TMDL Staff Report found all wetlands to be an overall methylmercury source.
- The DMCP Review quantified dredging loss in water and sediment, whereas the 2010 TMDL Staff Report only quantified dredging loss in sediment.
- The DMCP Review quantified losses from particle settling and photodegradation, whereas the 2010 TMDL Staff Report assumed these losses were equal to the difference between quantified sources and losses.

There are multiple available methods to measure various methylmercury loss pathways in the Delta. Similar to the sources (Section 6), methylmercury losses in the Delta were measured in various ways depending on the loss pathway and land use type. The DMCP Review used whole-ecosystem monitoring to estimate losses for particle settling (Section 6.3.2) and tidal wetlands (Section 6.3.6), and relied on models to estimate flows for outflows to San Francisco Bay (Section 6.3.1) and south of Delta exports (Section 6.3.4).

Table 6.30: Methylmercury Loads Lost from the Delta for WYs 2000-2019

Loss	Type	Estimated Annual Load Lost (g/yr)	Estimated Annual Load Lost (%)
Outflow to San Francisco Bay (X2)	Export	1,121.370	30.66%
Particle Settling & Accumulation in Biota	Within-Delta	1,087.000	29.72%
Photodegradation	Within-Delta	924.059	25.26%
Delta Mendota Canal	Export	220.024	6.02%
California Aqueduct	Export	174.947	4.78%
Dredging	Within-Delta	66.545	1.82%
Tidal Wetlands	Within-Delta	60.533	1.65%
Cache Creek Settling Basin	Within-Delta	3.415	0.09%
Total MeHg Losses:		**3,657.893 g/yr**	**100.00%**

Table 6.31: Methylmercury Concentrations for the Delta's Major Water Exports

Site	Number of Samples	Min. MeHg Conc. (ng/L)[95]	Ave. MeHg Conc. (ng/L)	Annual Ave. Conc. (ng/L)	Median MeHg Conc. (ng/L)	Max. MeHg Conc. (ng/L)
Delta Mendota Canal	65	ND	0.092	0.090	0.079	0.515
California Aqueduct	42	ND	0.075	0.074	0.059	0.178
Outflow to San Francisco Bay (X2)	129	ND	0.099	0.097	0.079	0.417

[95] ND: Non-detect, below MDL. Analytical MDLs were 0.0234 ng/L or less. Board staff developed a script to estimate ND values based on data distribution to calculate methylmercury concentration and load statistics.

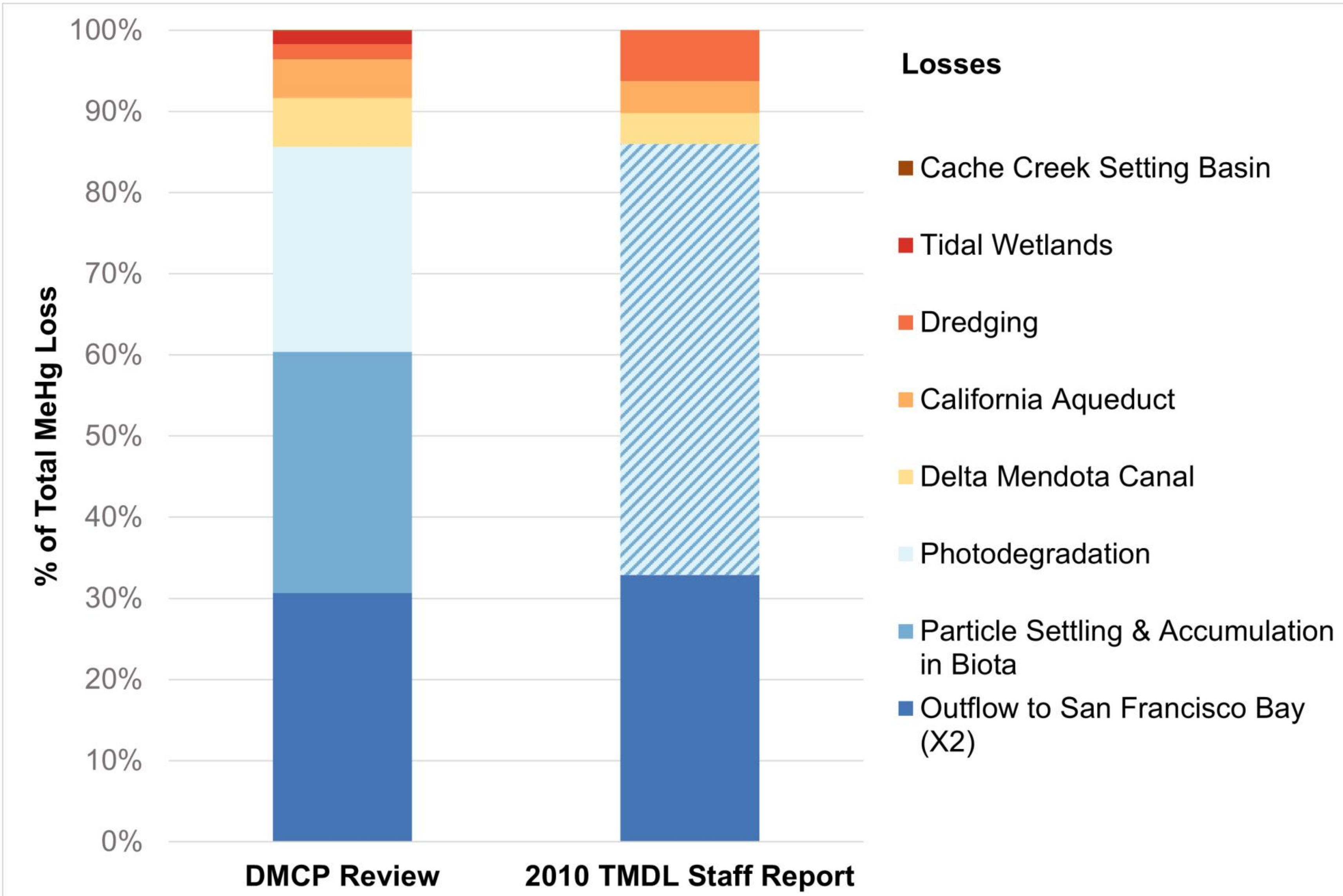

Figure 6.15: Percentage of Methylmercury Loss Exports for the DMCP Review and 2010 TMDL Staff Report

6.3.1 Outflow to San Francisco Bay

Consistent with the 2010 TMDL Staff Report, outflow to the San Francisco Bay is the primary way that methylmercury is lost from the Delta. For the DMCP Review, methylmercury in the Delta outflow to San Francisco was evaluated using aqueous unfiltered samples collected at X2 and Mallard Island. X2 is the location in the Bay-Delta Estuary with two parts per thousand 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. Mallard Island is the mercury compliance boundary between San Francisco Bay Regional Board and Central Valley Regional Board. Board staff selected these monitoring locations from the compiled aqueous data (Appendix A.2) based on geographic location. Board staff excluded data from the Mallard Slough station because it is located in the channel on the south site of Mallard Island and has limited flow compared to the X2 and Mallard Island stations.

Daily Delta outflow flow rates were obtained from DWR's Dayflow model (https://data.cnra.ca.gov/dataset/dayflow). The methylmercury data used for the DMCP Review are from the 2010 TMDL Staff Report, years 1999 through 2001 and 2003; Task 2 of the 2008 CALFED Mercury Project Final Report, years 2005 through 2006; and Delta RMP, years 2018 through 2019 (see Appendix A.2 for data used in this analysis). Figure 6.16 and Figure 6.17 show trends in methylmercury concentration by water year and month, respectively. Figure 6.18 and Figure 6.19 show trends in flow data by water year and month, respectively.

Board staff maintained consistency with the methods used in the 2010 TMDL Staff Report to calculate methylmercury loss to San Francisco Bay, except with the use of medians instead of averages. Methylmercury concentration data were pooled by month to calculate monthly median concentrations. Monthly median concentrations were multiplied by monthly median flow volumes for WYs 2000-2019 to estimate monthly loads and summed to calculate an annual methylmercury load of approximately 1,121 g/yr. This accounts for about 31% of identified Delta methylmercury losses.

Methylmercury transport from the Delta to San Francisco Bay can be both advective, from water flowing downstream, and dispersive, from tidal flux. This calculated loss only accounts for advective export to San Francisco Bay. However, Task 2 of the 2008 CALFED Mercury Project Final Report found "dispersive methyl mercury flux is negligible on an annual basis at Mallard Island and that export loads can be estimated for the Delta by only calculating an advective term" (Foe *et al.* 2008). Task 2 of the 2008 CALFED Mercury Project Final Report recommends that further studies are needed to determine how the seasonality of methylmercury gradients near Mallard Island may result in dispersive flux (Foe *et al.* 2008).

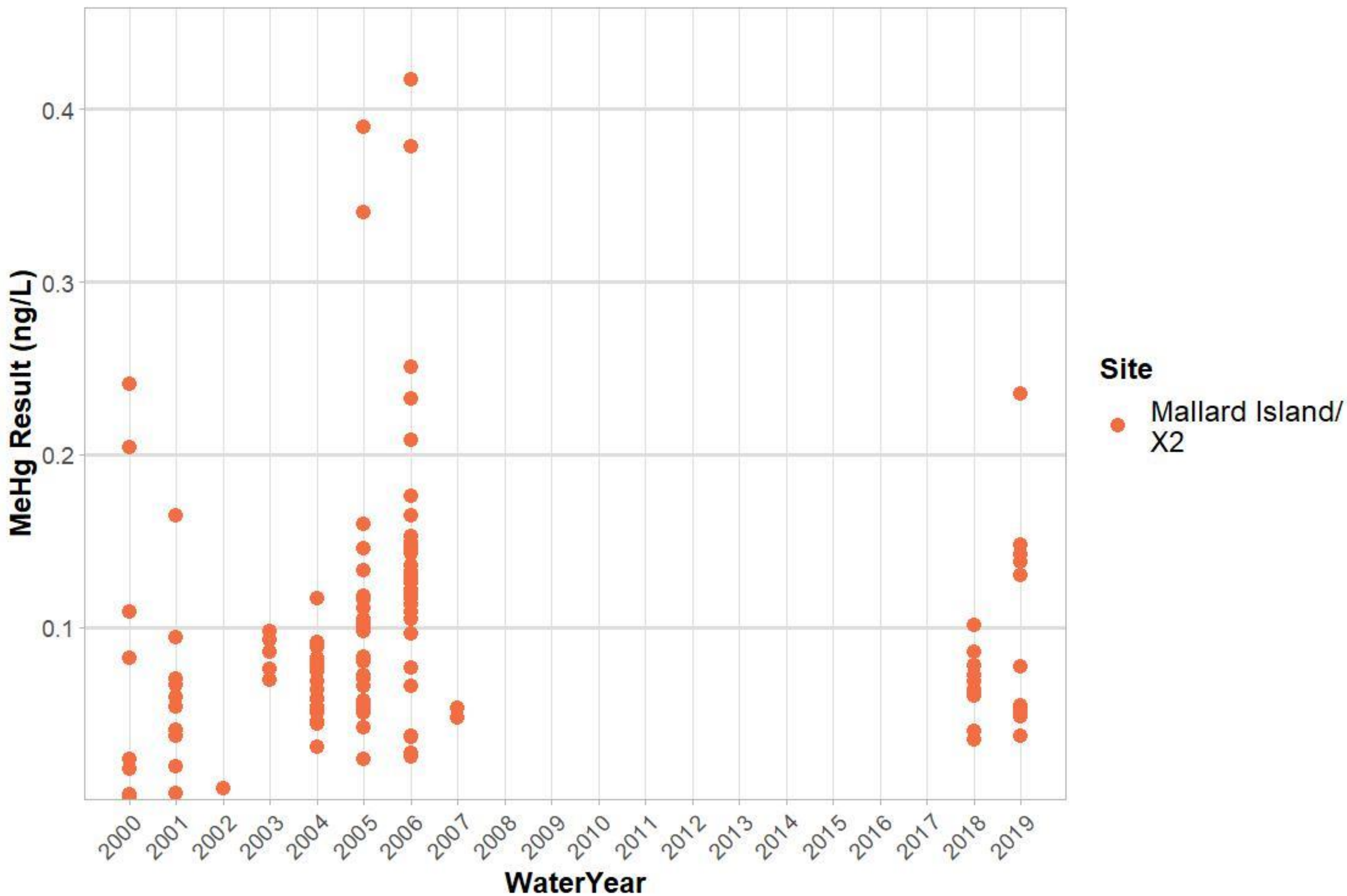

Figure 6.16: Methylmercury Data Used for Outflow to San Francisco Bay, by Water Year

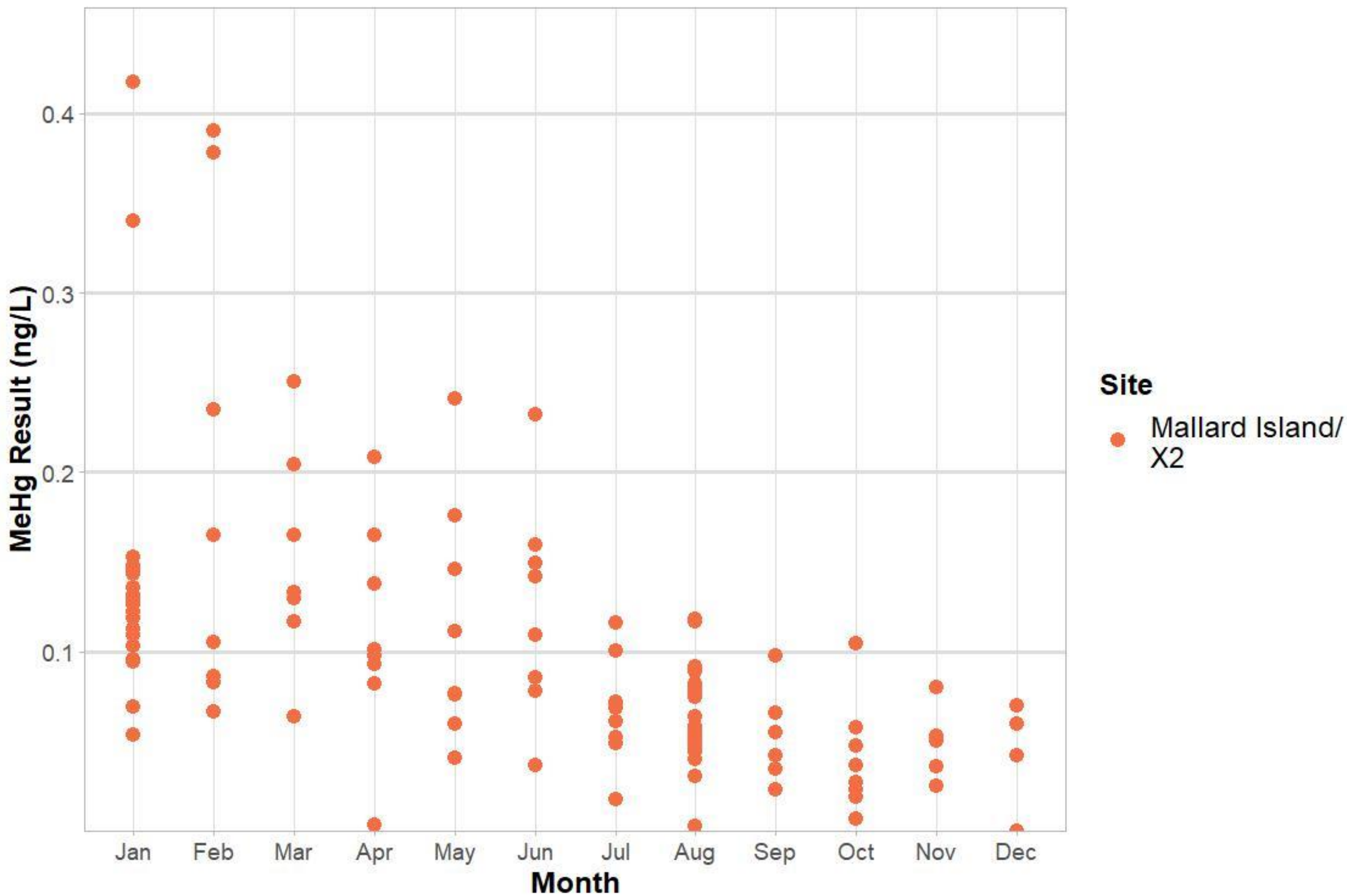

Figure 6.17: Methylmercury Data Used for Outflow to San Francisco Bay, by Month

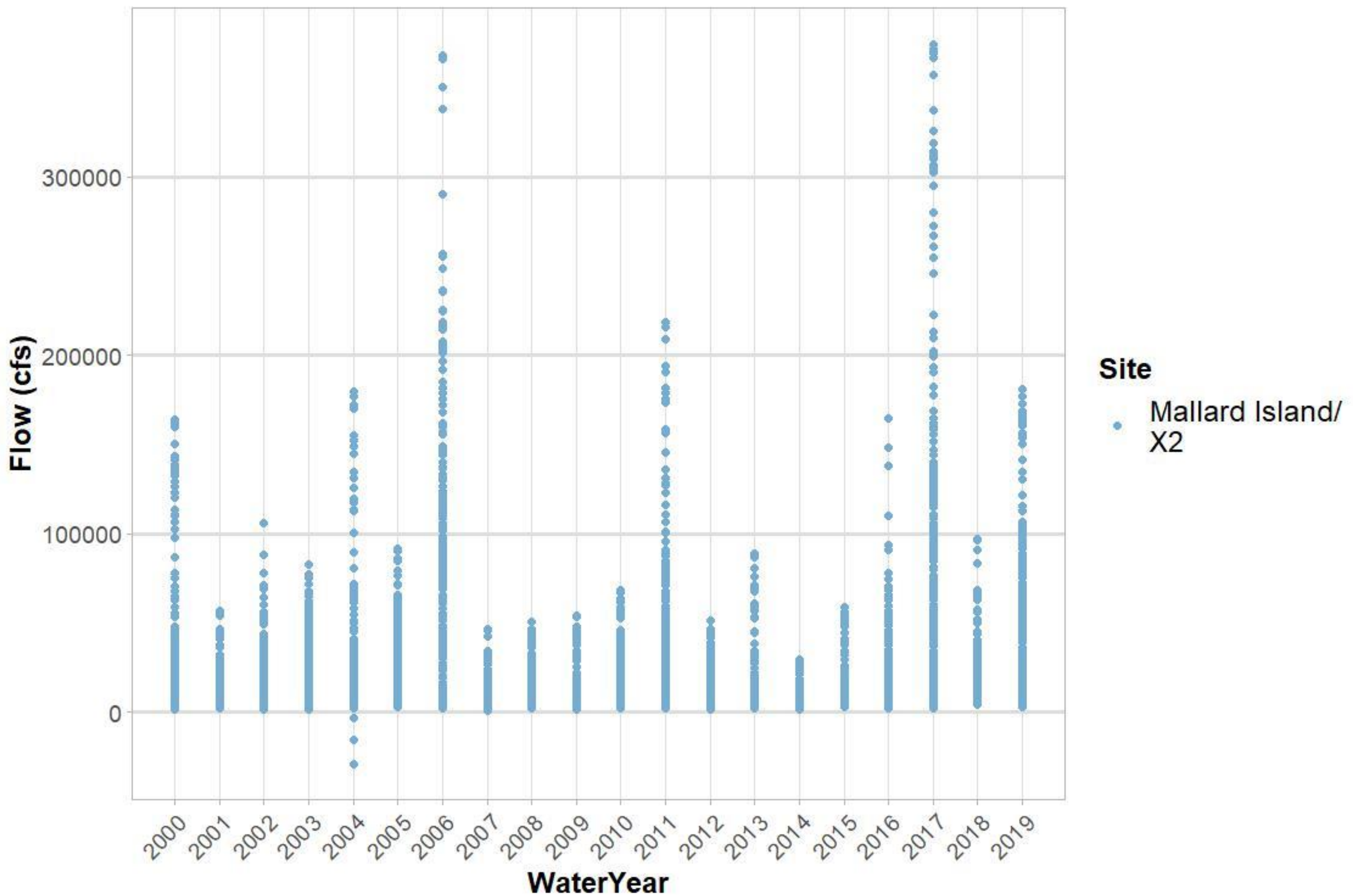

Figure 6.18: Flow Data Used for Outflow to San Francisco Bay, by Water Year

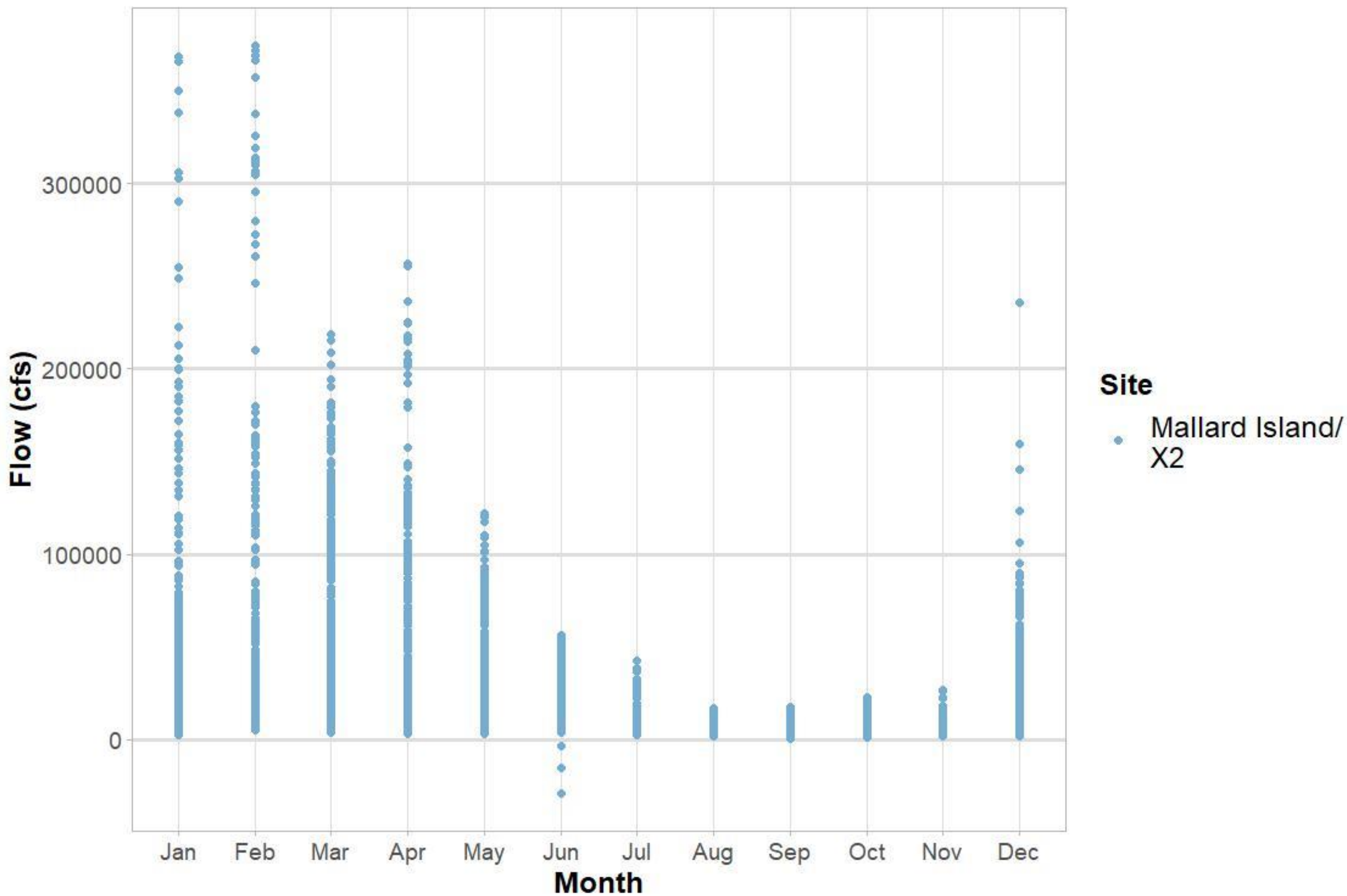

Figure 6.19: Flow Data Used for Outflow to San Francisco Bay, by Month

6.3.2 Particle Settling & Uptake by Biota

Board staff used data from Task 5.3a of the 2008 CALFED Mercury Project Final Report to estimate how much methylmercury is lost from particle settling in the Delta (Stephenson *et al.* 2008). Particulate fraction methylmercury losses were calculated with Equation 6.4 and assumed to be the difference of particulate loads between major sources to and exports from the Delta.

Equation 6.4: Particulate Methylmercury Load (Stephenson *et al.* 2008)

$$Particulate\ MeHg\ Load\ = Aqueous\ MeHg\ Load \times \left(1 - \left(\frac{fMeHg}{uMeHg}\right)\right)$$

Where:

fMeHg = Average filtered aqueous methylmercury concentration
uMeHg = Average unfiltered aqueous methylmercury concentration

Samples for sources were collected at Freeport, Vernalis, and Prospect Slough. Samples for exports were collected at Mallard Island, Delta Mendota Canal, and California Aqueduct. Net methylmercury losses were calculated on a monthly basis for years 2000 through 2006, which represent wet and dry conditions. Task 5.3a of the 2008 CALFED Mercury Project Final Report estimated methylmercury loss from particle settling to be 4.9 g/day or 1,788.5 g/yr (Stephenson *et al.* 2008). This estimate was the average of daily methylmercury particulate settling rates for all available months.

Rates from particle settling and flow are positively correlated, meaning particle settling and the proportion of incoming particle loads that are settled increase as flow increases (Stephenson *et al.* 2008). Flow and particle settling rates in Delta channels vary with the weather and water management practices, so to maintain this variation in the loss calculation, Board staff took the median of each month’s particle settling rates and summed these rates to get an annual methylmercury loss of 1,087 g/yr (Table 6.32).

It should also be noted that this estimate covers the area of the Delta between 2008 CALFED Mercury Project Final Report’s source and export sites. Board staff acknowledges this may be an overestimate of methylmercury settling loss because settling should be inherently included in load estimations for wetlands and agricultural lands in the Delta.

Stephenson *et al.* (2008) hypothesized that part of their measurements of particulate methylmercury loss account for biota uptake. During times of low flow, a higher proportion of particulate methylmercury than sediment is lost in Delta waterways. During times of high flow, a higher proportion of sediment than particulate methylmercury is lost in Delta waterways. It may be that under low flow most particulate methylmercury is adsorbed up by phytoplankton and then consumed by filter feeding organisms, while under high flow mostly larger sediment particles are transported and settled that have less attached methylmercury compared to smaller particles. Based on this, Board staff assumes that the estimation of methylmercury loss due to particle settling also includes an element of biotic uptake.

Most of the mercury that accumulates in biota is methylmercury. Ackerman and Eagles-Smith (2010) estimate that methylmercury accounts for 94.3% of the total mercury in fish. However, there is no singular rate of methylmercury uptake or accumulation in biota for the Delta. Each exposure is unique, and the rate depends on many factors including location, habitat type, food availability, initial aqueous concentration, and biota species, diet, growth rate, age, size, and residence time. Even data collected the same year at the Yolo Bypass Wildlife Area show conflicting results of bioaccumulation rates relative to species and habitat type (Ackerman and Eagles-Smith 2010; Ackerman *et al.* 2010). Another study found that mercury concentrations in fish were correlated with aqueous methylmercury, but mercury concentrations in invertebrates were correlated with sediment methylmercury (Windham-Myers *et al.* 2010). Therefore, a specific rate of methylmercury transfer to or accumulation in biota was not estimated for this update. Board staff expects that this loss pathway is only unaccounted for open water regions within the Delta MeHg TMDL Boundary (Section 6.2.2). Other assessed sources should inherently account for all processes, like biota uptake, in between methylmercury load source and export.

Stephenson *et al.* (2008) suggest using sediment trapping as a method to control methylmercury in the Delta.

Table 6.32: Estimated Annual Particulate Methylmercury Loss via Settling

Month	Median Settling Rate (g)
January	216
February	68
March	246
April	80
May	129
June	57
July	52
August	48
September	30
October	49
November	51
December	62
Total (g/yr)	**1,087**
Rate (g/day)	**2.978**

6.3.3 Photodegradation

Photodegradation is the degradation of methylmercury, the most bioavailable and toxic form of mercury, to inorganic mercury by light and is likely a major loss pathway for methylmercury in the Delta. Photodegradation reduces concentrations of methylmercury into inorganic divalent mercury or elemental mercury (Windham Myers *et al.* 2010). Once mercury is in its elemental state, either through photodegradation directly to elemental mercury or photodegradation to inorganic divalent mercury followed by reduction, it can volatize to the atmosphere (Gill 2008c).

Board staff used the rates provided in Table 5 of the 2008 CALFED Mercury Project Final Report Task 5.1 (Gill 2008c) because the data were collected from a variety of locations and conditions in the Delta open water, and rates were presented as total losses for each month. The rates were calculated using the following measurements:

1. Secchi disk depths from six locations in the Delta, data from CEDEN for years 2000 through 2005.
2. Average daily light exposure for the Delta, surface photosynthetically available radiation data from field measurements and University of California, Davis Climate Station (United States Department of Agriculture UV-B Monitoring and Research Program) for years 2004 through 2005.
3. Methylmercury concentrations from the 2010 TMDL Staff Report.

Updating the rates with newer data may make the loss estimation more accurate, but this was deemed not within the scope of the DMCP Review.

Equation 6.5: Methylmercury Loss from Photodegradation in the Delta

$$P = k \times d \times a \times m \times 10^3 \times 10^{-9}$$

Where:

P = loss of methylmercury from photodegradation (g/month)
k = photodegradation rate (ng/L/day)
d = 1% light level (m)
a = area of open water within the Delta MeHg TMDL Boundary (m^2)
m = days in each month
10^3 = conversion factor of cubic meters to liters (L/m^3)
10^{-9} = conversion factor of nanogram to gram (g/ng)

To estimate monthly methylmercury loss from photodegradation, Board staff adapted Equation 6.5 and used monthly photodegradation rates and 1% light levels from Task 5.1 of the 2008 CALFED Mercury Project Final Report. Resultant losses were added for all months to get an annual total loss for the Delta. The DMCP Review estimated that photodegradation results in a methylmercury loss of approximately 924 g/yr in Delta open waters[96] (Table 6.33).

Board staff only applied this rate to open water area within the Delta MeHg TMDL Boundary because open water was the only area for which benthic flux chambers were used to estimate loading (Section 6.2.2). This method of estimation measures gross sediment flux, and thus does not account for loss pathways such as photodegradation. In contrast, the whole-ecosystem monitoring method used for other land cover types inherently accounts for production and loss pathways in situ. Furthermore, it would be difficult to incorporate shading from vegetation or other obstructions into a rate beyond open water (Windham Myers *et al.* 2010).

While the DMCP Review used medians for the analysis of sources and losses, it should be noted that Task 5.1 of the 2008 CALFED Mercury Project Final Report used averages in calculating photodegradation rates. Board staff does not anticipate this to considerably impact the resultant rates, compared to if medians were used, because datasets for light exposure and depth are not expected to be as skewed as methylmercury and flow data.

Task 5.1 of the 2008 CALFED Mercury Project Final Report found that photodegradation rates were positively correlated with light exposure and initial methylmercury concentration (Gill 2008c). Board staff does not anticipate that the annual methylmercury loss would substantially change if current ambient methylmercury concentrations were incorporated into the photodegradation rate determination, variable k in Equation 6.5. However, if concentrations change significantly in the future, this may impact photodegradation rates.

Overall, photodegradation is an abiotic process and rates do not differ between filtered and unfiltered samples (Gill 2008c). Therefore, Board staff does not anticipate microbial demethylation to be a considerable loss pathway in Delta open waters.

[96] Excludes open water areas in the Cache Creek Settling Basin.

Table 6.33: Estimated Methylmercury Loss from Photodegradation in Delta Open Waters

Delta TMDL Subarea	Open Water Area (ac)	Open Water Area (%)	Open Water Area (m^2)	Warm Season MeHg Daily Load (g/day)	Cool Season MeHg Daily Load (g/day)	Annual MeHg Load (g/yr)
Central Delta	25,772.332	43.78%	104,300,627.305	1.302	0.834	404.514
Marsh Creek	12.075	0.02%	48,868.037	0.001	0.000	0.190
Mokelumne/ Cosumnes Rivers	204.952	0.35%	829,442.070	0.010	0.007	3.217
Sacramento River	9,746.444	16.55%	39,443,859.518	0.492	0.315	152.977
San Joaquin River	3,425.668	5.82%	13,863,678.163	0.173	0.111	53.768
West Delta	12,505.682	21.24%	50,610,494.486	0.632	0.405	196.285
Yolo Bypass - North (excludes CCSB)	1,349.783	2.29%	5,462,573.343	0.068	0.044	21.186
Yolo Bypass - South	5,856.544	9.95%	23,701,431.831	0.296	0.190	91.922
Total	**58,873.480**	**100.00%**	**238,260,974.752**	**2.973**	**1.906**	**924.059**

6.3.4 South of Delta Exports

Since the 2010 TMDL Staff Report, there has been limited mercury monitoring in water exported to southern California through the CVP via the Delta Mendota Canal and SWP via the California Aqueduct. In 2018 and 2019, the Delta RMP monitored for methylmercury at the Delta Mendota Canal. To calculate the amount of methylmercury exported to southern California, Board staff used the Delta RMP data in combination with available monitoring data collected at the Delta Mendota Canal and California Aqueduct export sites.[97] Board staff obtained the volume of water exported by the Delta Mendota Canal and California Aqueduct from the Dayflow model, as was done in the 2010 TMDL Staff Report (see Appendix A.2 for data used in this analysis). Figure 6.20 and Figure 6.21 show trends in methylmercury concentration by water year and month, respectively. Figure 6.22 and Figure 6.23 show trends in flow data by water year and month, respectively.

Consistent with the 2010 TMDL Staff Report, Board staff regressed daily methylmercury concentrations against corresponding flow rates to determine whether concentrations could be predicted from flow. Neither the Delta Mendota Canal nor the California Aqueduct had significant regression results, therefore loads were calculated by multiplying median concentrations and water volumes. Board staff calculated the median of all methylmercury data for Delta Mendota Canal and California Aqueduct to be 0.079 and 0.059 ng/L, respectively. These estimates are similar to those in the 2010 TMDL Staff Report and Task 2 of the 2008 CALFED Mercury Project Final Report methylmercury mass balance (Foe *et al.* 2008). The median of total annual flow volumes for WYs 2000-2019 were multiplied by the median methylmercury concentrations to get a total annual load for each export site. This resulted in a loss of 220.024 and 174.947 grams of methylmercury per year from the Delta Mendota Canal and California Aqueduct, respectively. In total, an estimate of 394.972 grams of methylmercury are lost per year from exports to southern California.

[97] Appendix A.2 provides references and details on the data used, samples were collected at the same locations as those used in the 2010 TMDL Staff Report.

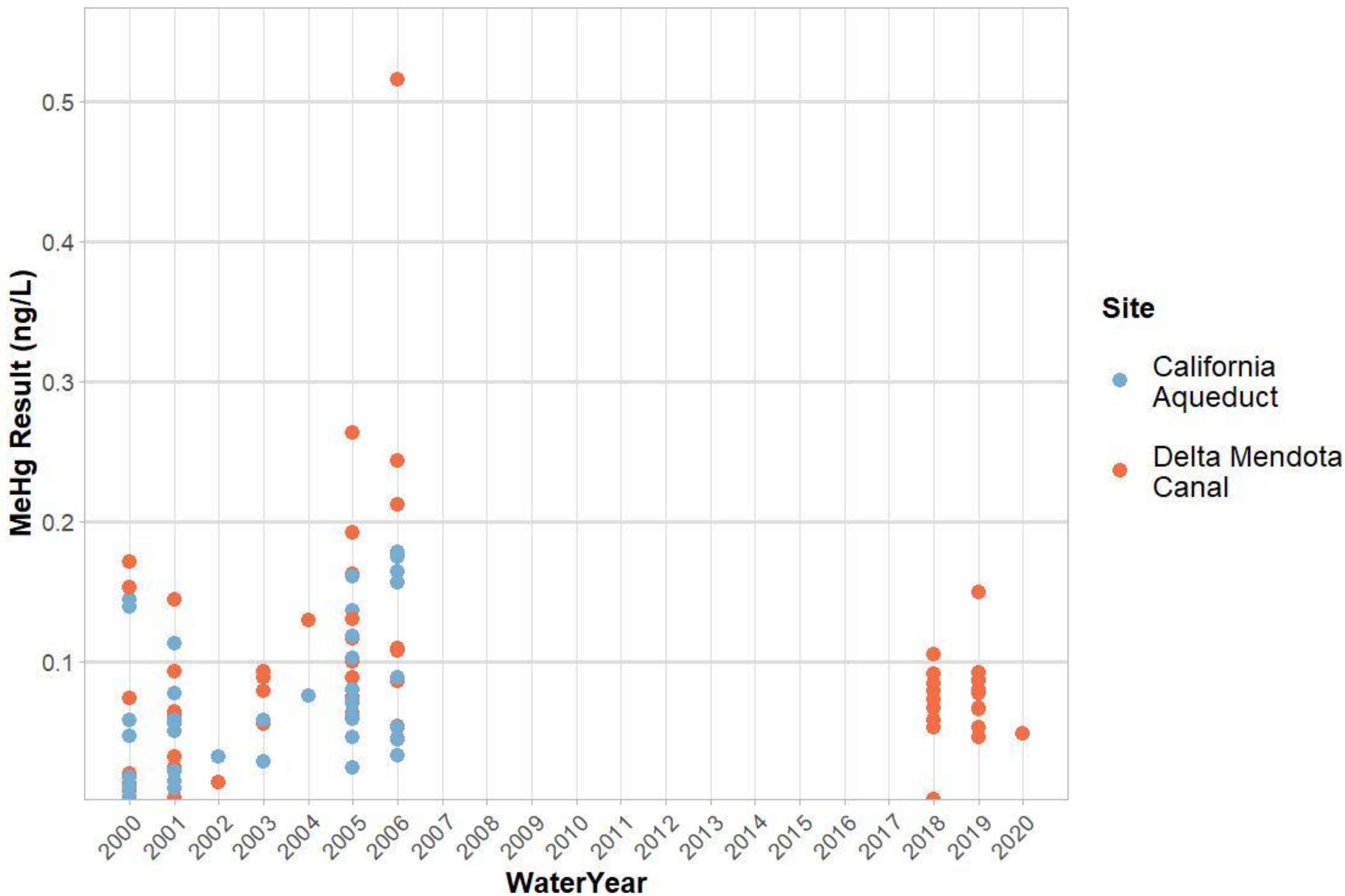

Figure 6.20: Methylmercury Data Used for South of Delta Exports, by Water Year

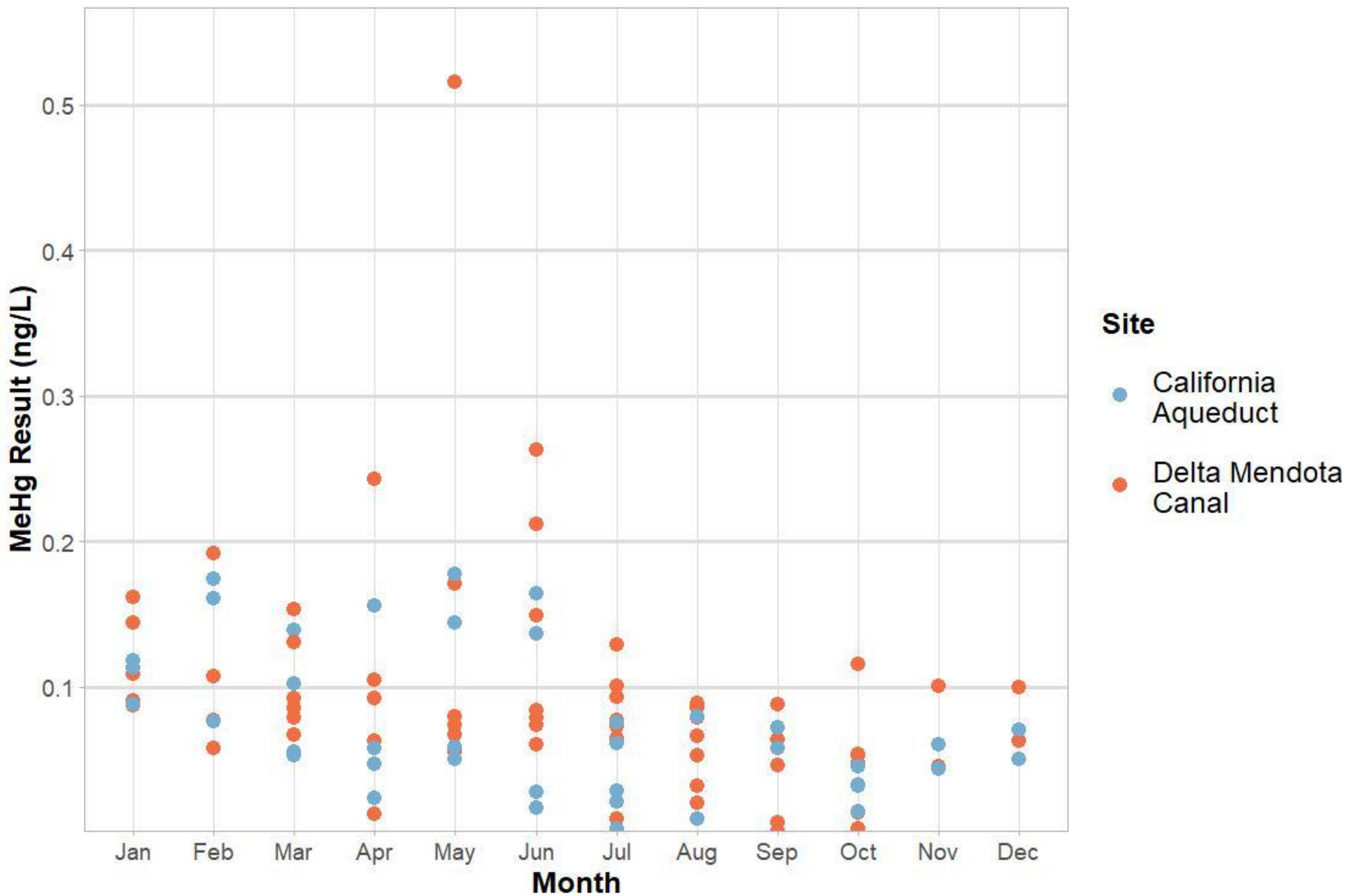

Figure 6.21: Methylmercury Data Used for South of Delta Exports, by Month

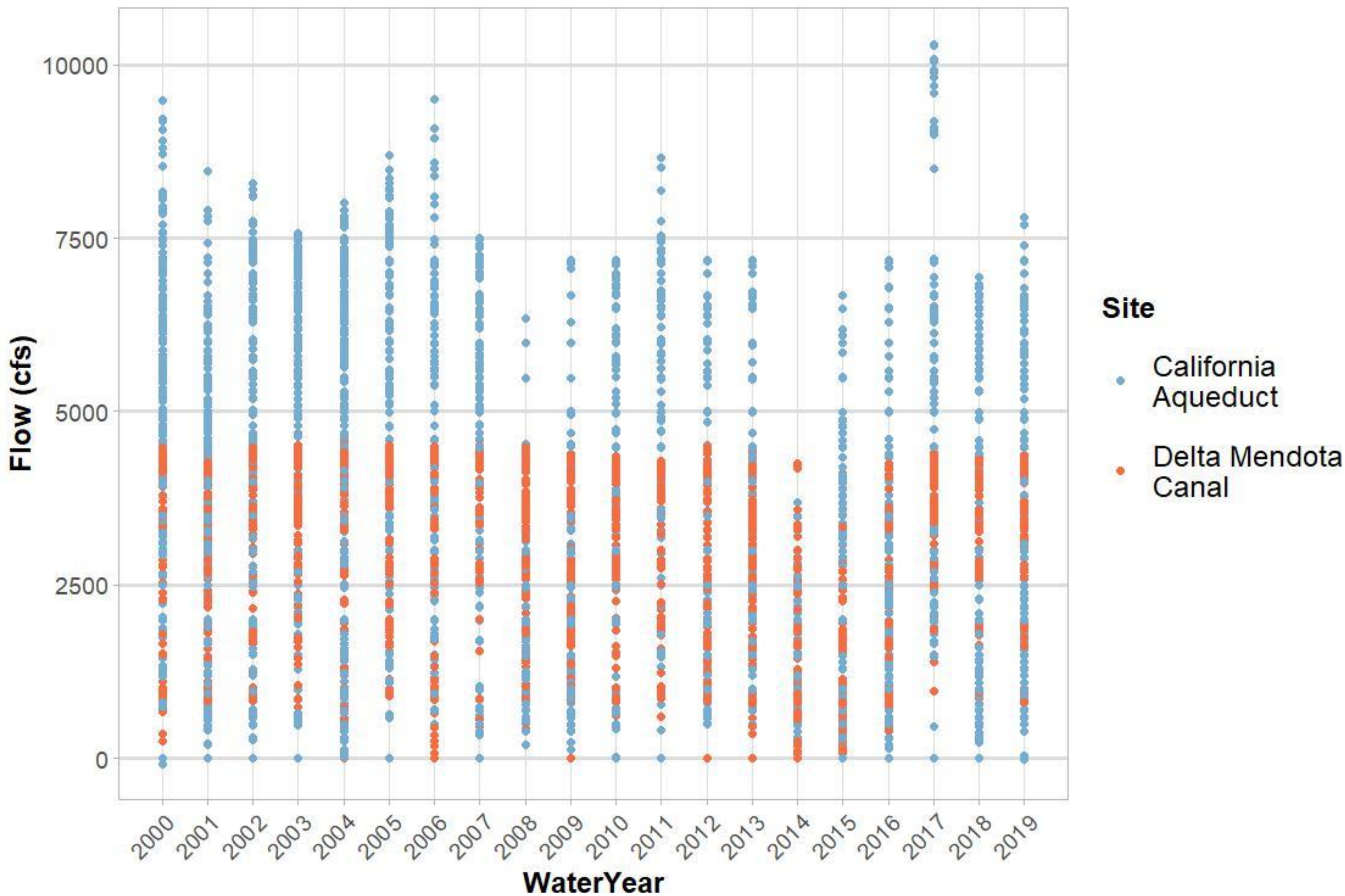

Figure 6.22: Flow Data Used for South of Delta Exports, by Water Year

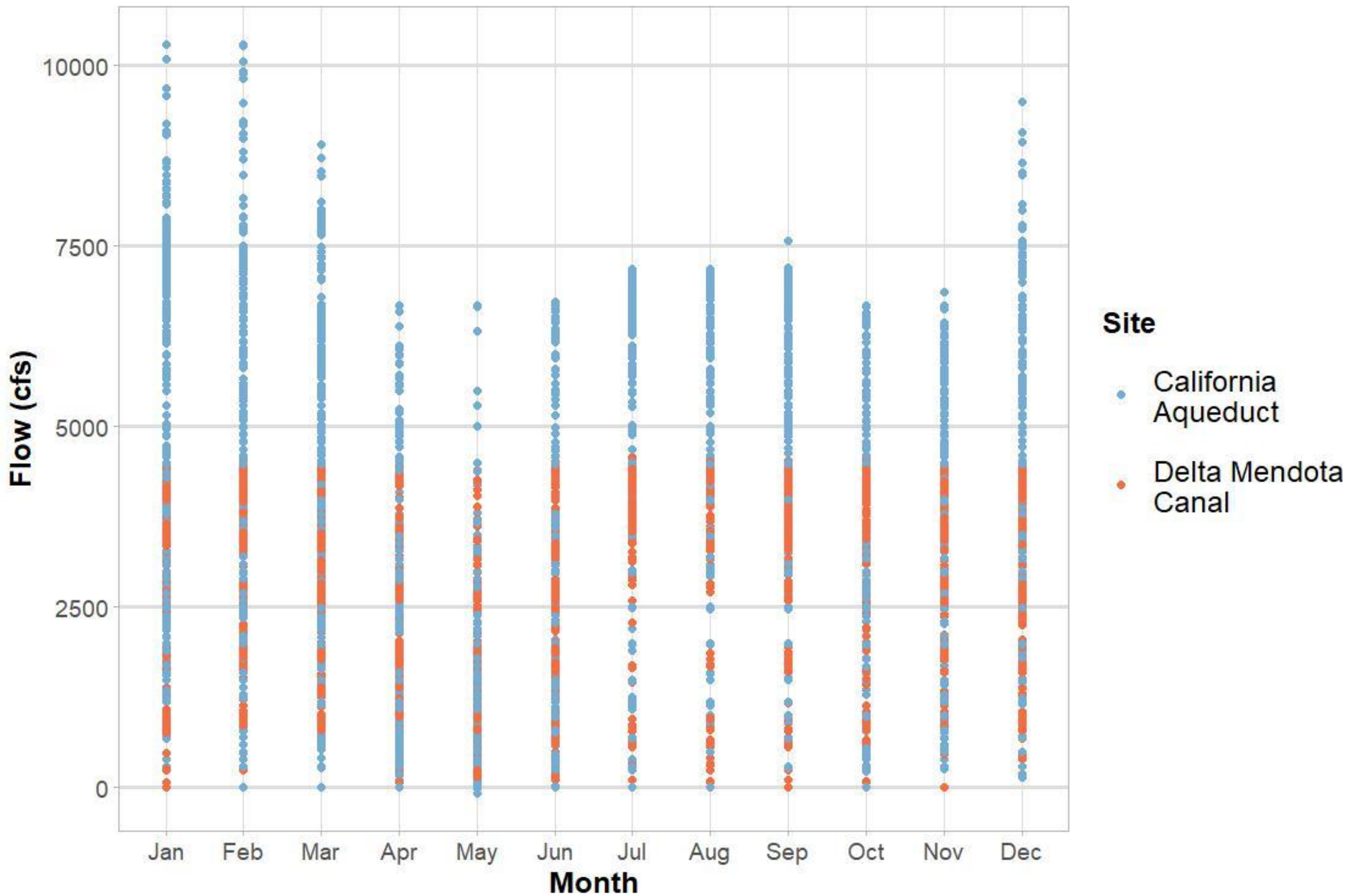

Figure 6.23: Flow Data Used for South of Delta Exports, by Month

6.3.5 Dredging

Dredging activities occur annually on an as-needed basis in the Delta to maintain channel depth and remove problematic sediment buildup. Dredge material is typically removed from channel bottoms by suction pumping but may also be removed by clamshell excavators. The material is placed in disposal ponds on Delta islands, upland areas, or other approved locations like wetland restoration sites and the Antioch Dunes National Wildlife Refuge. After placement of dredge material in DMPSs, the water will either be held to infiltrated into the ground or discharged through return flows.

At the time the DMCP was developed, no methylmercury data were available to assess concentrations in return flows from DMPSs within the Delta MeHg TMDL Boundary (Figure 6.24). The finalized 2010 TMDL Staff Report included data from methylmercury monitoring at five DMPSs in the Delta in 2008, which were conducted after first draft release of the DMCP report. The monitoring results indicated (1) return flows from the DMPSs had higher average and median methylmercury concentrations than concentrations measured in receiving waters, and (2) methylmercury concentrations within the DMPSs increased above inflow levels. These results suggested that methylmercury is produced in DMPSs and discharges from the DMPSs were a source of methylmercury within the Delta.

Similar to the 2010 TMDL Staff Report, methylmercury data have not been gathered on dredged material removed from within the Delta MeHg TMDL Boundary. However, aqueous methylmercury concentration data have been gathered upstream and downstream of dredging activities and within DMPSs. Additionally, total mercury samples in DWSCs sediment prior to dredging activities are available. To estimate methylmercury removed from dredging activities, Board staff used the aqueous methylmercury concentrations of source water and estimated mass of methylmercury in the sediment. Consistent with the 2010 TMDL Staff Report, methylmercury mass in sediment was calculated using a ratio of methylmercury to total mercury. The 2010 TMDL Staff Report (Section 6.3.3) did not estimate the annual aqueous methylmercury mass removed from dredging. For this update, Board staff calculated the aqueous methylmercury mass removed by using the median aqueous methylmercury concentrations calculated in Section 5.2 and the annual volume of water removed by dredging.

During the first phase of the DMCP, Board staff worked with USACE staff and contractors to estimate volume of DMPS return flows, amount of methylmercury produced by DMPSs, and methylmercury loads discharged within the Delta MeHg TMDL Boundary. The DMCP required DWR, USACE, the Port of Sacramento, the Port of Stockton, and other State and federal agencies conducting dredging and excavation projects in the Delta MeHg TMDL Boundary to conduct characterization and control studies of dredging project effects on total mercury and methylmercury concentrations, export, load, and management practices. USACE submitted the Methylmercury Summary Report to complete control study requirements (USACE 2019). The Board staff summary on the USACE Methylmercury Summary Report can be found in Appendix E.13.

This section includes estimates for two types of dredging projects: (1) large scale suction dredging in the Sacramento and Stockton DWSCs conducted by USACE that occur annually at varying locations in the Delta; and (2) smaller scale dredging projects typically conducted by individual permittees that occur only once, as needed, to remove burdensome sediment in the Delta. Board staff estimated aqueous methylmercury and sediment-bound methylmercury masses from dredged slurry removal and DMPS discharges from both project types, described more in detail below.

6.3.5.1 USACE Deep Water Ship Channel Dredging Projects

In this section, Board staff analyzed annual aqueous methylmercury removed and discharged from DWSC dredging activities. Methylmercury loads within the Delta MeHg TMDL Boundary were calculated using aqueous methylmercury concentrations and estimated effluent volume data provided from the USACE Methylmercury Summary Report (USACE 2019), annual methylmercury summary reports, and via email (Meakes 2022). Data used in this analysis are listed in Appendix A.2. As seen in Figure 6.24, there are four Delta TMDL subareas that contain USACE DMPSs: Sacramento River, Yolo Bypass - South, West, and Central subareas. Board staff did not have data on USACE dredging activities in the Yolo Bypass - North, Mokelumne/Cosumnes Rivers, Marsh Creek, or San Joaquin River subareas, likely attributed to locations of DWSCs and DMPSs. Thus, methylmercury loads estimated in this section were only calculated for the four Delta TMDL subareas that contain USACE DMPSs. Typically, DMPSs located within the West and Central subareas receive dredged material from the Stockton DWSC and DMPSs located within the Yolo Bypass - South and Sacramento River subareas receive dredged material from the Sacramento DWSC.

6.3.5.1.1 Methylmercury Concentration

Aqueous Methylmercury Concentration Used to Estimate Mass Removed from the Delta from Deep Water Ship Channel Dredging Projects

Board staff used the median aqueous methylmercury concentration for each subarea calculated in Table 5.1 to represent ambient concentrations. Some methylmercury concentration data sampled upstream of dredging activities was available from USACE reports. Board staff decided not to use the USACE report data to estimate ambient concentrations since data were limited and location of upstream monitoring was highly variable, ranging anywhere from 200 to 2,000 feet upstream of dredging activities and exact locations were not consistently recorded.

Aqueous Methylmercury Concentration Used to Estimate Mass Discharged to the Delta from Deep Water Ship Channel Dredging Projects

For subareas that contain DMPSs, DMPS methylmercury concentrations were first grouped by DMP cell[98], if the site was separated into sectioned-off cells, to get the median concentration for that site's monitoring event. Then, concentrations were grouped for all monitoring events that occurred in that site for that year to get a median

[98] A DMP cell is an isolated area within the DMPS. Not all DMPSs have DMP cells.

concentration. Next, a median of the yearly concentrations for each site was calculated to get a representative concentration for that site. Lastly, a median of all DMPS median concentrations per Delta TMDL subarea was calculated, if applicable. This was used for the West and Central subareas, because multiple DMPSs are located within those subareas. Only one DMPS, S-31, was studied for the Yolo Bypass - South subarea. No DMPSs were studied within the Sacramento River subarea. Board staff assigned the Sacramento River subarea the median concentration for the Yolo Bypass - South subarea of 1.390 ng/L. Reasons for doing so include (1) the DMPSs in these subareas share the same source water from the Sacramento DWSC, and (2) the concentration is also the median concentration of all the calculated DMPSs median concentrations.

6.3.5.1.2 Flow

Water Volume Used to Estimate Methylmercury Mass Removed from the Delta from Deep Water Ship Channel Dredging Projects

Board staff estimated the amount of water removed by USACE dredging projects by assuming water is 90% of dredged slurry volume, which is the percentage used by USACE in the dredging control study (USACE 2019). USACE provided the estimated quantity of sediment dredged in each project from 2009 through 2020, where sediment was assumed to compose 10% of dredged slurry volume (Meakes 2022). The estimated quantity of water removed was totaled for each of the four Delta TMDL subareas where USACE dredging activities took place and divided by the number of years of data provided, 12 years, in order to estimate the amount of water removed by dredging projects per subarea for any given year (Table 6.34)[99]. The result was approximately 1,235 ac-ft of water removed by USACE dredging projects in both the Sacramento and Stockton DWSCs on an annual basis.

Water Volume Used to Estimate Methylmercury Mass Discharged to the Delta from Deep Water Ship Channel Dredging Projects

Board staff evaluated the USACE Methylmercury Summary Report equation used to estimate effluent discharge volume from DMPSs and found the equation relied on the following three variables for their estimate: (1) estimated volume of water in dredged slurry placed in the DMPS; (2) estimated volume capacity of the DMPS that is filled with slurry; and (3) estimated volume of water lost from evaporation and percolation (USACE 2019). Board staff did not use the USACE equation to estimate the amount of water discharged back to the Delta because variables in the equation were not accurate to estimate effluent discharge. For example, several USACE equation calculations resulted in a negative effluent water volume, indicating no discharge occurred despite dredging crews noting discharge had occurred. Also, some USACE equation results estimated that discharge volumes were greater than the amount of water placed in the DMPS.

[99] Not all Delta TMDL Subareas are dredged every year.

Equation 6.6: Dredged Material Placement Site Effluent Discharge Volume

$$W = \left[\left({}^{9s}/_{4840a}\right) - (d \times 0.138889)\right] \times 4840a$$

Where:

W = Estimated effluent water volume (cy)
s = Dredged sediment (cy)
4840 = Conversion factor from acre to square yards (yd^2/ac)
a = DMPS wetted surface area (ac)
d = Number of days water held at DMPS (7 or 14 days)
0.138889 = Rate of lateral evaporation percolation (yd/day)

Board staff created Equation 6.6 to estimate effluent discharge volume by:

- Using USACE reported quantity of dredged sediment in cubic yards
- Using USACE's dredge slurry ratio of 10% sediment
- Assuming DMPS acreages used in the USACE equation are areas wetted by dredged slurry
- Estimating the depth of each DMPS equals the volume of water placed divided by the wetted area
- Assuming a DMPS is a rectangular cuboid since the slope of each DMPS is unknown
- Using the USACE equation's evaporation and percolation rate of 0.5 inches (in) per day
- Using the USACE equation's estimate for the time dredge slurry is held prior to discharge is seven days at each DMPS except Roberts I, which holds water for 14 days (USACE 2019)

To estimate an annual effluent water volume for Delta TMDL subareas, Board staff calculated the average of estimated effluent water volumes from DMPSs for years 2009 to 2020. Board staff considered using the median to estimate effluent water volumes but were not considered representative. For example, DMPSs within the Sacramento River subarea only reported effluent discharge for two years. The 12-year median effluent volume in the Sacramento River subarea resulted in a 0, which was not representative of the years that discharge occurs. Taking the median of only the two years of estimated volume for the Sacramento River subarea grossly overestimated the amount of water discharged annually. Therefore, rather than using the median effluent volume for the Sacramento River subarea, Board staff used the 12-year average effluent volume, which resulted 36.206 ac-ft/yr.

USACE reported that no DMPS within the Yolo Bypass - South subarea discharged effluent water from 2009 to 2020, which resulted in a median and average effluent volume of 0 (Meakes 2022). Board staff assigned Sacramento River subarea's effluent volume of 36.206 ac-ft/yr to the Yolo Bypass - South subarea to account for any discharges in the subarea that may occur in the future.

To maintain consistency in methodology, Board staff also used the average to calculate annual effluent water volumes for the West and Central subareas, respectively 137.550 and 528.985 ac-ft/yr.

In all, Board staff calculated the approximate annual volume of water discharged from DMPSs in the four Delta TMDL subareas to be 739 ac-ft for USACE related projects.

6.3.5.1.3 Load

To estimate the annual aqueous methylmercury load from USACE DWSC dredging projects, Board staff subtracted the amount removed by dredging from the amount discharged from DMPSs.

To calculate the estimated mass of aqueous methylmercury removed annually by USACE related dredging projects in the four subareas, Board staff multiplied the median aqueous methylmercury concentration in each subarea calculated in Section 5.2 by the estimated amount of water removed per subarea. This resulted in the amount of aqueous methylmercury removed by USACE projects to be approximately 0.118 g/yr (Table 6.34).

Board staff calculated the aqueous methylmercury mass load for the West, Central, Yolo Bypass - South, and Sacramento River subareas by multiplying the median DMPS aqueous methylmercury concentration of each subarea by the 12-year annual average effluent discharge water volume. From this, the annual aqueous methylmercury load from USACE dredging activities in the DWSCs within the Delta MeHg TMDL Boundary is estimated to be 1.874 g/yr (Table 6.35).

Subtracting the estimated amount of aqueous methylmercury removed by dredging, 0.118 g/yr, from the estimated amount discharge from DMPSs, 1.874 g/yr, results in a load of 1.756 g/yr for USACE DWSC projects.

This suggests that methylmercury is being produced within DMPSs, and discharges from DMPSs are a source of aqueous methylmercury to the Delta. Board staff recommends strict implementation of control measures and best management practices at DMPSs, such as not discharging water from DMPSs or discharging water one to three days after placement. Studies summarized in the USACE Methylmercury Summary Report determined methylmercury concentrations increased after day three of placing water (USACE 2019). For more information on DMPS study conclusions, see the USACE Methylmercury Summary Report summary in Appendix E.13.

6.3.5.2 Smaller Dredging Projects

Smaller dredging projects occur within the Delta MeHg TMDL Boundary each year, as needed. The purpose of these projects may be to remove sediment build up from marinas or channels that are limiting the flow of water or depth needed for boat clearance. These projects are permitted through CWA Section 401 Certifications or Waste Discharge Requirements, or both, to remove a maximum amount of sediment from the project area over a five-year period. Some projects may remove less than the permit-allowed quantity of sediment from the project area in the work season over multiple years or all in one year's work season. Further, these projects may place their dredged slurry in a managed DMPS, temporarily constructed DMPS (lined or unlined), or in an impervious container that will be removed from the site at a later date. Thus, some projects may hold the slurry until turbid materials settle then discharge effluent water back into the Delta or other channel, or they may hold the water for evaporation, percolation, or disposal offsite.

A comprehensive list of recent smaller dredging project information needed to estimate methylmercury concentrations were unavailable at the time of the DMCP Review. This may be because smaller dredging projects have less monitoring and reporting requirements in issued permits.

6.3.5.2.1 Methylmercury Concentration

Aqueous Methylmercury Concentration Used to Estimate Mass Removed from the Delta from Smaller Dredging Projects

Board staff did not have aqueous methylmercury concentration data for waterways upstream of smaller dredging project activities. Since smaller dredging projects can occur anywhere in the Delta, Board staff determined that using the weighted median aqueous methylmercury concentration of the Delta of 0.079 ng/L from Table 5.1 was the most appropriate concentration to represent ambient waters.

Aqueous Methylmercury Concentration Used to Estimate Mass Discharged to the Delta from Smaller Dredging Projects

As mentioned above, Board staff had difficulties finding aqueous methylmercury concentrations for effluent volume returns from smaller dredging projects. Little information was known at the time of the DMCP Review on effluent discharge practices done by these smaller projects, thus Board staff assumed discharge practices are similar to the DWSC dredging projects and use DMPSs. Since smaller dredging projects occur anywhere in the Delta, Board staff used the median DMPS effluent concentration of all subareas, 1.390 ng/L, for the aqueous methylmercury concentration of discharges from smaller dredging project DMPSs.

6.3.5.2.2 Flow

Water Volume Used to Estimate Methylmercury Mass Removed from the Delta from Smaller Dredging Projects

To estimate the volume of water removed by smaller dredging projects, Board staff assumed the ratio of sediment to water in dredged slurry is the same ratio assumed for USACE DWSC projects, 10% sediment and 90% water. Board staff then used the estimated amount of 64,400 cubic yards of sediment removed annually from smaller projects from Section 6.3.3 of the 2010 TMDL Staff Report. Thus, estimated amount of water removed from smaller dredging projects annually is 579,600 cubic yards, or about 359 ac-ft.

Water Volume Used to Estimate Methylmercury Mass Discharged to the Delta from Smaller Dredging Projects

Because effluent discharge volumes, location, slurry holding protocol, and other details are unknown for the smaller dredging projects, Board staff assumed that small dredging project practices are similar to USACE dredging practices. These assumptions include the following: same percentages of sediment and water in slurry; water is held for similar amounts of time and within unlined DMPSs; and water is discharged back into the Delta after being held.

Board staff assessed the volumes of water removed and discharged by USACE DWSC projects to determine the percentage of water returned from DWSC dredging activities to the Delta is approximately 60%. As mentioned above, Board staff estimated approximately 359 ac-ft of water is removed from the Delta annually from smaller dredging projects. Board staff used the effluent volume ratio above to approximate 216 ac-ft of water is returned annually to the Delta from smaller dredging projects.

6.3.5.2.3 Load

To estimate the annual aqueous methylmercury load from smaller dredging projects, Board staff subtracted the amount removed by dredging from the amount discharged from DMPSs. Both amounts are calculated by multiplying the aqueous methylmercury concentration by the volume of water.

The estimated amount of aqueous methylmercury removed annually from smaller dredging projects was determined by multiplying the weighted median aqueous methylmercury concentration of the Delta calculated in the Table 5.1 by the estimated amount of water removed. Approximately 0.035 grams of aqueous methylmercury is removed by smaller dredging projects each year (Table 6.36).

Board staff multiplied the estimated annual effluent discharge volume by the median USACE DMPS effluent aqueous methylmercury concentration of all subareas to get the estimated annual load of 0.370 grams of aqueous methylmercury (Table 6.37).

Subtracting the estimated amount of aqueous methylmercury removed by dredging, 0.035 g/yr, from the estimated amount discharge from DMPSs, 0.370 g/yr, results in a load of 0.335 g/yr for smaller dredging projects.

As mentioned in the USACE DWSC Dredging Projects Load section above, this suggests that methylmercury is being produced within DMPSs, and discharges from DMPSs are a source of aqueous methylmercury to the Delta. However, these estimates heavily rely on assuming that smaller dredging project practices are similar to USACE dredge practices and assuming the amount of sediment removed annually was accurately estimated in the 2010 TMDL Staff Report. Thus, this may be an overestimate of methylmercury loading to the Delta if smaller dredging projects do not remove as much sediment and if not all smaller dredging projects release dredged slurry back into Delta waterways.

Nonetheless, Board staff recommends the same implementation of control measures and best management practices listed USACE DWSC Dredging Projects Load section above for any small dredging project effluent discharges. This includes not discharging the water to allow for evaporation and percolation, disposing the water at an appropriate offsite location that is not hydrologically connected to waters of the state, or discharging water one to three days after placement.

6.3.5.3 Net Load

Equation 6.7: Methylmercury Net Load from Delta Waterways by Dredging

$$MeHg\ Net\ Load = Aqueous\ MeHg\ Load + Sediment\ MeHg\ Load$$

To estimate the net load of methylmercury to the Delta from dredging activities, Board staff added estimated aqueous methylmercury loads to estimated sediment-bound methylmercury loads (Equation 6.7).

6.3.5.3.1 Aqueous Methylmercury Load

The sections above detailed how aqueous methylmercury loads were calculated for both dredging project types, USACE-related DWSC dredging projects and smaller dredging projects, that typically occur annually in the Delta.

Equation 6.8: Aqueous Methylmercury Removed from Delta Waterways by Dredging

$$Aqueous\ MeHg\ Removed = \begin{matrix} DWSC\ Aqueous \\ MeHg\ Removed \end{matrix} + \begin{matrix} Smaller\ Projects \\ Aqueous\ MeHg\ Removed \end{matrix}$$

$$0.153\ g/yr = 0.118\ g/yr + 0.035\ g/yr$$

It was calculated that 0.118 grams of aqueous methylmercury is removed from DWSC dredging project activities and 0.035 grams of aqueous methylmercury is removed from smaller dredging project activities in the Delta, annually. Using Equation 6.8 to sum the amount of aqueous methylmercury removed by all dredging project activities, approximately 0.153 grams of aqueous methylmercury are removed from within the Delta MeHg TMDL Boundary by dredging activities each year.

Equation 6.9: Aqueous Methylmercury Discharged to Delta Waterways from Dredged Material Placement Sites

$$Aqueous\ MeHg\ Discharged = \begin{matrix} DWSC\ Aqueous \\ MeHg\ Discharged \end{matrix} + \begin{matrix} Smaller\ Projects \\ Aqueous\ MeHg\ Discharged \end{matrix}$$

$$2.243\ g/yr = 1.874\ g/yr + 0.370\ g/yr$$

Board staff estimated that 1.874 grams of aqueous methylmercury is discharged from DMPSs from DWSC dredging project activities and 0.370 grams of aqueous methylmercury discharged from DMPSs from smaller dredging project activities in the Delta, annually. Using Equation 6.9, the estimated aqueous methylmercury discharged from all DMPSs from dredging activities in the Delta MeHg TMDL Boundary is 2.243 g/yr.

Equation 6.10: Aqueous Methylmercury Load from Dredging Activities

$$Aqueous\ MeHg\ Load = \frac{Aqueous\ MeHg}{Discharged} - \frac{Aqueous\ MeHg}{Removed}$$

$$2.090\ g/yr = 2.243\ g/yr - 0.153\ g/yr$$

The aqueous methylmercury load from dredging projects in the Delta was determined by subtracting the amount of aqueous methylmercury removed from Delta waterways, 0.153 g/yr, from the amount of aqueous methylmercury discharged from DMPSs, 2.243 g/yr. Using Equation 6.10, the annual load of aqueous methylmercury from all dredging project types in the Delta MeHg TMDL Boundary is approximately 2.090 grams.

6.3.5.3.2 Sediment-Bound Methylmercury Load

The 2010 TMDL Staff Report included an estimate of methylmercury in the sediment removed by dredging activities. For the DMCP Review, Board staff estimated the amount of methylmercury in sediment removed from channels by dredging, and in turbid discharges from DMPSs.

Estimated Mass of Sediment-Bound Methylmercury in Dredged Sediment Removed from Delta Waterways

Board staff calculated a revised estimate of methylmercury in dredged sediment by using the:

- Annual estimated sediment removed by dredging projects in the Delta MeHg TMDL Boundary
- Median of total mercury levels in recent pre-dredged sediment provided by USACE
- Specific gravity of soils in the Sacramento and Stockton DWSC provided by USACE
- Median ratio of methylmercury to total mercury surficial sediment concentrations (Table 6.38)

The 2010 evaluation used the average ratio of 0.006 methylmercury to total mercury (MeHg:THg) concentrations in surficial sediment calculated by Heim and others (2003) (see Table 6.18 of the 2010 TMDL Staff Report). Board staff decided to use the median ratio of 0.003 instead of the average ratio to maintain consistency with the linkage model methods (Table 6.39).

Two assumptions listed in Section 7.2.3 of the 2010 TMDL Staff Report were (1) dredged slurry contains 50% water content and 50% sediment content, and (2) a cubic yard (cy) of dredged slurry contained about 570 kilograms of dry sediment. In the DMCP Review, Board staff assumed that (1) dredged slurry is 90% water content and 10% sediment content per USACE reports, and (2) specific gravity of soils provided by USACE accurately represent soil density of sediment removed from the channels (USACE 2019).

Equation 6.11: Total Mercury Mass in Dredged Sediment

$$\frac{THg\ Removed}{kg/yr} = \frac{Dredged\ Sed}{Volume\ cy/yr} \times \frac{Median\ \ THg}{mg/kg} \times \frac{Soil\ Density}{kg/cy} \times 10^{-9}\ mg/kg$$

Using Equation 6.11, Board staff estimated the total mercury mass removed by dredged sediment to be 40.181 kg/yr for all project types.

Equation 6.12: Sediment-Bound Methylmercury Removed from Delta Waterways by Dredging, using the Ratio of Methylmercury to Total Mercury in Equation 6.3 of the 2010 TMDL Staff Report

$$Sediment\ MeHg\ Removed = THg\ Removed\ \times\ MeHg{:}THg$$

$$120.544\ g/yr = 40.181\ kg/yr \times 10^{3}\ g/kg \times\ 0.003$$

Board staff used Equation 6.12 to estimate the methylmercury mass removed from Delta Waterway channels in dredged sediment to be 120.544 g/yr.

As stated in Section 6.3.4 of the 2010 TMDL Staff Report, “[u]se of surficial sediment MeHg:[THg] to estimate methylmercury mass removed by dredging assumes that MeHg:[THg] 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.” For the DMCP Review, Board staff maintained these assumptions.

Estimated Mass of Sediment-Bound Methylmercury in Turbid Discharges to Delta Waterways from Dredged Material Placement Sites

Because mercury-bound sediment was included in the methylmercury loss estimate, Board staff evaluated the mass of mercury-bound sediment in turbid effluent water discharged from DMPSs. Turbidity data from USACE dredging projects from 2014 through 2017 was used to find the median turbidity of inflow water to, and discharge water from, DMPSs (USACE 2019). It should be noted that (1) turbidity samples were collected at the same location within the DMPSs, either at the discharge drain or weir, and (2) multiple samples were collected on days when the DMPS was simultaneously receiving dredged slurry water inflow while actively discharging effluent water.

Board staff found that the median difference in turbidity in a DMPS while receiving dredge slurry and while discharging water was zero, which would imply that effluent water was as turbid as the dredge slurry (Table 6.40). However, the average difference in turbidity was -7.394 nephelometric turbidity units (NTU), implying effluent turbidity was less than dredge slurry. Because dredged slurry is reportedly held at DMPSs to allow turbid materials to settle prior to discharge, Board staff used the arithmetic mean difference in turbidity.

Board staff maintained the assumption that dredge slurry is 90% water and 10% sediment. Using this assumption with the arithmetic mean difference in turbidity, Board staff estimated there was an 12.6% decrease in turbidity in effluent water[100]. Board staff further assumed the proportion of sediment and water decreased linearly over time, meaning effluent discharges are approximately 91.26% water and 8.74% sediment.

Using the volume of effluent water estimated for USACE and smaller dredging projects in flow sections above and assumed percentage of effluent discharges to be 91.26%, Board staff was able to estimate the amount of sediment in turbid effluent water to be approximately 147,435 cubic yards per year. Board staff multiplied the estimated volume of sediment discharged by the methylmercury density, grams per cubic yard (g/cy), in the source slurry water.[101]

Equation 6.13: Sediment-bound Methylmercury Discharged to Delta Waterways from Dredged Material Placement Sites

$$Sediment\ MeHg\ Discharged = \frac{Stockton\ DWSC}{Sediment\ MeHg} + \frac{Sacramento\ DWSC}{Sediment\ MeHg} + \frac{Smaller\ Projects}{Sediment\ MeHg}$$

$$51.909\ g/yr = 26.545\ g/yr + 8.468\ g/yr + 16.896\ g/yr$$

Board staff estimates the amount of methylmercury in sediment from DMPS turbid discharges in the Delta MeHg TMDL Boundary to be 51.909 grams per year, the summation of estimated methylmercury concentrations in sediment from effluent discharges from the Stockton DWSC, Sacramento DWSC, and smaller dredging projects (Equation 6.13; Table 6.41).

[100] Median turbidity of inflow was 58.7 NTU, using assumed average difference of -7.394 NTU from inflow to effluent results in assumed effluent turbidity of 51.3, which is a 12.6% decrease of inflow turbidity.

[101] Methylmercury concentration in sediment and disturbance within the DMPSs prior to placement of dredge slurry is unknown, so methylmercury concentration in dredge slurry only was evaluated in this estimate.

Equation 6.14: Sediment-bound Methylmercury Load from Dredging Activities

$$Sediment\ MeHg\ Load = \frac{Sediment\ MeHg}{Discharged} - \frac{Sediment\ MeHg}{Removed}$$

$$-68.636\ g/yr = 51.909\ g/yr - 120.544\ g/yr$$

Using Equation 6.14, approximately 68.636 grams of sediment-bound methylmercury is removed from the Delta from all dredging activities in the Delta MeHg TMDL Boundary. This estimates that approximately 43% of methylmercury in sediment removed by dredging projects is discharged back to the Delta. Board staff recommends dredging projects do not discharge water from DMPSs while actively receiving dredged slurry to reduce turbid discharges.

6.3.5.3.3 Total Methylmercury Load

To determine how dredging activities impact methylmercury in the Delta, Board staff summed the estimated amount removed by dredging activities and the estimated amount discharged from DMPSs.

Equation 6.15: Methylmercury Removed from Delta Waterways by Dredging

$$MeHg\ Removed = Aqueous\ MeHg\ Removed + Sed\ MeHg\ Removed$$

$$120.698\ g/yr = 0.153\ g/yr + 120.544\ g/yr$$

Methylmercury in sediment is estimated to be the majority loss pathway of methylmercury in dredging projects. Using Equation 6.15, 120.698 grams of methylmercury is estimated to be removed annually by dredging activities within the Delta MeHg TMDL Boundary. The 2010 TMDL Staff report estimated 341 grams of methylmercury removed by dredging from sediment alone. The difference in these numbers is likely due to the use of medians in the DMCP Review instead of averages as in the 2010 evaluation, assumed ratio of water and sediment in dredged slurry from 50:50 to 90:10, and revised assumed soil density based on provided soil specific gravity.

Equation 6.16: Methylmercury Discharged to Delta Waterways from Dredged Material Placement Sites

$$MeHg\ Discharged = Aqueous\ MeHg\ Discharged + Sed\ MeHg\ Discharged$$

$$54.152\ g/yr = 2.243\ g/yr + 51.909\ g/yr$$

Adding the amount of aqueous methylmercury, 2.243 g/yr, and sediment-bound methylmercury, 51.909 g/yr, in turbid effluent discharges from DMPSs within the Delta MeHg TMDL Boundary results in the estimated methylmercury discharge mass of 54.153 g/yr methylmercury (Equation 6.16).

Equation 6.17: Methylmercury Net Load from Dredging Activities

$$MeHg\ Net\ Load = MeHg\ Discharged - MeHg\ Removed$$

$$-66.545\ g/yr = 54.152\ g/yr - 120.698\ g/yr$$

Board staff estimates that annual dredging activities within the Delta are a net sink of methylmercury, removing approximately 120.698 grams while dredging channel bottoms and discharging approximately 54.152 grams from DMPSs. In total, dredging projects are expected to be a methylmercury loss of 66.545 g/yr (Equation 6.17).

As mentioned previously, implementation of control measures and best management practices may increase the removal of methylmercury by dredging activities in the Delta. Board staff recommends dredging projects do not discharge dredged slurry, if possible. Instead, to hold and allow dredged slurry to evaporate and percolate or dispose of in an appropriate manner where it will not be reintroduced into waters of the state. If water must be discharged from DMPSs, Board staff recommends (1) discharges not occur while the site is actively receiving slurry and (2) discharges occur within one to three days after slurry placement to reduce methylmercury production.

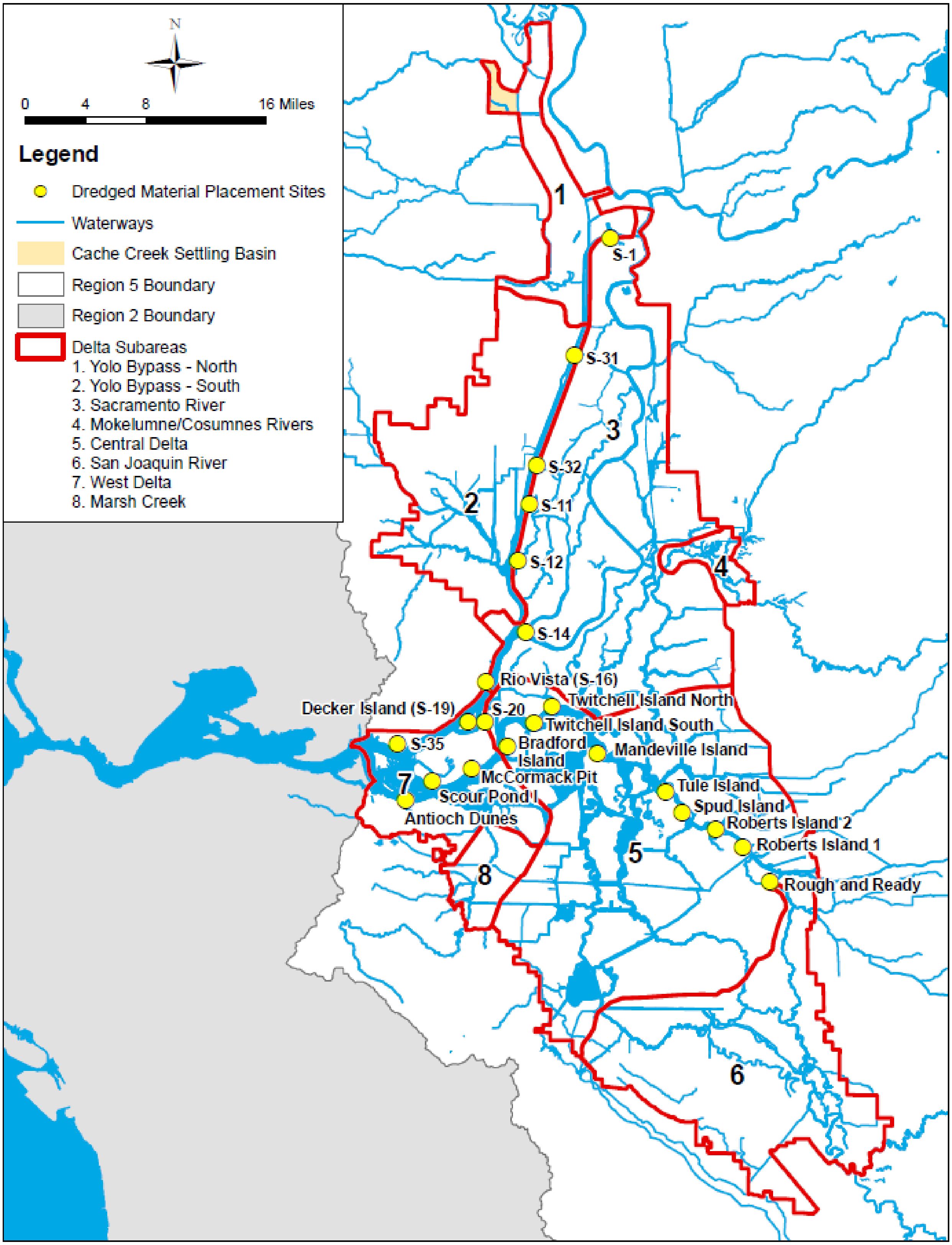

Figure 6.24: Map of Dredged Material Placement Site Locations in the Delta

Table 6.34: Estimated Annual Aqueous Methylmercury Removed from Delta Waterways by Deep Water Ship Channel Dredging Projects

Dredging Location	Delta TMDL Subarea	Upstream MeHg Concentration (ng/L)[102]	Water Volume Removed (ac-ft)	Water Volume Removed (L)	Aqueous MeHg Removed (ng/yr)	Aqueous MeHg Removed (g/yr)
Stockton DWSC	West Delta	0.065	218.961	269,979,234	17,548,650	0.018
Stockton DWSC	Central Delta	0.067	671.097	827,462,908	55,440,015	0.055
Sacramento DWSC	Yolo Bypass - South	0.191	245.672	302,913,754	36,349,651	0.036
Sacramento DWSC	Sacramento River	0.079	98.886	121,925,847	9,632,142	0.010
Total			**1,234.616**	**1,522,281,743**	**118,970,457**	**0.118**

Table 6.35: Estimated Annual Aqueous Methylmercury Discharged to Delta Waterways from Deep Water Ship Channel Dredging Project Dredged Material Placement Sites[103]

Dredging Location	Delta TMDL Subarea	MeHg Effluent Concentration (ng/L)	Water Volume Discharged (ac-ft)	Water Volume Discharged (L)	Aqueous MeHg Discharged (ng/yr)	Aqueous MeHg Discharged (g/yr)
Stockton DWSC	West Delta	9.390	137.550	169,598,798	1,592,447,918	1.592
Stockton DWSC	Central Delta	0.241	528.985	652,238,268	157,189,423	0.157
Sacramento DWSC	Yolo Bypass - South	1.390	36.206	44,641,646	62,051,887	0.062
Sacramento DWSC	Sacramento River	1.390	36.206	44,641,646	62,051,887	0.062
Total			**738.946**	**911,120,358**	**1,873,741,116**	**1.874**

[102] Median aqueous methylmercury concentrations per subarea from Table 5.1.

[103] The Sacramento River subarea was assigned the aqueous methylmercury concentration of the Yolo Bypass - South subarea. The Yolo Bypass - South subarea was assigned the estimated effluent volume of the Sacramento subarea.

Table 6.36: Estimated Annual Aqueous Methylmercury Removed from Delta Waterways by Smaller Dredging Projects

Upstream MeHg Concentration (ng/L)[104]	Water Volume Removed (ac-ft)	Water Volume Removed (L)	Aqueous MeHg Removed (ng/yr)	Aqueous MeHg Removed (g/yr)
0.079	359.254	443,133,180	35,007,521.22	0.035

Table 6.37: Estimated Annual Aqueous Methylmercury Discharged to Delta Waterways from Smaller Dredging Project DMPSs

MeHg Effluent Concentration (ng/L)[105]	Water Volume Discharged (ac-ft)	Water Volume Discharged (L)	Aqueous MeHg Discharged (ng/yr)	Aqueous MeHg Discharged (g/yr)
1.390	215.552	265,879,908	369,573,072	0.370

Table 6.38: Mass of Methylmercury Removed by Dredging Project Type in the Delta

Delta Dredging Project	Volume of Dredged Sediment (cy/yr)[106]	Median THg Sediment Concentration (mg/kg)[107]	Specific Gravity of Soil[108]	Soil Density (kg/m^3)	Soil Density (kg/cy)	Sediment THg Removed (kg/yr)	Sediment THg Removed (g/yr)	MeHg:THg Median Ratio[109]	Sediment MeHg Removed (g/yr)
Sacramento DWSC	61,741	0.129	2.559	2,559.0	1,956.5	15.583	15,582.793	0.003	46.748
Stockton DWSC	159,490	0.044	2.555	2,555.0	1,953.4	13.708	13,708.361	0.003	41.125
Smaller Dredging Projects	64,400	0.0865	2.557	2,557.0	1,955.0	10.890	10,890.340	0.003	32.671
Total	**285,631**					**40.181**	**40,181.495**		**120.544**

[104] Weighted median of subarea methylmercury concentration by area (Table 5.1).
[105] Median of Delta TMDL Subarea USACE DMPS effluent methylmercury concentration.
[106] Volume of annual dredged sediment for the Sacramento and Stockton Deep Water Ship Channels from USACE reported cubic yards of dredged material from years 2009 through 2020. Volume of dredged sediment for smaller dredging projects from the 2010 TMDL Staff Report.
[107] Median total mercury sediment concentration from USACE total mercury pre-dredge sediment concentration from 2010 to 2017.
[108] Specific gravity of soil for the Sacramento and Stockton DWSCs provided in the USACE Methylmercury Summary Report Table 9 (USACE 2019). Board staff used the median soil specific gravity of Sacramento and Stockton for the specific gravity soil of smaller dredging projects, which locations vary in the Delta each year.
[109] Median ration of methylmercury to total mercury in surficial sediments evaluated by Heim and others (2003).

Table 6.39: MeHg:THg in Deep Water Ship Channel Surficial Sediments (Table 6.18 of the 2010 Delta TMDL Staff Report, data source from Heim *et al.* 2003)

Deep Water Ship Channel	Location	MeHg Conc. (ng/g)	THg Conc. (ng/g)	MeHg:THg Ratio
Sacramento	Sacramento DWSC	0.49	194.7	0.0025
Stockton	Little Connection Slough	0.2	82.51	0.0024
Stockton	Headreach Cutoff	1.86	89.46	0.0208
Stockton	Port of Stockton Turnabout #1	0.32	193.78	0.0017
Stockton	Port of Stockton Turnabout #2	0.32	130.3	0.0025
			Median Ratio	**0.003**
			Average Ratio	**0.006**

Table 6.40: Turbidity in Dredged Material Placement Sites Sampled During Inflow and Discharge Events

Year	DMPS	Inflow Turbidity During Active Dredging (NTU)	Turbidity While Discharging (NTU)	Difference in Turbidity from Effluent and Inflow (NTU)
2014	Roberts I	54.5	60.7	6.2
2015	Roberts I	5.6	5.6	0
2016	Bradford Island	62.9	62.9	0
2016	Twitchell Island North	170	170	0
2017	Rough and Ready	10.235	9.17	-1.065
2017	Twitchell Island North	172.5	123	-49.5
			Median	**0**
			Average	**-7.394**

Table 6.41: Annual Mass of Sediment-bound Methylmercury Discharged from Dredged Material Placement Sites by Dredging Project Type in Delta

Delta Dredging Project	Volume of Effluent Water (cy/yr)	Volume of Effluent Total, Water and Sed (cy/yr)	Volume of Effluent Sed (cy/yr)	MeHg in Sediment (g/cy)[110]	MeHg in Effluent Sediment (g/yr)
Stockton DWSC	1,074,929.131	1,177,875.445	102,946.314	0.000257853	26.545
Sacramento DWSC	116,778.878	127,962.829	11,183.951	0.000757163	8.468
Smaller Projects	347,760.000	381,065.089	33,305.089	0.000507298	16.896
Total	1,539,468.009	1,686,903.363	147,435.354		**51.909**

[110] Methylmercury in sediment in grams per cubic yard determined by dividing the amount of methylmercury in sediment removed by the volume of dredged sediment in Table 6.38.

6.3.6 Tidal Wetlands

For all wetlands, the 2010 TMDL Staff Report used wetland flux rates from two experimental ponds on Twitchell Island. Wetland type, for example tidal and nontidal, was not differentiated in the 2010 load estimate and the flux rate was based on data collected in two experimental wetlands on Twitchell Island. The rate used in the 2010 TMDL Staff Report was noted by the DWR to not accurately represent tidal wetland methylmercury characteristics (Lee and Manning 2020). This prompted DWR to conduct a characterization study of methylmercury and other related parameters in tidal wetlands in and around the Delta MeHg TMDL Boundary. DWR staff summarized their findings in the DWR Tidal Wetlands Report (Lee and Manning 2020).[111]

For the DMCP Review, Board staff used data collected for the DWR Tidal Wetlands Report between 2014 and 2019 to estimate loading from tidal wetlands, based on three located within the Delta MeHg TMDL Boundary: Yolo Bypass Wildlife Area Tidal Wetland, North Lindsey Slough Tidal Wetland, and Westervelt Cosumnes River Tidal Wetland. The DWR Tidal Wetlands Report also included an analysis of methylmercury at Blacklock Tidal Wetland, which is located in Suisun Marsh. Since Suisun Marsh is outside of the Delta MeHg TMDL Boundary, Board staff did not include the results in this analysis. DWR selected these wetlands to study for many reasons including that they were not hydrodynamically leaky, meaning they could determine a full water balance as much as possible. In April 2022, Board staff was notified by DWR staff of newly processed data for the report based on comments received by an ISRP. These data were received after Board staff estimated loading from tidal wetlands and were therefore not included in the DMCP Review. Associated methylmercury and flow data were available for all three wetlands.

Data were pulled from each source, compiled in Excel, and loaded into RStudio for further organization and analysis. Appendix A.2 provides references and details on the data used in the DMCP Review.

6.3.6.1 Acreage

Board staff assumed the area contributing to methylmercury production or degradation is the area that is wetted and dried as the tide moves in and out. This contributing area is assumed to be the tidal drainage area at ordinary high tide mark (highest flood point) minus the area of tidal channel (assumed to be the lowest ebb point). To estimate per area loading, acreages for two of the three wetlands were used from the DWR Tidal Wetlands Report. Westervelt was listed as having a maximum area of 500 acres, 22 of which are tidal channels. Thus, the contributing area for Westervelt is assumed to be 478 acres. Similarly, North Lindsey had a maximum area of 22 acres, 1.8 of which is tidal channel, with the contributing area of 20.2 acres. The report did not provide a maximum area for the Yolo Bypass Wildlife Area Tidal Wetland. Based on land use cover used to create Figure 6.8, Board staff calculated the area to have a wetland maximum of 761.6 acres. The report stated 33.1 acres of this area is tidal channel.

[111] See Appendix E.10 for the Board staff summary on the DWR Tidal Wetlands Report.

Thus, the contributing area for the Yolo Bypass Wildlife Area Tidal Wetland is estimated to be 728.5 acres.

To extrapolate the per area rate to all tidal wetlands in the Delta, tidal wetland acreages were estimated from the USFWS NWI. As mentioned in section 6.2.2 of the 2010 TMDL Staff Report, types of wetlands in the Delta MeHg TMDL Boundary are primarily seasonal wetlands and tidal, salt, brackish, and freshwater marshes. Appendix D.15 describes the grouping of USFWS wetland map to tidal and nontidal wetlands, as shown in Figure 6.8. Board staff estimated approximately 10,563 acres of tidal habitat within the Delta MeHg TMDL Boundary, excluding the CCSB, during WYs 2000-2019.

6.3.6.2 Methylmercury Concentration

Board staff used the following assumptions about methylmercury data from the DWR Tidal Wetlands Report:

- Composite, total, and grab samples were treated equivalently for analysis and calculations.
- Since methylmercury samples were not available in each wetland for every month, Board staff applied the median monthly rate to all tidal wetlands in the Delta MeHg TMDL Boundary.
- Though the 2010 TMDL Staff Report used seasonal rates, the DMCP Review used monthly rates. Board staff assumed that the median of concentrations grouped by month are representative of each month across all years.

Methylmercury concentrations were primarily measured by an autosampler at the same time as a flow measurement. Board staff assigned tide cycle type to the methylmercury measurements based on sample time. In cases where the methylmercury sample time did not match the flow measurement time, the tide cycle type closest in time was assigned. The median of monthly concentrations across all available years was calculated for each combination of wetland, tide cycle, and month. Figure 6.25, Figure 6.26, and Figure 6.27 display methylmercury data from Westervelt Cosumnes River Tidal Wetland, North Lindsey Slough Tidal Wetland, and Yolo Bypass Wildlife Area Tidal Wetland, respectively.

6.3.6.3 Flow

Board staff made the following assumptions about flow data:

- Ebb is synonymous with outflow and flood is synonymous with inflow.
- The ebb and flood cycles are the same from year-to-year for each month, so that a monthly median flow rate could be calculated across years.
- Slack tide, the period between a tide change when the flow rate is 0 cfs, values were assigned to the prior tide cycle. For example, if the tide was changing from ebb to flood, the slack tide was assigned as ebb. because the tide was at its lowest ebb point.

- Reported values for Westervelt were treated as actual values, however Board staff noted that there was a flood event that led to water level being too high for the deployed inlet sensor to accurately read flow.

Flow data were provided in cfs in 15-minute intervals. Board staff changed all instances of slack tide to match the preceding tidal cycle (i.e., ebb or flood) and removed any incomplete tidal cycles[112]. The measurements for the very first and last tidal cycles were removed since measurements did not begin at slack tide and were assumed to be partial.

Flow data were grouped by wetland and tide cycle, then multiplied by the number of seconds in 15 minutes to get the volume of flowing water in a 15-minute period[113]. These volumes were summed by month for all available years, then were divided by the number of 15-minute periods in the month to get an average volume per 15-minute period for each combination of wetland, tide cycle, and month. Average volumes were then converted to liters per month (multiplying by 15 minutes in 12 hours[114], then days in each month) to get a representative total volume of water per each combination of wetland, tide cycle, and month.

6.3.6.4 Load

This section describes the methods used to estimate loading for tidal wetlands, which are similar to those used for the nontidal load estimation (Section 6.2.3).

Board staff assumed that methylmercury production load from tidal wetlands is represented by the ebb load minus the flood load.

Loads were calculated by multiplying monthly volumes and median methylmercury concentrations for each wetland, tide cycle, and month.[115] For each wetland and month, the flood load was subtracted by the ebb load to get the net load. Net loads were divided by contributing wetland area, and then divided by the number of days in each month to get representative monthly rates in ng/m^2/day. Board staff calculated the median of these rates for each month across all three wetlands to get median monthly rates for all tidal wetlands.

Board staff applied the median monthly load rates to the area of tidal wetlands in each Delta TMDL subarea. Loads for all months and subareas were summed to get total annual load. A summary of these findings is presented in Table 6.42.

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[112] For this, 16 minutes was used instead of 15 because due to slight variation in the data and multiple intervals with 16-minute breaks.

[113] Board staff assumed that each flow measurement is representative of flow for the following 15 minutes.

[114] Board staff assumed each day consisted of half ebb and half flood.

[115] There was not always associated flow and methylmercury data for each wetland, but when grouping all three wetlands together there is at least some flow and methylmercury data for each month.

This evaluation determined that tidal wetlands in the Delta MeHg TMDL Boundary are a net loss of approximately 61 grams of methylmercury per year. Therefore, tidal wetlands may contribute about 2% of the methylmercury loss to the Delta and Yolo Bypass.

The finding that tidal wetlands are a net loss of methylmercury is consistent with the DWR Tidal Wetlands Report (Lee and Manning 2020). This could be because these tidal wetlands do not dry out, so there is not that “first flush” effect of increased methylmercury production common in habitats with a drying and wetting cycle.

As mentioned in Nontidal Wetlands Section 6.2.3, Board staff recognizes that methylmercury production within Delta wetlands has been shown to be highly variable depending on a range of conditions. Similar to the recommendation in the DWR Tidal Wetlands Report, Board staff also recommends further studies to characterize methylmercury production in tidal wetlands within the Delta MeHg TMDL Boundary. Such studies could improve understanding of monthly and seasonal loads, and methylmercury control options like limiting source water mercury loads, modifying wetland construction, and modifying hydrologic designs. Section 3.5 describes the conditions which affect methylmercury production in wetlands and possible controls.

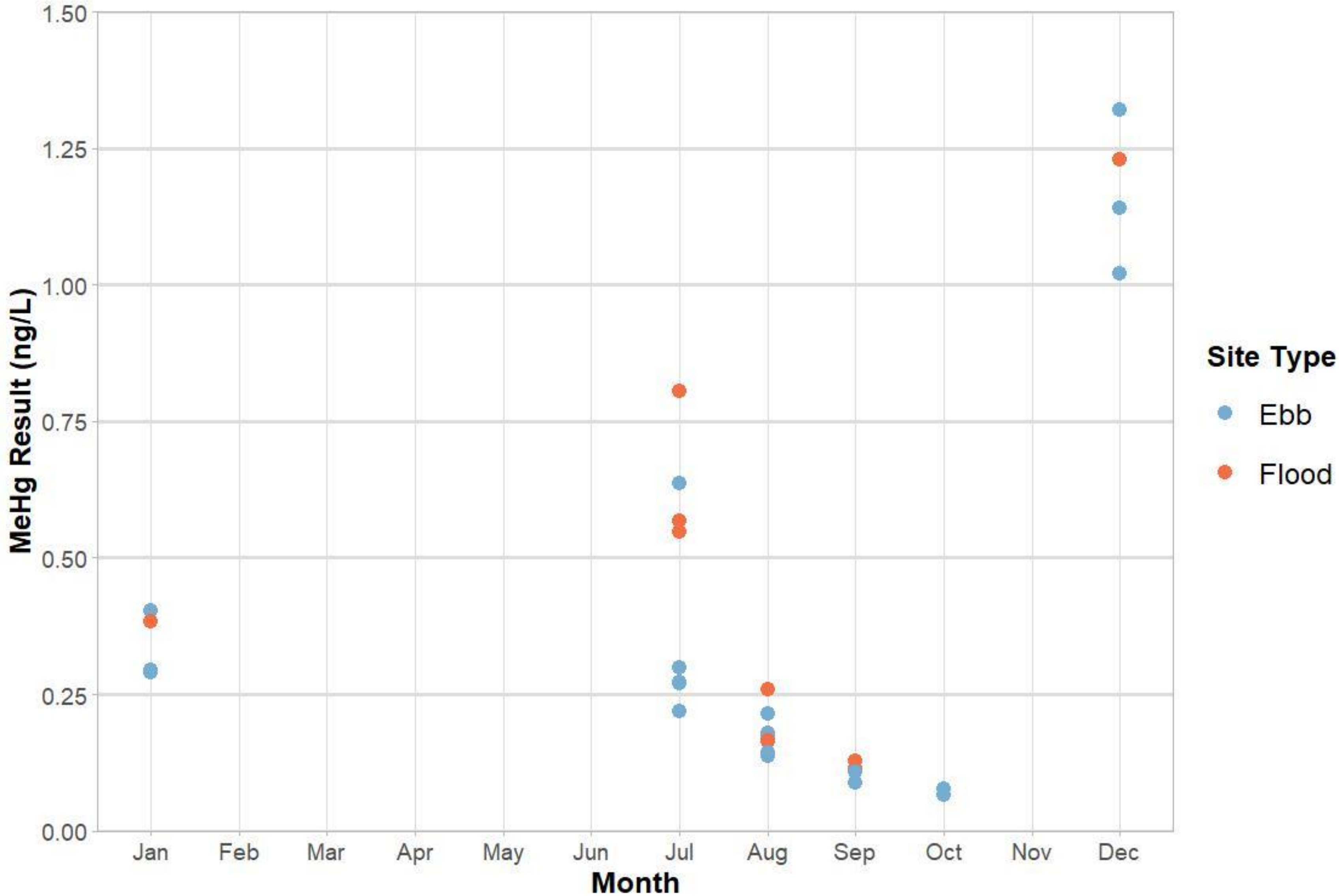

Figure 6.25: Summary of Raw Monthly Methylmercury Data Used for Westervelt Cosumnes River Tidal Wetland

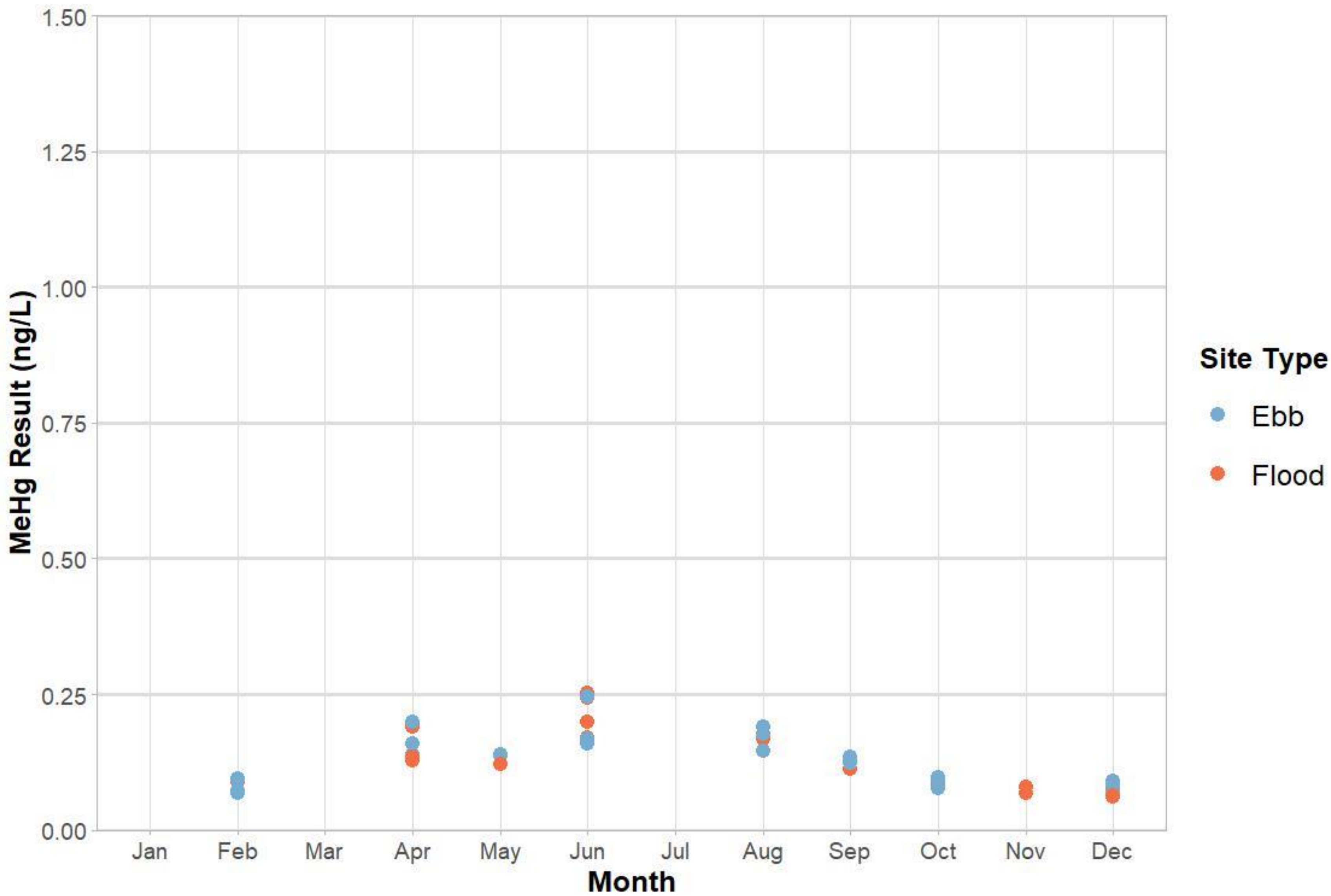

Figure 6.26: Summary of Raw Monthly Methylmercury Data Used for North Lindsey Slough Tidal Wetland

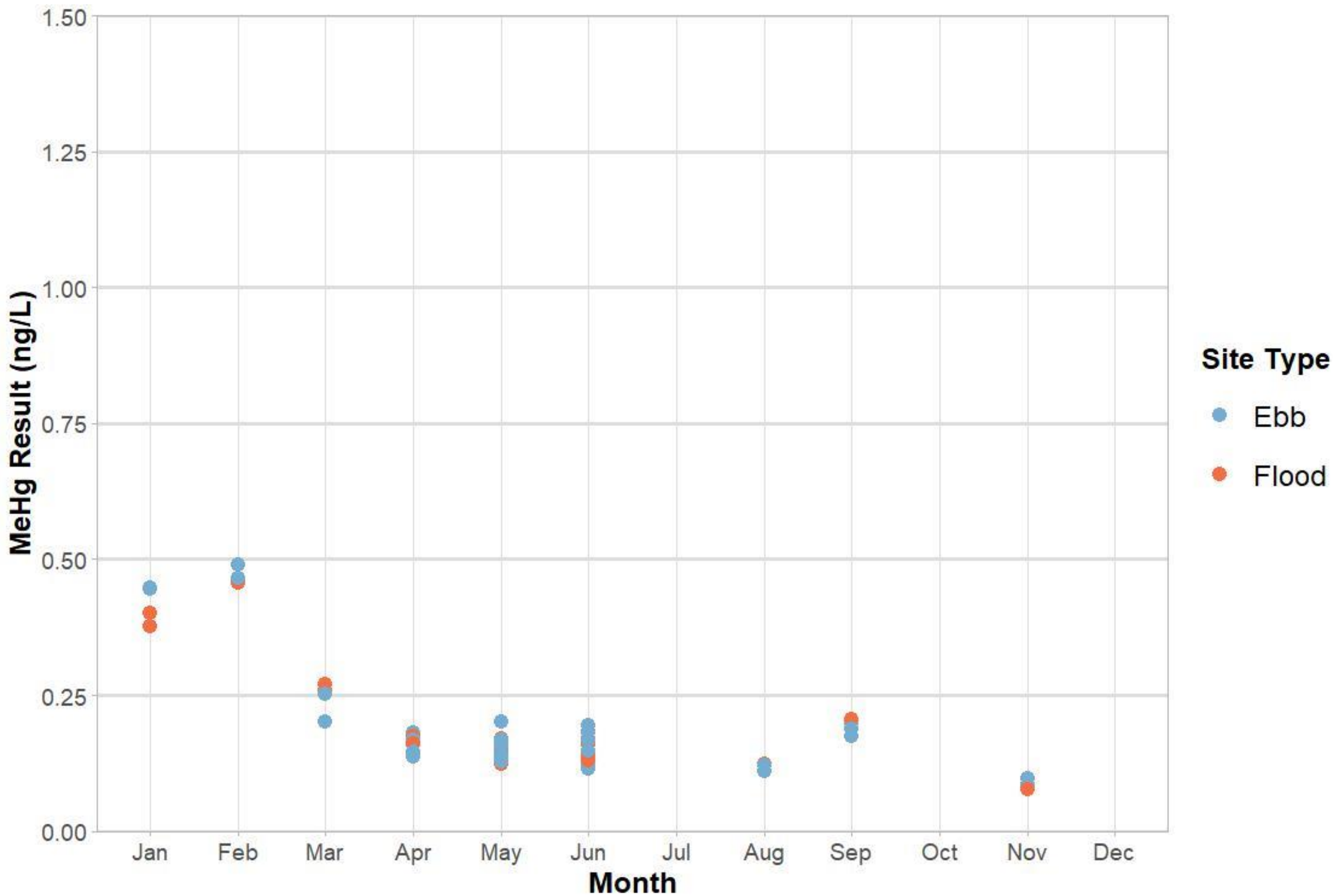

Figure 6.27: Summary of Raw Monthly Methylmercury Data Used for Yolo Bypass Wildlife Area Tidal Wetland

Table 6.42: Methylmercury Loss from Tidal Wetland Habitats in Each Delta TMDL Subarea[116]

Delta TMDL Subarea	Tidal Wetland Area (ac)	Tidal Wetland Area (%)	Tidal Wetland Area (m^2)	Warm Season MeHg Daily Load (g/day)	Cool Season MeHg Daily Load (g/day)	Annual MeHg Load (g/yr)
Central Delta	3,406.224	32.25%	13,784,987.871	-0.078	-0.019	-19.520
Marsh Creek	0	0.00%	0	0	0	0
Mokelumne/ Cosumnes Rivers	104.199	0.99%	421,694.599	-0.002	-0.001	-0.597
Sacramento River	785.702	7.44%	3,179,735.280	-0.018	-0.004	-4.503
San Joaquin River	356.311	3.37%	1,441,990.533	-0.008	-0.002	-2.042
West Delta	3,833.155	36.29%	15,512,779.374	-0.088	-0.021	-21.967
Yolo Bypass - North	86.392	0.82%	349,629.450	-0.002	0.000	-0.495
Yolo Bypass - South	1,990.866	18.85%	8,057,034.114	-0.046	-0.011	-11.409
Total	**10,562.849**	**100.00%**	**42,747,851.221**	**-0.242**	**-0.058**	**-60.533**

[116] Warm and cool seasons are for reference only and were not used in calculating the annual loads. Warm and cool seasons are consistent with the 2010 TMDL Staff Report definitions. Warm season is defined as March through September (214 days), and cool season is defined as October through February (151 days). These rows were calculated by adding the loads for these months and dividing by the number of days in the season.

6.3.7 Cache Creek Settling Basin

The CCSB is a 3,600-acre (ac) structure located at the base of the Cache Creek watershed, receiving inflows from Cache Creek and outflowing to the Yolo Bypass. USACE initially constructed the CCSB in 1937 to contain sediment and maintain the flood capacity of the Yolo Bypass and was modified in 1993 to increase its sediment trapping efficiency. Proposals to raise the outflow weir by six feet were discussed and were planned to occur in 2017; however, at the time of the DMCP Review, the outflow weir has not been raised and is planned to remain as is (ICF 2021). DWR currently manages CCSB and submitted a Loads Determination Report: Mercury Control Studies for the CCSB (Appendix E.3E.3 Final Loads Determination Report: Mercury Control Studies for the Cache Creek Settling Basin, Yolo County, California), as required by the DMCP.

The 2010 TMDL Staff Report estimated loading from the CCSB as a tributary source. In the DMCP Review, Board staff incorporated the CCSB within the scope of the Delta TMDL Boundary and considered it as a within-Delta source of methylmercury. Tributary loading from Cache Creek to the CCSB was assessed in Section 6.2.1.

Consistent with methods used in Section 6.2.1, Board staff used available stream flow gage and monitoring data from WYs 2000-2019 to estimate monthly flow volumes, methylmercury concentrations, and loads for the CCSB's two outflows, as described below.

6.3.7.1 Methylmercury Concentration

Methylmercury concentration estimates for the CCSB Outflow and Overflow Weir locations were compiled by Board staff from multiple sources to ensure all available data were used for the DMCP Review. Data sources used were CEDEN, the 2010 TMDL Staff Report, aqueous monitoring by Board staff in 2019, and the DMCP Review Linkage Analysis data compilation (Appendix A.2). Duplicate observations in the compiled data set were removed by processing in Excel and R. Ultimately, only the DMCP Review Linkage Analysis data compilation had recent CCSB monitoring data for utilization in this assessment.

Sample locations used to represent methylmercury concentrations for the Outflow and Overflow Weir were selected by geographic locations within the CCSB waterways (Figure 6.28).

Consistent with methods used in the 2010 TMDL Staff Report and with methods described in Section 6.2.1.1 to estimate Cache Creek inflows to CCSB, the median of pooled monthly data was calculated for tributaries with monthly methylmercury data. Table 6.43 summarizes the methylmercury concentrations used to estimate annual loads from CCSB.

6.3.7.2 Flow

Board staff used methods consistent with calculating Cache Creek inflows to CCSB described in Section 6.2.1.2 to calculate CCSB outflows.

Available streamflow data for the CCSB Outflow and Overflow Weir were gathered from USGS NWIS. NWIS only had data available from March 2009 through April 2019 for the CCSB Outflow gage and February 2008 through April 2019 for the CCSB Overflow Weir gage. Data were exported as monthly averages of daily flows in cfs, per year (e.g., March 2009 mean daily flow at the CCSB Outflow stream gage was 295.2 cfs). Both the CCSB Outflow and Overflow Weir datasets were incomplete, as was the Cache Creek inflow to the CCSB dataset. Board staff observed that gaps in data mostly corresponded with dry months and dry years.

To maintain consistency with flow calculations described in Section 6.2.1.2, Board staff filled data gaps of monthly averages of daily flows with zero, pooled monthly averages across all selected years, and calculated the monthly averages to obtain representative daily flows in cfs for each month.[117] Monthly averages were multiplied by the respective number of days per month and seconds per day to calculate monthly volumes in cubic feet, then volumes were converted from cubic feet to liters. Board staff considered many options for determining representative annual flow and determined this was the most representative of the CCSB Outflow and Overflow Weir due to intermittent flows (Appendix F).

Board staff estimated water volumes from the CCSB to be approximately 192,236 ac-ft per year (Table 6.44). Inflows from Cache Creek to CCSB were estimated in Section 6.2.1 to be about 186,659 ac-ft per year. Subtracting the inflow volume from Cache Creek from the outflow volume of CCSB, the basin discharges approximately 5,577 ac-ft of additional water to the Delta each year. Board staff attribute the extra flow to precipitation runoff and agricultural returns.

6.3.7.3 Load

For the DMCP Review, CCSB was included as part of the Yolo Bypass - North Delta TMDL subarea. Because CCSB was within the Delta MeHg TMDL Boundary, Board staff evaluated tributary annual methylmercury loading from Cache Creek inflows to CCSB. This was unlike the 2010 TMDL Staff Report, which considered the outflows of CCSB to the Yolo Bypass as the Cache Creek watershed tributary load to the Delta. Though CCSB is within the Yolo Bypass - North Delta TMDL subarea, Board staff decided to use streamflow gages and methylmercury monitoring data to determine methylmercury loading from the basin instead of estimating loading by land cover runoff. Reasons for using the available flow and monitoring data to determine loading for the basin instead of the runoff-based loading include (1) using data gathered by entities during Phase 1 of the DMCP, (2) availability of streamflow and methylmercury data in

[117] Because data gaps may be attributed to low flow below gage reader, no flow, or gage error, Board staff assumed the flow was zero and assigned all data gaps a flow of zero. This resulted in several months with representative monthly flow of zero cfs, despite having methylmercury data for that month that implies water was present.

the basin, and (3) assessing methylation within the CCSB by using the same methodology for estimating inflow and export loads. Monthly methylmercury loading for the Outflow and Overflow Weir locations were calculated using average monthly flows and monthly median concentrations. The CCSB methylmercury loading to the Yolo Bypass was determined by summing monthly loads for both the Outflow and Overflow Weir locations, 13.195 grams and 56.736 grams respectively. Board staff estimates methylmercury inflow loading to the basin to be 73.346 grams and methylmercury loading from the basin to be 69.931 grams, a difference of -3.415 grams, which indicates that the CCSB acts as a net sink for methylmercury (Table 6.45).

To compare estimated annual loading of the CCSB to the 2010 TMDL Staff Report estimates, Board staff found the average annual loading from Cache Creek inflows and CCSB outflows using the monthly average concentrations multiplied by the same monthly average flow values used in Section 6.3.7.2. This resulted in the estimated annual inflow load from Cache Creek to be 80.356 grams, load from CCSB Outflow to be 19.792 grams, and load from CCSB Overflow Weir to be 149.958 grams. Subtracting the Cache Creek inflow load of 80.356 grams from the cumulative CCSB outflow load of 169.750 grams[118] results in a net difference of 89.394 g/yr, which indicates that the CCSB acts as a net source of methylmercury. The 2010 TMDL Staff Report estimated the average annual CCSB outflow load to be about 137 grams of methylmercury using available data from WYs 2000-2003, a relatively dry period. DWR estimated the CCSB average annual outflow load in the *Final Loads Determination Report: Mercury Control Studies for the Cache Creek Settling Basin, Yolo County, California* to be 220 grams for the period of WYs 2010-2019 (Brown and Nosacka 2020).

The average annual loads from CCSB estimated using more recent data, both in the DMCP Review and the DWR CCSB Final Loads Report, are higher than the 2010 TMDL Staff Report's estimate. Board staff has shown that whether the CCSB is considered a net sink or source of methylmercury varies depending on the flow calculation methods using the same data. Additionally, the DWR CCSB Final Loads Report determined that the CCSB can be a net sink or source depending on the fraction (i.e., total, dissolved, or suspended) of methylmercury and total mercury (Brown and Nosacka 2020E.3 Final Loads Determination Report: Mercury Control Studies for the Cache Creek Settling Basin, Yolo County, California).[119] Thus, Board staff encourage the development and implementation of upstream methylmercury and inorganic mercury control programs both within and upstream of the CCSB. Effective control program monitoring and implementation should result in the reduction of methylmercury loading from Cache Creek to CCSB, from CCSB to the Delta, and thereby from the Delta to the San Francisco Bay.

[118] The total gross load from the CCSB using the average annual load from the CCSB Outflow and CCSB Overflow Weir equals 169.750 grams.

[119] See Appendix E.3 for the Board staff summary on the control study conducted on CCSB.

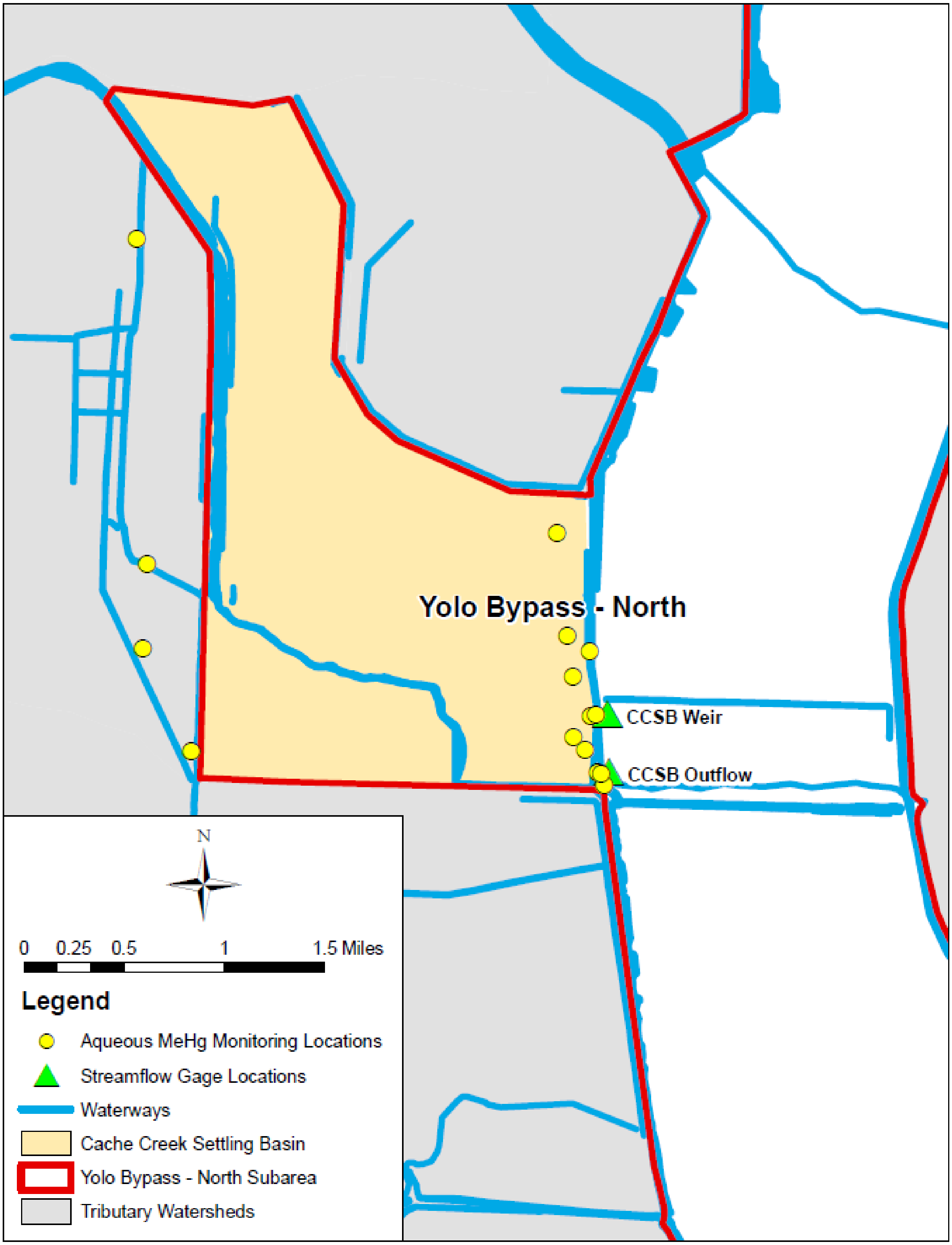

Figure 6.28: Methylmercury Concentration Sample Locations and Stream Flow Gage Locations Used to Estimate Cache Creek Settling Basin Loading

Table 6.43: Pooled Median Methylmercury Concentrations for Cache Creek Settling Basin

Outflow Location	Number of Samples	Minimum MeHg Concentration (ng/L)	Maximum MeHg Concentration (ng/L)	Median MeHg Concentration (ng/L)
CCSB Overflow Weir	17	0.125	3.320	0.333
CCSB Outflow	76	0.020	4.415	0.296

Table 6.44: Streamflow Gages Used to Estimate Cache Creek Settling Basin Outflow Water Volumes

Station Name	Site ID	Latitude	Longitude	Data Range	Estimated Annual Water Volume (L)[120]	Estimated Annual Water Volume (ac-ft)	Estimated Annual Water Volume (M ac-ft)
Cache C Overflow Weir From Settling Bas Nr Wood'ld	11452800	38.68278	-121.6719	Feb. 2008 - Apr. 2019	244,758,969,948	150,007.321	0.198
Cache C Outflow From Settling Basin Nr Settling Basin Nr Woodland CA	11452900	38.67861	-121.6717	Mar. 2009 - Apr. 2019	49,085,666,436	37,347.607	0.040

[120] Flow volumes estimated using zeros to substitute missing data and mean of monthly flows to best represent flows during the WYs 2000-2019 period.

Table 6.45: Estimated Annual Methylmercury Loads for Cache Creek Settling Basin Outflows

Location	Estimated Water Volume (L/yr)[121]	Pooled Median MeHg Conc. (ng/L)	Estimated MeHg Load (g/yr)[122]
CCSB Overflow Weir	244,758,969,948	0.333	56.736
CCSB Outflow	49,085,666,436	0.296	13.195
CCSB Cumulative Outflows	**237,119,530,336**		**69.931**
Cache Creek Inflows	230,240,367,860	0.252	73.346
CCSB Discharges	6,879,162,476		**-3.415**

[121] Flow volumes estimated using zeros to substitute missing data and mean of monthly flows to best represent flows during the WYs 2000-2019 period.

[122] Annual loads were calculated by summing monthly load estimates, which were determined by multiplying monthly average flow volume by monthly median methylmercury concentration (not the pooled median methylmercury concentration displayed in this table).

6.3.8 Other Potential Loss Pathways

The 2010 TMDL Staff Report listed photodegradation, particle settling, and uptake by biota as other potential loss pathways of methylmercury in the Delta. Specific estimates for each of these losses were not quantified but were assigned the methylmercury loss remainder of their methylmercury mass balance, -7.6 g/day. For the DMCP Review, Board staff evaluated and estimated loss amounts for photodegradation in Section 6.3.3 and particle settling in Section 6.3.2. Uptake by biota is assumed by Board staff to account for an unknown portion of the particle settling rate and is also summarized in Section 6.3.2. Described below are other potential loss pathways of methylmercury in the Delta that Board staff was not able to quantify in the DMCP Review, volatilization (Section 6.3.8.1) and water diversions from the Contra Costa Canal, Mokelumne Aqueduct, and North Bay Aqueduct (Section 6.3.8.2).

6.3.8.1 Volatilization

CALFED 2008 Task 5.4 studied the volatilization of dissolved gaseous mercury (DGM). The report found that in the San Francisco Bay-Delta, 0.99 micrograms per square meter per year ($\mu g/m^2/yr$) of DGM is lost via volatilization. DGM consists mainly of gaseous elemental mercury but can consist of up to 0.75% methylmercury. DGM volatilization rates are sensitive to temperature, wind speed, and relative saturation of mercury at the air-water interface.

Volatilization of methylmercury was included as a component of DWR's Open Water Report (DiGiorgio *et al.* 2020). At the time of DMCP Review, a measurement of this component was unknown. It is possible that this estimate could be extracted from the DSM2-Hg model at a later time.

The DMCP Review did not estimate volatilization of methylmercury as a potential loss pathway. Board staff does not expect this exclusion to substantially affect the methylmercury mass balance results. Further research could be conducted to consider what other species of mercury contribute to DGM and how much methylmercury is lost via volatilization in the Delta MeHg TMDL Boundary.

6.3.8.2 Contra Costa Canal, Mokelumne Aqueduct, & North Bay Aqueduct

Other water diversions from the Delta may serve as unaccounted methylmercury loss pathways. The Contra Costa Canal, Mokelumne Aqueduct, and North Bay Aqueduct are likely relatively small loss pathways compared to exports to San Francisco Bay and southern California. Though Dayflow may have useful flow data for these diversions, there was no methylmercury data available for these losses. The Contra Costa Canal and Mokelumne Aqueduct are not named waterways in Appendix 43 of the Basin Plan (CVRWQCB 2019). The 2010 TMDL Staff Report named the Contra Costa Canal in Table 2.2 as a diversion from the Delta but did not name the Mokelumne Aqueduct in the report. The North Bay Aqueduct is an underground pipeline that diverts water from Barker Slough to the Cordelia Pumping Plant in Fairfield and is part of the SWP.

Consistent with the 2010 TMDL Staff Report, methylmercury losses from these canals were not quantitatively considered in the DMCP Review source analysis.

6.4 Methylmercury Mass Balance

Board staff reviewed and updated the DMCP source analysis after additional Delta-specific studies were completed, as was required by the DMCP. Board staff used data from recent studies to revise the methylmercury source analyses for each Delta TMDL subarea, including the most recent CALFED studies and the Control and Characterization studies required by the DMCP. These studies provided data to better estimate and update methylmercury input and export loads for WYs 2000-2019. Figure 6.29 illustrates the Delta's daily median methylmercury inputs and exports based on the annual loads presented in Table 6.4 and Table 6.30, respectively. Board staff determined in the DMCP Review that tributary inflows account for about 74% of methylmercury sources to the Delta during the WYs 2000-2019. In situ open water sediment flux accounts for about 12%, agricultural returns account for approximately 5%, atmospheric deposition accounts for about 4%, nontidal wetland habitats accounts for 3%, NPDES WWTFs effluent contribute about 1%, and urban runoff contributes about 0.3% of methylmercury inputs. For Delta methylmercury losses, Board staff estimated approximately 31% lost in outflow to San Francisco Bay, 30% lost due to settling and biota uptake, 25% lost through photodegradation, 6% exported in the Delta Mendota Canal, 5% exported by the California Aqueduct, 2% lost through dredging activities, 2% lost in tidal wetland habitats, and 0.1% lost in CCSB.

The methylmercury mass balance balances to approximately 90% (Table 6.46). The 10% difference may be due to uncertainty of loading estimates, unaccounted-for sources, or suggests that the Delta is a net sink of approximately one-tenth of methylmercury loading. Board staff estimated the median annual methylmercury inputs and exports to be approximately 9.049 g/day (3.3 kg/yr) and 10.022 g/day (3.7 kg/yr), respectively. The volume of methylmercury exported to San Francisco Bay and Southern California is about 46% of all methylmercury input volumes. This means only about 46% of methylmercury coming into the Delta is exported from the Delta. The remaining 54% of methylmercury is staying within the Delta, suggesting that the Delta acts as a net sink for methylmercury. The finding that the Delta is a net sink for methylmercury is consistent with conclusions from the 2010 TMDL Staff Report, Task 2 of the 2008 CALFED Mercury Project Final Report (Foe *et al.* 2008), and DWR Open Water Report (DiGiorgio *et al.* 2020). Task 2 of the 2008 CALFED Mercury Project Final Report also determined that about 50% of the incoming methylmercury load to the Delta is lost in-situ (Foe *et al.* 2008), compared to the DWR Open Water Report finding of an estimated 13% (DiGiorgio *et al.* 2020).

6.4.1 Climate Change

Comments from the ISRP for the DMCP Phase 1 control studies suggested that the Central Valley Water Board develop a climate change adaptation framework to update the DMCP (Branfireun *et al.* 2019). For the DMCP Review, Board staff determined that too much uncertainty surrounds the impacts of climate change on methylmercury cycling to incorporate a climate model in the methylmercury mass balance since the scale and direction of climate impacts will vary by location, water year, hydrological regime, and climate change projection. It would be especially challenging to quantify climate change impacts in the methylmercury source analysis and mass balance because methylmercury source and loss estimates were assessed individually and separately. A unified, conservative model of methylmercury sources and losses may allow for the incorporation of climate change impacts, but at the time of the DMCP Review, such a model for the entire Delta does not exist and creating one was not within the scope of the DMCP Review. However, Board staff anticipates that the inclusion of more recent years of methylmercury and flow data should account for some of the expected patterns in the next 100 years, which are described in more detail below for methylmercury loads and in the water balance for flows (Section 6.1.12).

In California, climate change is increasing temperatures and the frequency and severity of floods, droughts, and wildfires. The effects of climate change will have varied and competing consequences for mercury loading, methylation, and bioaccumulation, but likely will result in higher fish mercury concentrations (Ahonen *et al.* 2018; Kozak *et al.* 2021). As described in the *Draft Staff Report for Scientific Peer Review for the Amendment to the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California, Mercury Reservoir Provisions - Mercury TMDL and Implementation Program for Reservoirs*, increases in water temperature may stimulate primary production, which could have varying effects on fish mercury concentrations (Austin and Smitherman 2017). Field and laboratory experiments have shown that mercury concentrations in fish are significantly higher with predicted warming temperatures, most likely due to increased metabolic rates (Dijkstra *et al.* 2013).

Expected changes in weather include increased severity of drought and storms, reduced snowpack, and shifts in the timing of seasonal runoff (Dettinger 2011; DiGiorgio *et al.* 2020). It is unknown exactly how these changes will affect methylmercury production, degradation, and bioavailability. During flood years, it is expected that previously exposed and oxidized submerged sediments will produce more methylmercury (Ni *et al.* 2021). Increased flood duration, variability, and extent may increase methylmercury production in the Delta (DiGiorgio *et al.* 2020). Fluctuating water levels in upstream reservoirs may increase methylmercury loading from tributaries (Eckley *et al.* 2017). Intense floods would likely also increase erosion of mercury-bound sediments, runoff, and discharge of mercury from upstream tributaries, especially from areas affected by historical hydraulic gold mining. Future work to quantify the effects of climate change on methylmercury mass balances in the Delta could include accounting for more extreme floods by modifying flow and land cover used in the DMCP Review, and increasing the area of open water sediment flux using the Delta Science Program’s Flood Map.

Precipitation variability and the proportion of precipitation that falls as rain versus snow are expected to increase, but this should not substantially affect the methylmercury loading from atmospheric deposition (Branfireun *et al.* 2021). One of the major sources of atmospheric mercury is the practice of burning coal for energy. This practice will decrease with local and in-state efforts to control greenhouse gas emissions, therefore reducing this source of atmospheric mercury.

Wildfires release mercury into the atmosphere by burning sources like mercury enriched soil, vegetation, household, and industrial items containing mercury or previously atmospherically deposited mercury in the area. Mercury released by wildfires can then mobilize into the watershed during and after a storm event. Studies have found that mercury emissions increase with fire severity and depend on soil and forest type (Monohan and Keeble-Toll 2019; Webster *et al.* 2016). Future work to quantify these effects in methylmercury mass balances could include modifying DMCP Review land cover to represent increased erosion and runoff from burned areas and applying an expected percentage increase of intense wildfires to atmospheric deposition estimates. Webster and others (2016) estimated mercury emissions from forest fires across the entire Western United States, but more specific studies are needed to scale these effects to the Delta.

Photodegradation rates are related to light exposure and initial methylmercury concentration (Gill 2008c). Board staff is unable to predict future changes in aquatic and riparian vegetation cover and turbidity in open water habitat but increases in both of these factors would decrease photodegradation loss rates of methylmercury. For instance, the removal of invasive vegetation cover from Delta waterways would increase photodegradation. However, the proposed Delta Conveyance Project plans to reintroduce sediment to Delta waterways to increase turbidity for Delta smelt habitat, which could result in decreased photodegradation and impairment of beneficial uses (ICF 2022). Decreases in photodegradation would likely result in more methylmercury in outflows to the San Francisco Bay and exports to southern California.

Future increases in growth of photosynthetic organisms, also known as primary productivity, and subsequent decaying vegetation may deplete DO, increase sediment organic matter concentrations, and overall enhance methylmercury production (Austin and Smitherman 2017). Increased primary productivity may decrease fish mercury concentrations through algal bloom dilution and somatic growth dilution[123], or increase fish mercury concentrations from higher water column shading and thus lower photodegradation of methylmercury.

Sea level rise will result in increased saltwater intrusion in the Delta. Higher salinity will increase reduced sulfur in organic matter and sulfate in water, both of which affect mercury methylation, sequestration, and bioavailability (Branfireun *et al.* 2021). The Delta Science Program's Flood Map could be used to account for salinity intrusion under future sea level rise scenarios. Sea level rise is expected to continue to raise the water level in the Delta. The additional water may put more pressure on old and failing levees, resulting in levee breeches, more area of open water and tidal wetland habitat, and changes in upland land cover. Based on the DMCP Review methylmercury source analysis, more area of open water would increase open water sediment flux methylmercury loading in the Delta, while more area of tidal wetland habitat would

[123] Algal bloom dilution occurs when more algae in the system dilutes mercury levels in biota at the start of biomagnification, because zooplankton consume the same amount of algae regardless of how much there is (Pickhardt *et al.* 2005). Somatic growth dilution occurs when organisms experience a greater than proportional gain in biomass relative to toxicant concentrations when consuming food with high nutritional content (Peace *et al*. 2016).

decrease methylmercury loading in the Delta. Natural or historically mined mercury-bound sediments in areas influenced by sea level rise in the Delta would experience more wet-dry cycles and increase methylmercury loads.

Given the above scenarios, effects of climate change will likely increase methylmercury loading in the Delta. The uncertainties and variabilities in future conditions highlight the need for Delta-specific methylmercury management strategies to protect beneficial uses as environmental conditions change. Board staff continues to recommend the development of upstream control programs to reduce tributary mercury loading to the Delta.

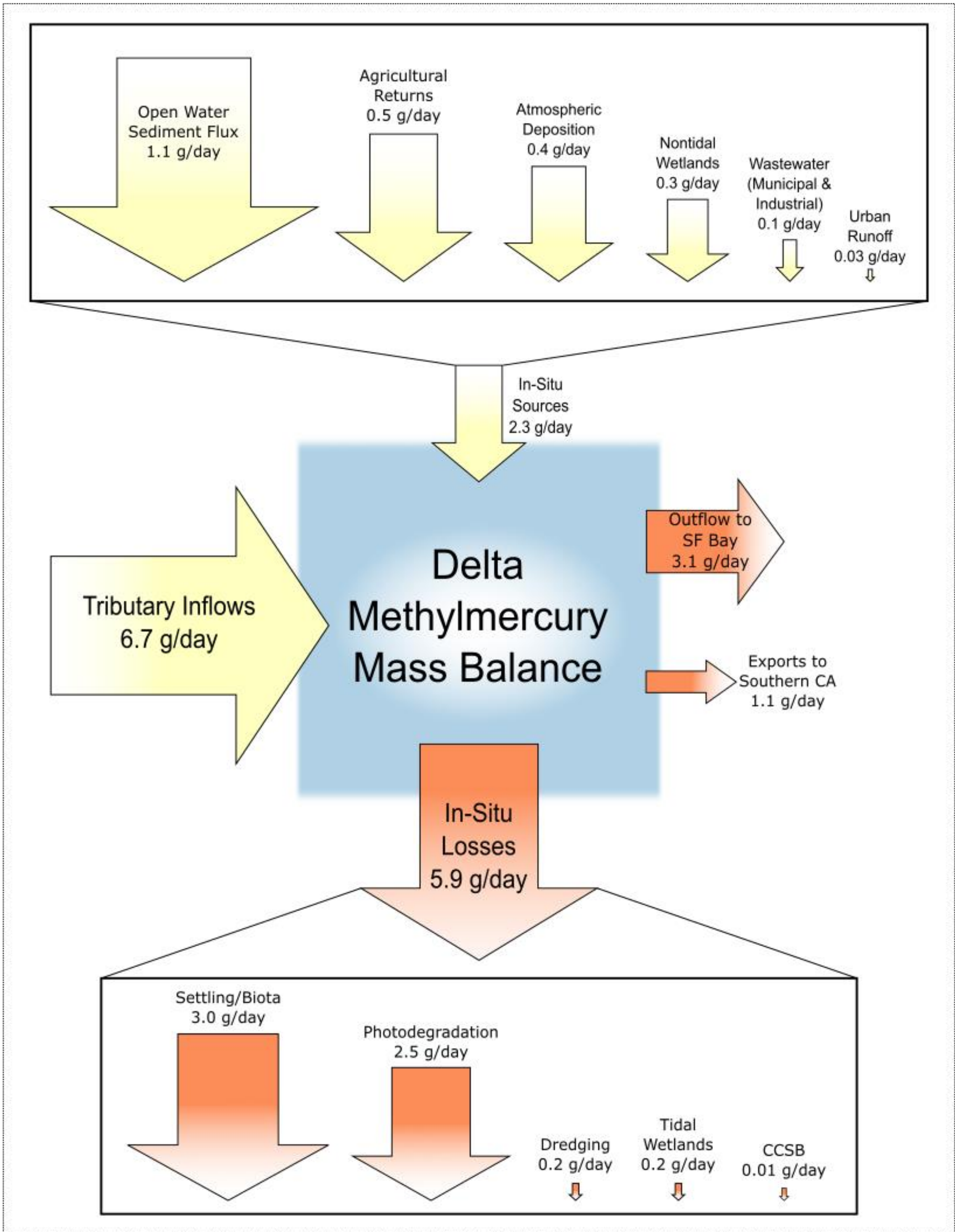

Figure 6.29: Methylmercury Mass Balance in the Delta Methylmercury TMDL Boundary

Table 6.46: DMCP Review Methylmercury Mass Balance in the Delta Methylmercury TMDL Boundary

Description	Type	Annual Load (g/yr)	Daily Load (g/day)	Daily Load (%)
Tributary Inflows	Source	2,459.999	6.740	74.48%
Open Water Sediment Flux	Source	391.344	1.072	11.85%
Agricultural Returns	Source	173.212	0.475	5.24%
Atmospheric Deposition	Source	140.617	0.385	4.26%
Nontidal Wetlands	Source	92.853	0.254	2.81%
Wastewater (Municipal & Non-Municipal)	Source	34.704	0.095	1.05%
Urban Runoff	Source	10.103	0.028	0.31%
Sum of Sources		**3,302.833**	**9.049**	**100.00%**
Outflow to San Francisco Bay (X2)	Loss	-1,121.370	-3.072	30.66%
Particle Settling & Accumulation in Biota	Loss	-1,087.000	-2.978	29.72%
Photodegradation	Loss	-924.059	-2.532	25.26%
Delta Mendota Canal	Loss	-220.024	-0.603	6.02%
California Aqueduct	Loss	-174.947	-0.479	4.78%
Dredging	Loss	-66.545	-0.182	1.82%
Tidal Wetlands	Loss	-60.533	-0.166	1.65%
Cache Creek Settling Basin	Loss	-3.415	-0.009	0.09%
Sum of Losses		**-3,657.893**	**-10.012**	**100.00%**
Mass Balance		**-355.060**	**-0.973**	**90.29%**

6.5 Key Points

- Sources of methylmercury in the Delta MeHg TMDL Boundary include tributary inflows from upstream watersheds and in-situ sources include open water sediment flux, agricultural returns, atmospheric deposition, nontidal wetlands, CCSB, municipal and non-municipal wastewater, and urban runoff. During the WYs 2000-2019 period, approximately 74% of identified methylmercury loading to the Delta came from tributary inputs while in-situ sources accounted for approximately 26% of the load.
- Losses of methylmercury in the Delta MeHg TMDL Boundary include outflow to San Francisco Bay, particle settling and uptake by biota, photodegradation, dredging, and exports to southern California. During the WYs 2000-2019 period, approximately 41% of identified methylmercury loss occurred outside the Delta while in-situ losses accounted for approximately 59% of the load. This indicates that the Delta is a net long-term sink for methylmercury.
- For WYs 2000-2019, the water balance equated to approximately 87% and the methylmercury balance equated to approximately 90%, indicating that the major water and methylmercury sources and losses have been identified.
- Board staff did not quantitatively account for climate change in the methylmercury source analysis but anticipate that the inclusion of more recent years of methylmercury and flow data should account for some of the expected patterns in the next 100 years.

7 SOURCE ANALYSIS – TOTAL MERCURY & SUSPENDED SEDIMENT

During the DMCP Review, Board staff considered updating the total mercury and suspended sediment (THg/TSS) source analysis, Section 7 of the 2010 TMDL Staff Report. After evaluation of the section, it was determined that an update to the THg/TSS source analysis was not necessary in the DMCP Review. A summary of the 2010 TMDL Staff Report's assessment is included below.

The DMCP addresses sources of methylmercury and total mercury impairment in the Delta by focusing on methylmercury controls and reductions. As described in the 2010 TMDL Staff Report, methylmercury was chosen as the WQO constituent of concern because it poses the biggest health risk to human and wildlife health. Since methylmercury is a function of total mercury concentrations in sediment, controlling and reducing THg and TSS transport will reduce methylation of sediment-bound mercury and bioaccumulation of methylmercury in the food web. Tributaries were identified as the largest source of THg to the Delta and Board staff maintains the total mercury allocation on upstream tributaries to the Delta is necessary. For these reasons, in the DMCP Review, Board staff did not feel it was necessary to update the THg/TSS source analysis but did include a reevaluation of the methylmercury source analysis in Section 6.

The 2010 TMDL Staff Report's THg/TSS source analysis determined and ranked potential sources of THg and TSS by load and relationship to methylmercury. A THg and TSS mass balance was developed, and reductions were assigned to upstream sources. Though this information is still useful for upstream mercury control programs, updating such information was not within the scope of the DMCP Review. Future upstream mercury control programs would provide updated and more detailed THg/TSS source analyses when programs are developed. Upstream control programs can have a narrower scope for individual watershed analyses and include appropriate mercury and suspended sediment management practices.

The 2010 TMDL Staff Report evaluated compliance with the San Francisco Bay Water Board's Mercury TMDL[124] that assigned a 330 kg/yr mercury allocation by implementing a total mercury load reduction of 110 kg/yr to the Central Valley watershed (SFBRWQCB 2006). Since the majority of total mercury loading to the Delta comes from tributary sources, the 2010 TMDL Staff Report applied the total mercury load reduction to tributary inputs to the Delta. Board staff identified tributary inputs as the primary source of THg loading to the Delta, with Sacramento River being the largest contributor (see Table 7.1 of the 2010 TMDL Staff Report). Board staff continue to recommend the development of future upstream control programs to reassess watershed specific THg and TSS source loading and the implementation of mercury and sediment controls to achieve compliance with the San Francisco Bay Water Board's

[124] The San Francisco Bay Water Board's Mercury TMDL was revised in 2007 with corrections that did not pertain to the mercury allocation or load reduction assigned to the Central Valley (SFBRWQCB 2007).

Mercury TMDL allocation. Specific compliance requirements, including timeframe, for the Central Valley watershed mercury allocation state:

> *Attainment of the load allocation shall be assessed as a five-year average annual mercury load 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.*
>
> *The allocation for the Central Valley watershed should be achieved within 20 years after the Central Valley Water Board begins implementing its TMDL load reduction program. Studies need to be conducted to evaluate the time lag between the remediation of mercury sources and resulting load reductions from the Delta. An interim loading milestone of 385 kg/yr of mercury, halfway between the current load and the allocation, should be attained ten years after implementation of the Central Valley Delta TMDL begins. This schedule will be reevaluated as the load reduction plans are implemented.* (SFBRWQCB 2006)

The 2010 TMDL Staff Report also evaluated compliance with the CTR total mercury drinking water criterion of 50 ng/L promulgated by the USEPA (40 CFR § 131.38(b)(1)), and assumed that achieving the 110 kg/yr total mercury reduction assigned by the San Francisco Bay Water Board will result in compliance with the CTR. Board staff maintained this assumption for the DMCP Review. If this assumption is later determined to be false, further reductions should be implemented through upstream control programs to reduce total mercury loading to the Delta.

The Basin Plan lists the WQOs for sediment in Section 3.1.15 and for turbidity in Section 3.1.21 (CVRWQCB 2019). Board staff ensured turbidity or sediment WQOs in the Basin Plan do not rely on a revision of the THg/TSS source analysis in the DMCP Review. Compliance, monitoring, and control methods for turbidity and sediment are regulated through project permits, such as NDPES, MS4, Waste Discharge Requirement, and 401 Water Quality Certifications.

The 2010 TMDL Staff Report recommended the implementation of upstream control programs prior to Phase 2 of the DMCP (see Section 8.2 of the 2010 TMDL Staff Report Section 8.2), but adequate upstream control programs have not yet been implemented. Revising the THg/TSS source analysis in the DMCP Review is not necessary to allocate THg reductions upstream or within the Delta MeHg TMDL Boundary. The 2010 TMDL Staff Report also recommended conducting watershed-specific source analyses for THg and TSS to update source loads, ranks, mass balances, and reductions; however, an upstream control program would be required and prioritized in future workplans. Board staff agrees with comments from control study entities that mercury modeling efforts should incorporate THg and TSS measurements to better understand each constituent's relationship with mercury. Such data should be site-specific to represent the mass balance more accurately.

Though Board staff determined the THg/TSS source analysis did not require updates in the DMCP Review, Board staff continues the recommendation from the 2010 TMDL Staff Report for a 110 kg/yr total mercury reduction assigned jointly to the tributaries that drain to the Delta. This recommendation supports compliance with the CTR total mercury drinking water criterion of 50 ng/L and the San Francisco Bay Water Board's 110 kg/yr total mercury reduction assigned to the Central Valley watershed. Board staff continues support the determination in the 2010 TMDL Staff Report that specific limits for individual watershed exports of THg and TSS should not be defined in the DMCP to allow greater flexibility in developing upstream control programs.

7.1 Key Points

For the DMCP Review, Board staff determined that revision of the total mercury and suspended sediment source analysis was not necessary for the following reasons:

- The 2010 TMDL Staff Report linkage analysis did not use total mercury or suspended sediment data to determine numeric targets for methylmercury.
- After review of recent literature, tributary sources are still the primary source of THg loading to the Delta, consistent with conclusions from the 2010 TMDL Staff Report's THg/TSS source analysis.
- Implementation of future upstream mercury control programs is necessary to comply with the San Francisco Bay Water Board's total mercury allocation to the Central Valley.
- Board staff recommends a 110 kg/yr total mercury reduction assigned jointly to Delta tributaries, consistent with recommendations in the 2010 TMDL Staff Report and in support of compliance with USEPA's CTR drinking water criterion and the San Francisco Bay Water Board's total mercury allocation to the Central Valley watershed.

8 METHYLMERCURY ALLOCATIONS, TOTAL MERCURY LIMITS, & MARGIN OF SAFETY

This section presents the DMCP Review recommended point (waste load) and nonpoint (load) methylmercury allocations for methylmercury sources to the Delta. Reductions in ambient water methylmercury concentrations are required to reduce methylmercury concentrations in fish. Section 8.1 describes the proposed methylmercury load and waste load allocations for within-Delta and tributary inputs, Section 8.2 reinstates the watershed total mercury limit recommendations from the 2010 TMDL Staff Report, and Section 8.3 describes the proposed margin of safety. Section 8.4 describes the effects of seasonal and inter-annual variability, including potential future conditions, on the DMCP Review proposed allocations.

8.1 Methylmercury Allocations

This section describes how Board staff calculated the proposed methylmercury load and waste load allocations for the DMCP Review.

8.1.1 Definition of Total Maximum Daily Load

Equation 8.1: TMDL, the Sum of Individual Allocations

$$TMDL = \Sigma Waste\ Load\ Allocations + \Sigma Load\ Allocations + Margin\ of\ Safety$$

A TMDL represents the sum of all individual allocations in a waterbody (Equation 8.1). Allocations are divided among “waste load allocations” (WLAs) for point sources and “load allocations” (LAs) for nonpoint sources, including natural background sources. The TMDL must be less than or equal to the waterbody’s assimilative capacity (Section 8.1.1.2). TMDLs must also account for seasonal variations in water quality and include a margin of safety to account for uncertainty in predicting how well pollutant reductions will result in meeting water quality standards (33 USC § 1313(d)(1)(C)). A TMDL need not be stated as a daily load; it can be expressed in other appropriate measures (40 CFR § 130.2(i)).

The 2010 TMDL Staff Report listed waste load allocations for discharges from existing and future NPDES WWTFs, MS4s, and load allocations for existing and future wetlands, open-water sediments, agricultural lands, and atmospheric deposition within the Delta and Yolo Bypass. Allocations were based on a mix of gross and net load estimates for methylmercury inputs: methylmercury net rate inputs for agricultural lands and wetlands; and methylmercury gross rate inputs for atmospheric deposition, open water sediment flux, tributaries, urban runoff, NPDES WWTFs, and NPDES MS4s. Natural background sources included atmospheric deposition, methylmercury flux from wetland sediments, methylmercury flux from open water sediments, and runoff from upland areas that existed prior to anthropogenic pollution emissions. Examples of human-related mercury pollution includes erosion and transport of mercury-contaminated sediments from historical mining activities in tributary watersheds; mercury in local and international industrial and municipal emissions; and water management activities. Board staff assumed load allocations for wetlands, open water, and atmospheric deposition incorporated natural background sources because data used in the 2010 TMDL Staff Report were limited and unable to distinguish nonpoint sources from natural background. All allocations were expressed in terms of average annual loads.

For the DMCP Review, Board staff used only annual gross median methylmercury loading from sources to and within the Delta MeHg TMDL Boundary, estimated using data from WYs 2000-2019. Thus, the Delta MeHg TMDL waste load allocations apply to discharges from permitted dredging activities, existing and future NPDES WWTFs, and existing and future NPDES MS4s within the Delta MeHg TMDL Boundary. Load allocations apply to agricultural returns, atmospheric deposition, open water, nontidal wetlands, tidal wetlands, Cache Creek Settling Basin, tributary inflows, and runoff from urban areas outside MS4 jurisdictions. Natural background sources include atmospheric deposition, methylmercury sediment flux from open water, and erosion from upland mercury mineral deposits that existed prior to anthropogenic pollution emissions. Though more data were available for the DMCP Review, natural background and nonpoint sources were indistinguishable for both atmospheric deposition and open water sediment flux.

Board staff proposes allocations for the DMCP Review (Section 8.1.3) in terms of median annual loads, which could be expressed in daily terms by dividing each allocation by 365. Median annual loads, rather than daily loads, should account for seasonal and long-term variability, reduce monitoring frequency requirements for dischargers while maintaining data reliability for compliance, and better represent fish tissue concentrations for attaining and maintaining fish tissue objectives.

Similar to the 2010 TMDL Staff Report, the TMDL methylmercury allocations were made in terms of the assimilative capacity in each of the Delta TMDL subareas.[125] In order to estimate a subarea's assimilative capacity, Board staff needed to determine the aqueous methylmercury concentration percent reduction required for each subarea to meet the proposed aqueous MeHg implementation goal. A subarea-specific methylmercury TMDL was developed because the sources and percent reductions are different in each Delta TMDL subarea. Section 8.1.1.1 describes methods Board staff used to determine percent reductions and Section 8.1.1.2 details estimating each subarea's assimilative capacity.

8.1.1.1 Subarea Percent Reduction

To determine Delta TMDL subarea percent reductions required to meet the aqueous MeHg implementation goal, subarea ambient aqueous methylmercury concentrations needed to be quantified. The amount of reduction needed in each subarea is expressed

[125] The 2010 TMDL Staff Report included methylmercury allocations jointly for the Yolo Bypass - North and Yolo Bypass - South, using the cumulative assimilative capacity for both Delta TMDL subareas. Board staff maintained this method in the DMCP Review.

as a percentage of the aqueous methylmercury concentration. Percent reductions for each Delta TMDL subarea are calculated using Equation 8.2, below.

Equation 8.2: Percent Reduction for Each Delta TMDL Subarea

$$\frac{Percent}{Reduction} = \left(1 - \left(\frac{Proposed\ Aq\ MeHg}{Imp\ Goal\ (ng/L)} \div \frac{Subarea\ Ambient}{MeHg\ Conc\ (ng/L)}\right)\right) \times\ 100\%$$

Where:

Proposed Aq MeHg Imp Goal = 0.059 ng/L
Subarea Ambient MeHg Conc = Ambient aqueous methylmercury concentration of each Delta TMDL subarea (ng/L)
100% = Conversion factor from decimal to percent (%)

In the 2010 TMDL Staff Report, the aqueous MeHg implementation goal for methylmercury in ambient water linked to fish tissue methylmercury targets was the annual average concentration of 0.06 ng/L (see Section 5 of the 2010 TMDL Staff Report), which included a 10% margin of safety. To determine Delta TMDL subarea ambient concentrations at the time, Board staff tested two scenarios that averaged available aqueous methylmercury concentration data. Scenario A used data from March 2000 to October 2000, which matched the linkage data used in Section 5 of the 2010 TMDL Staff Report. Scenario B used all available data at the time, from March 2000 to September 2004. Ultimately, Scenario B was used because it had a larger dataset that was more representative of seasonal variations and resulted in similar reductions as Scenario A. Though Scenario B was stated to have similar reductions as Scenario A, it was slightly more protective for the entire Delta MeHg TMDL Boundary.

For the DMCP Review, Board staff calculated two scenarios for percent reductions using similar methods to the 2010 TMDL Staff Report (Table 8.1). The proposed aqueous MeHg implementation goal of 0.059 ng/L calculated in Section 5.3, which includes a 3.3% margin of safety, was used. Scenario A used two methods for estimating Delta TMDL subarea methylmercury concentrations. The first method resulted in regressed median aqueous methylmercury concentrations for five subareas determined from the linkage model (Section 5.2, Table 5.1). The remaining three subarea methylmercury concentrations were estimated using the median of the five most recent years’, up to 2019, annual concentrations. Scenario B used all available aqueous methylmercury data for WYs 2000-2019. Delta TMDL subarea concentrations for Scenario B were determined by finding the daily median, then the water year median, and finally the median of all water years.

Board staff compared the two scenarios for the DMCP Review and recommend the use of the proposed reductions listed in Scenario B for the calculation of assimilative capacity. Scenario B includes a larger dataset that is more representative of seasonal, annual, and climactic variations because the 20-year dataset includes a greater mix of data from different water year hydrologic classifications (Table 6.2). Additionally, Scenario B has a greater reduction requirement within the Delta MeHg TMDL Boundary than Scenario A, which is more protective of human and wildlife health. These reasons are consistent with the 2010 TMDL Staff Report's justification for using Scenario B. Furthermore, Board staff recommends Scenario B for the DMCP Review because it uses one consistent method for calculating all subarea median concentrations.

Differences in Scenario B of the DMCP Review and 2010 TMDL Staff Report include the DMCP Review's use of medians instead of averages, and use of a larger dataset. Medians were used in the DMCP Review to maintain consistency with calculations of the linkage model (Section 5) and methylmercury source analysis (Section 6). The March 2000 to September 2004 dataset of the 2010 TMDL Staff Report percent reduction was a relatively dry period whereas the WYs 2000-2019 dataset for the DMCP Review is a longer period with mixes of wet and dry years.

Similar to the 2010 TMDL Staff Report, Board staff anticipates that as the median concentration of methylmercury in each Delta TMDL subarea decreases to the aqueous MeHg implementation goal, targets for fish tissue concentrations will be attained.

Additionally, Board staff calculated the WYs 2000-2019 Delta TMDL subarea average methylmercury concentrations for direct comparison to the 2010 TMDL Staff Report Scenario B average concentrations and the aqueous MeHg implementation goal of 0.06 ng/L (Table 8.2). The WYs 2000-2019 average concentrations for the Central Delta, Marsh Creek, Yolo Bypass - North and South subareas are greater than those listed in the 2010 TMDL Staff Report, leading Board staff to conclude that ambient concentrations have increased in these subareas. Concentrations for Mokelumne/Cosumnes Rivers, Sacramento River, San Joaquin River, and West Delta subareas have decreased by comparison, but none met the 2010 TMDL Staff Report's aqueous MeHg implementation goal of 0.06 ng/L.

Table 8.1: Aqueous Methylmercury Percentage Reductions Needed in Delta TMDL Subareas to Meet the DMCP Review Proposed Implementation Goal of 0.059 ng/L

Scenario	Delta TMDL Subarea	Aq. MeHg Conc. (ng/L)	Dataset Range (WYs)	Calculation Method	Percent Reduction Needed to Meet the Proposed MeHg Goal
A	Central Delta	0.068	2016-2019	Linkage Model Regressed Median	12.73%
A	Marsh Creek	0.237	2011-2014	Pooled Median	75.11%
A	Mokelumne/ Cosumnes Rivers	0.12	2017-2019	Linkage Model Regressed Median	50.85%
A	Sacramento River	0.091	2016-2019	Linkage Model Regressed Median	35.23%
A	San Joaquin River	0.086	2016-2019	Linkage Model Regressed Median	31.73%
A	West Delta	0.079	2018-2019	Linkage Model Regressed Median	24.93%
A	Yolo Bypass - North	0.185	2013-2017	Pooled Median	68.02%
A	Yolo Bypass - South	0.191	2015-2019	Pooled Median	69.11%
A	Yolo Bypass - North & South	0.175	2015-2019	Pooled Median	66.29%
B	Central Delta	0.088	2000-2001, 2003-2006, 2010, 2011, 2016-2019	Pooled Median	33.01%
B	Marsh Creek	0.196	2003-2004, 2011-2014	Pooled Median	69.90%
B	Mokelumne/ Cosumnes Rivers	0.108	2000-2001, 2003-2006, 2013-2014, 2017-2019	Pooled Median	45.37%
B	Sacramento River	0.089	2000-2019	Pooled Median	33.80%
B	San Joaquin River	0.133	2000-2007, 2011, 2016-2019	Pooled Median	55.52%
B	West Delta	0.062	2000-2011, 2013, 2015, 2018-2019	Pooled Median	4.07%
B	Yolo Bypass - North	0.192	2000-2001, 2003-2006, 2010-2017	Pooled Median	69.19%
B	Yolo Bypass - South	0.193	2000-2007, 2011, 2014-2019	Pooled Median	69.47%
B	Yolo Bypass - North & South	0.204	2000-2007, 2010-2019	Pooled Median	71.01%

Table 8.2: Comparison of 2010 TMDL Staff Report Scenario B Delta TMDL Subarea Concentrations and Aqueous MeHg Implementation Goal with WYs 2000-2019 Average Subarea Concentrations

Delta TMDL Subarea	2010 TMDL Staff Report Average Annual Aqueous MeHg Concentration (ng/L)	2010 TMDL Staff Report Aqueous MeHg Implementation Goal (ng/L)	WYs 2000-2019 Average Annual Aqueous MeHg Concentration (ng/L)
Central Delta	0.06	0.06	0.268
Marsh Creek	0.224	0.06	0.227
Mokelumne/ Cosumnes Rivers	0.166	0.06	0.140
Sacramento River	0.108	0.06	0.094
San Joaquin River	0.16	0.06	0.147
West Delta	0.083	0.06	0.069
Yolo Bypass - North & South	0.273	0.06	0.445

8.1.1.2 Subarea Assimilative Capacity

A waterbody's assimilative capacity represents the maximum rate of pollutant loading that the waterbody can acquire without violating water quality standards.

Equation 8.3: Assimilative Capacity, Assessed Per Delta TMDL Subarea

$$\begin{matrix}Assimilative \\ Capacity\,(g/yr)\end{matrix} = \begin{matrix}Source\ MeHg \\ Inputs\,(g/yr)\end{matrix} \times \left(100\% - \begin{matrix}Percent \\ Reduction\end{matrix}\right)$$

Where:

Source MeHg Inputs = Sum of all methylmercury source loads to and within a Delta TMDL subarea (g/yr)

Percent Reduction = Reduction percentage applied to the Delta TMDL subarea methylmercury concentration to meet the proposed aqueous MeHg implementation goal of 0.059 ng/L, found using Equation 8.2 (%)

Board staff used Equation 8.3 to calculate the assimilative capacity for each Delta TMDL subarea.

For the 2010 TMDL Staff Report, Board staff did not use the percent reduction for the West Delta subarea of 28% calculated in their Scenario B, instead assigning it a zero-percent reduction. Reasons for this include: the aqueous methylmercury concentration for the subarea required little reduction to meet the aqueous MeHg implementation goal; reductions of methylmercury concentrations from upstream Delta TMDL subareas would result in reduced concentrations of within-Delta flows to the West and Central Delta subareas; and implementation of upstream management practices from tributary watersheds would also result in reduced concentrations in all subareas. The 2010 TMDL Staff Report also includes these reasons for the recommendation of not assigning a percent reduction to the Central Delta subarea, even though their Scenario B determined a zero-percent reduction for the subarea.

To calculate the assimilative capacity of each Delta TMDL subarea in the DMCP Review, Board staff needed to quantify the subarea's methylmercury inputs based on the information determined in the methylmercury source analysis (Section 6). Table 8.3 through Table 8.9 display methylmercury gross source inputs for each subarea[126], not net loads which are listed in the methylmercury mass balance (Section 6.4). Sources like open water[127], tidal wetlands, and dredging are net sinks of methylmercury in the Delta, and sources like nontidal wetlands and agricultural returns have a loss aspect that reduces their net methylmercury loading to the Delta. Board staff recommends that these sources maintain or improve their methylmercury export rates, which may include reducing their methylmercury input loads or increasing their methylmercury export loads or both (Table 8.10). Sources with export rates greater than 100% in Table 8.10 are net

[126] Yolo Bypass - North and South subarea methylmercury inputs are not shown separately but as cumulative of the two subareas, displayed in Table 8.9.

[127] Board staff assumed open water acts as a net sink in the Delta due to methylmercury losses of particle settling, uptake by biota, and photodegradation. Section 6.2.2 details open water sediment flux methylmercury loading.

sinks of methylmercury because they remove more methylmercury from the Delta than discharge to the Delta.

Using percent reductions from Table 8.1 and methylmercury inputs from Table 8.3 through Table 8.9, Board staff was able to determine assimilative capacity for the Delta TMDL subareas (Table 8.11). Where the 2010 TMDL Staff Report applied zero-percent reductions for the Central and West Delta subareas, Board staff applied the calculated percent reductions in the DMCP Review Scenario B for both subareas. Because the Central Delta subarea average annual concentration increased by almost 450%, Board staff believes applying the percent reduction is necessary to reduce aqueous methylmercury concentrations. Though the annual average concentration in the West Delta subarea has decreased, Board staff recommends applying the percent reduction of 4.07% to ensure the trend continues towards attainment of the aqueous MeHg implementation goal and does not increase like the Central Delta subarea over time.

Similar to the 2010 TMDL Staff Report, the DMCP Review does not include an assessment of within-Delta flows between Delta TMDL subareas. Board staff evaluated available aqueous methylmercury and flow data in the DMCP Review, but sampling and gage locations were not synonymous with Delta TMDL subarea boundaries of waterways to determine in and outflow methylmercury loading between subareas.

Table 8.3: Methylmercury Gross Loads to the Central Delta Subarea

MeHg Source	**Specific Source**	**Annual Median MeHg Load (g/yr)**
Agricultural Returns		234.578
Atmospheric Deposition		54.660
Open Water		171.314
Nontidal Wetlands		12.720
Tidal Wetlands		90.973
Tributary Inflows	Bear/Mosher Creeks (includes Fivemile Creek and White Slough)	13.698
Tributary Inflows	Calaveras River (includes Stockton Diversion Canal)	7.309
Urban Runoff (nonpoint source)		0.109
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	28.807
NPDES WWTF	City of Lodi White Slough WPCF	0.043
NPDES WWTF	Discovery Bay WWTP	0.040
NPDES WWTF	Lincoln Center GWTS	0.007
NPDES MS4	Caltrans	0.100
NPDES MS4	City of Lodi	0.020
NPDES MS4	Contra Costa County	0.262
NPDES MS4	Port of Stockton	0.150
NPDES MS4	San Joaquin County and City of Stockton	1.299
Central Delta Subarea Total		**616.090**

Table 8.4: Methylmercury Gross Loads to the Marsh Creek Subarea

MeHg Source	Specific Source	Annual Median MeHg Load (g/yr)
Agricultural Returns		11.036
Atmospheric Deposition		0.818
Open Water		0.080
Nontidal Wetlands		0.050
Tidal Wetlands		0.000
Tributary Inflows	Marsh Creek	1.231
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	0.003
NPDES WWTF	City of Brentwood WWTP	0.089
NPDES MS4	Contra Costa County	0.658
Marsh Creek Subarea Total		**13.965**

Table 8.5: Methylmercury Gross Loads to the Mokelumne/Cosumnes Rivers Subarea

MeHg Source	Specific Source	Annual Median MeHg Load (g/yr)
Agricultural Returns		8.948
Atmospheric Deposition		1.286
Open Water		1.362
Nontidal Wetlands		5.749
Tidal Wetlands		2.783
Tributary Inflows	Mokelumne River (includes Cosumnes River and Dry Creek)	156.614
Urban Runoff (nonpoint source)		0.020
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	0.062
NPDES MS4	Caltrans	0.005
Mokelumne/ Cosumnes Rivers Subarea Total		**176.830**

Table 8.6: Methylmercury Gross Loads to the Sacramento River Subarea

MeHg Source	Specific Source	Annual Median MeHg Load (g/yr)
Agricultural Returns		220.948
Atmospheric Deposition		22.966
Open Water		64.787
Nontidal Wetlands		16.438
Tidal Wetlands		20.984
Tributary Inflows	Morrison Creek (includes Laguna Creek and Florin/Elder Creek)	7.501
Tributary Inflows	Sacramento River (includes American River and Steelhead Creek)	1,551.921
Urban Runoff (nonpoint source)		0.166
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	7.126
NPDES WWTF	City of Rio Vista Beach WWTF	0.017
NPDES WWTF	City of Rio Vista Northwest WWTF	0.007
NPDES WWTF	City of Sacramento CWWCTS	2.363
NPDES WWTF	Sacramento Regional WWTP	28.858
NPDES MS4	Caltrans	0.212
NPDES MS4	City of Rio Vista	0.031
NPDES MS4	City of West Sacramento	0.643
NPDES MS4	Sacramento Stormwater Quality Partnership	1.041
Sacramento River Subarea Total		**1,946.011**

Table 8.7: Methylmercury Gross Loads to the San Joaquin River Subarea

MeHg Source	Specific Source	Annual Median MeHg Load (g/yr)
Agricultural Returns		132.209
Atmospheric Deposition		9.586
Open Water		22.771
Nontidal Wetlands		4.779
Tidal Wetlands		9.516
Tributary Inflows	French Camp Slough (includes Duck Creek, Littlejohns Creek, and Walker Slough)	12.225
Tributary Inflows	San Joaquin River	260.056
Urban Runoff (nonpoint source)		0.324
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	0.962
NPDES WWTF	City of Lathrop CTF	0.069
NPDES WWTF	City of Manteca WWQCF	0.154
NPDES WWTF	City of Stockton Regional WWCF	1.970
NPDES WWTF	City of Tracy WWTP	0.265
NPDES WWTF	Deuel Vocational Institution WWTP	0.015
NPDES WWTF	Mountain House CSD WWTP	0.025
NPDES MS4	Caltrans	0.064
NPDES MS4	City of Lathrop	0.434
NPDES MS4	City of Manteca	0.015
NPDES MS4	City of Tracy	1.606
NPDES MS4	Deuel Vocational Institution	0.029
NPDES MS4	Mountain House Community Services District	0.184
NPDES MS4	Port of Stockton	0.001
NPDES MS4	San Joaquin County	0.464
NPDES MS4	San Joaquin County and City of Stockton	0.274
San Joaquin River Subarea Total		**457.996**

Table 8.8: Methylmercury Gross Loads to the West Delta Subarea

MeHg Source	Specific Source	Annual Median MeHg Load (g/yr)
Agricultural Returns		21.800
Atmospheric Deposition		25.882
Open Water		83.128
Nontidal Wetlands		11.146
Tidal Wetlands		102.375
Urban Runoff (nonpoint source)		0.007
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	10.867
NPDES WWTF	Ironhouse SD WRF	0.072
NPDES MS4	Caltrans	0.018
NPDES MS4	Contra Costa County	1.319
West Delta Subarea Total		**256.614**

Table 8.9: Methylmercury Gross Loads to the Yolo Bypass - North & South Subareas

MeHg Source	**Specific Source**	**Annual Median MeHg Load (g/yr)**
Agricultural Returns		140.990
Atmospheric Deposition		25.419
Open Water		47.902
Nontidal Wetlands		66.131
Tidal Wetlands		55.479
Cache Creek Settling Basin		69.931
Tributary Inflows	Cache Creek (above Cache Creek Settling Basin)	73.346
Tributary Inflows	Dixon Area	2.287
Tributary Inflows	Fremont Weir	174.201
Tributary Inflows	Putah Creek	36.199
Tributary Inflows	Ridge Cut Slough (Knights Landing)	124.379
Tributary Inflows	Sacramento Weir	18.608
Tributary Inflows	Upper Lindsey/Cache Slough Area (includes Barker Slough)	2.467
Tributary Inflows	Ulatis Creek	8.134
Tributary Inflows	Willow Slough	9.825
Urban Runoff (nonpoint source)		0.022
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	6.325
NPDES WWTF	City of Davis WWTP	0.614
NPDES WWTF	City of Woodland WPCF	0.097
NPDES MS4	Caltrans	0.039
NPDES MS4	City of Rio Vista	0.008
NPDES MS4	City of West Sacramento	0.574
Yolo Bypass - North & South Subarea Total		**862.975**

Table 8.10: Recommended Methylmercury Export Rates to be Maintained or Improved by Certain Sources per Delta TMDL Subarea

Source	Delta TMDL Subarea	Median MeHg Input to Subarea (g/yr)	Median MeHg Export from Subarea (g/yr)	Net Load (g/yr)	MeHg Export Rate[128]
Agricultural Returns	Central Delta	234.578	180.377	54.201	77%
Agricultural Returns	Marsh Creek	11.036	8.486	2.550	77%
Agricultural Returns	Mokelumne/ Cosumnes Rivers	8.948	6.880	2.067	77%
Agricultural Returns	Sacramento River	220.948	169.897	51.052	77%
Agricultural Returns	San Joaquin River	132.209	101.661	30.548	77%
Agricultural Returns	West Delta	21.800	16.763	5.037	77%
Agricultural Returns	Yolo Bypass - North & South	140.990	113.233	27.757	80%
Cache Creek Settling Basin	Yolo Bypass - North & South	69.931	73.346	-3.415	105%
Dredging	Central Delta	28.807	53.013	-24.206	184%
Dredging	Marsh Creek	0.003	0.007	-0.003	189%
Dredging	Mokelumne/ Cosumnes Rivers	0.062	0.118	-0.056	189%
Dredging	Sacramento River	7.126	19.799	-12.673	278%
Dredging	San Joaquin River	0.962	1.822	-0.860	189%
Dredging	West Delta	10.867	26.533	-15.667	244%
Dredging	Yolo Bypass - North & South	6.325	12.359	-6.034	195%
Nontidal Wetlands	Central Delta	12.720	2.626	10.094	21%
Nontidal Wetlands	Marsh Creek	0.050	0.010	0.039	21%
Nontidal Wetlands	Mokelumne/ Cosumnes Rivers	5.749	1.187	4.562	21%

[128] Methylmercury export rates in this table are the percentage of mass methylmercury removed (exports) from the mass methylmercury discharged (inputs) from the Delta TMDL subarea by the listed source (i.e., Export Rate = (Median MeHg Export ÷ Median MeHg Input) * 100%).

Source	Delta TMDL Subarea	Median MeHg Input to Subarea (g/yr)	Median MeHg Export from Subarea (g/yr)	Net Load (g/yr)	MeHg Export Rate[128]
Nontidal Wetlands	Sacramento River	16.438	3.394	13.044	21%
Nontidal Wetlands	San Joaquin River	4.779	0.987	3.792	21%
Nontidal Wetlands	West Delta	11.146	2.301	8.844	21%
Nontidal Wetlands	Yolo Bypass - North & South	66.131	13.654	52.477	21%
Tidal Wetlands	Central Delta	90.973	110.493	-19.520	121%
Tidal Wetlands	Marsh Creek	0.000	0.000	0.000	0%
Tidal Wetlands	Mokelumne/ Cosumnes Rivers	2.783	3.380	-0.597	121%
Tidal Wetlands	Sacramento River	20.984	25.487	-4.503	121%
Tidal Wetlands	San Joaquin River	9.516	11.558	-2.042	121%
Tidal Wetlands	West Delta	102.375	124.342	-21.967	121%
Tidal Wetlands	Yolo Bypass - North & South	55.479	67.383	-11.904	121%

Table 8.11: Assimilative Capacity Calculations for Each Delta TMDL Subarea

Delta TMDL Subarea	Annual Median MeHg Conc. (ng/L)	Percent Reduction Need to Achieve Proposed Goal of 0.059 ng/L	Annual Median MeHg Load from Identified Sources (g/yr)	Assimilative Capacity (g/yr)
Central Delta	0.088	33.01%	616.090	412.709
Marsh Creek	0.196	69.90%	13.965	4.204
Mokelumne/ Cosumnes Rivers	0.108	45.37%	176.830	96.601
Sacramento River	0.089	33.80%	1,946.011	1,288.243
San Joaquin River	0.133	55.52%	457.996	203.711
West Delta	0.062	4.07%	256.614	246.183
Yolo Bypass - North & South	0.204	71.01%	862.975	250.199
Yolo Bypass - North	0.192	69.19%	581.019	179.009
Yolo Bypass - South	0.193	69.47%	281.956	86.082

8.1.2 Allocation Strategy

The allocation strategy used for the DMCP Review largely mimics the allocation strategy described in Section 8.1.2 of the 2010 TMDL Staff Report, described below.

The main similarities are:

- Atmospheric deposition was not given a load allocation reduction requirement (i.e., a 100% load allocation) resulting in the load allocation for all Delta TMDL subareas being set equal to the annual methylmercury load.
- Waste load and load allocations account for expected expansions to existing and new sources.
- Waste load allocations account for point sources whose effluent methylmercury concentration is below the aqueous methylmercury goal and provide a discharger-specific waste load allocation for future growth.
- Waste load allocations require improvement of discharges with methylmercury concentrations greater than the aqueous methylmercury goal but are not required to improve below the aqueous methylmercury goal.

The main differences in the DMCP Review are:

- Discharges from nonpoint source urban areas, which are urban areas outside of an MS4 jurisdiction, have load allocation reduction requirements. The 2010 TMDL Staff Report did not recommend load allocation reductions for urban areas outside of an MS4 jurisdictional area.
- All Delta TMDL subareas were determined to require a reduction in ambient aqueous methylmercury concentrations to meet the aqueous MeHg implementation goal. Whereas the 2010 TMDL Staff Report used zero-percent reductions for the Central and West Delta subareas as described in Section 8.1.1.2.
- All point and nonpoint sources with a methylmercury concentration greater than the aqueous MeHg implementation goal were given a reduction in each subarea. In the 2010 TMDL Staff Report all point and nonpoint sources in the Central and West Delta subareas had waste load and load allocations set at their average annual methylmercury load regardless of their methylmercury concentration.
- Allocations are based on gross loads from existing sources, whereas the 2010 TMDL Staff Report used a mix of gross and net loads of existing sources.
- Atmospheric deposition load allocations apply to precipitation methylmercury loading over all land cover types except urban. The 2010 TMDL Staff Report did not include atmospheric deposition over agricultural lands, open water, and wetlands.
- Unassigned NPDES allocations were allotted for WWTFs that do not operate under an NPDES permit and MS4s that do not have urban land cover within their jurisdictional boundary and within the Delta MeHg TMDL Boundary at the time of

the DMCP Review. This allocation is for existing WWTFs and MS4s that are not evaluated in the DMCP Review and those that do not yet exist. The 2010 TMDL Staff Report allotted unassigned NPDES allocations for facilities only.

8.1.3 Percent Allocation Calculations

This section describes how Board staff calculated methylmercury allocations for the DMCP Review. Board staff used the following steps, in order, to determine the allocations:

1. Set pre-determined allocations for applicable sources (see Section 8.1.3.1).
2. Calculated allocations for NPDES WWTFs, NPDES MS4s, and nonpoint source urban runoff with a median annual methylmercury concentration less than aqueous MeHg implementation goal (see Sections 8.1.3.2.2 and 8.1.3.3.1).
3. Calculated future growth allocations for NPDES WWTFs (see Section 8.1.3.2.2).
4. Calculated Unassigned NPDES Allocations for WWTFs, and MS4s (see Sections 8.1.3.2.4 and 8.1.3.3.3).
5. Calculated first iteration of percent allocations for all remaining sources, including NPDES WWTFs, and MS4s, and nonpoint source urban runoff with median annual methylmercury concentrations greater than the aqueous MeHg implementation goal (see Sections 8.1.3.4, 8.1.3.2.3, 8.1.3.3.2).
6. If the first iteration of the percent allocation, Step 5, required an applicable source to reduce its methylmercury concentration below the aqueous MeHg implementation goal, a delimited allocation was calculated for that source (see Section 8.1.3.4).
7. Calculated subsequent iterations of percent allocations repeating Steps 5 and 6 as necessary, until all applicable delimited percent allocations are set (see Section 8.1.3.4).

8.1.3.1 Pre-determined Allocation Calculations

The term "pre-determined allocation" refers to sources of methylmercury whose allocation is set equal to 100% of their calculated methylmercury load (Equation 8.4).

Equation 8.4: Pre-Determined Allocation

$$\begin{matrix}\textit{Pre-Determined MeHg} \\ \textit{Allocation}\ (g/yr)\end{matrix} = \begin{matrix}\textit{Pre-Determined} \\ \textit{Percent Allocation}\end{matrix} \times \begin{matrix}\textit{Median Annual} \\ \textit{MeHg Load}\ (g/yr)\end{matrix}$$

Where:

Pre-Determined Percent Allocation = 100%
Median Annual MeHg Load = A source's estimated median annual methylmercury load from available data in WYs 2000-2019 (g/yr)

In the 2010 TMDL Staff Report, pre-determined allocations were set for atmospheric deposition, urban runoff from outside of MS4 jurisdictional areas, all sources in the

Central Delta subarea, all sources in the West Delta subarea, NPDES WWTFs, whose annual average methylmercury concentration was less than the aqueous methylmercury implementation goal of 0.06 ng/L, NPDES WWTFs with future growth, and unassigned NPDES WWTFs allocations.

For the DMCP Review, pre-determined allocations were set for atmospheric deposition, open water sediment flux, tidal wetlands, dredging, NPDES WWTFs whose median methylmercury concentration was less than the proposed aqueous methylmercury implementation goal of 0.059 ng/L, NPDES WWTFs with future growth, and unassigned NPDES allocations. Additional similarities and differences between the 2010 TMDL Staff Report and the DMCP Review are described below.

Atmospheric deposition, NPDES WWTFs whose median methylmercury concentration was less than 0.059 ng/L, NPDES WWTFs with future growth, and unassigned NPDES allocations were given a pre-determined allocation consistent with 2010 TMDL Staff Report.

Pre-determined allocations were set for the gross loads of open water sediment flux, tidal wetlands, and dredging because open water habitat, tidal wetlands, and dredging activities were determined to be net sinks of methylmercury in the Delta. Details on how open water habitat was determined to be a net sink in the Delta can be found in Section 6.4. Section 6.3.6 describes the estimated methylmercury loss in tidal wetlands. Dredging methylmercury loss estimates are detailed in Section 6.3.5.

Board staff determined that urban runoff from outside of MS4 jurisdictional areas, appropriate sources in the Central Delta subarea, and appropriate sources in the West Delta subarea needed percent allocations applied in the DMCP Review. Nonpoint source urban runoff was not given a pre-determined allocation to maintain a consistent percent allocation method for all urban land cover runoff discharges within the Delta MeHg TMDL Boundary (Section 8.1.3.3). Because percent reductions were applied to the Central and West Delta subareas in the DMCP Review (Section 8.1.1.1), not all sources in these subareas were given a pre-determined allocation like in the 2010 TMDL Staff Report. Thus, applicable sources in these subareas are required to reduce methylmercury loading to meet each subarea’s respective assimilative capacity (Section 8.1.1.2).

8.1.3.2 NPDES WWTFs

This section describes how Board staff calculated NPDES WWTFs waste load allocations for the DMCP Review.

8.1.3.2.1 Population Growth

Anticipated population growth could result in increases in methylmercury loading to the Delta. For example, increasing populations may result in more urbanization and increase flow volumes from municipal facilities, which will increase methylmercury loading even if the discharge concentration is below the aqueous MeHg implementation goal.

The California Department of Finance (CDOF) predicts that populations in counties within the Delta MeHg TMDL Boundary will increase between 17% to 43% by 2060 (CDOF c2023)[129], with a median increase of 25%. This median percent of growth was used to calculate future growth methylmercury allocations for NPDES WWTFs with effluent methylmercury concentrations less than the aqueous MeHg implementation goal and the unassigned methylmercury allocations for NPDES WWTFs (Section 8.1.3.2.4).

8.1.3.2.2 Facilities with a Median Methylmercury Concentration Less than the Proposed Aqueous MeHg Implementation Goal of 0.059 ng/L

As described in Section 6.2.4, there are 17 NPDES WWTFs discharging to surface waters within the Delta MeHg TMDL Boundary. Table 8.12 shows the 12 facilities that have a median effluent methylmercury concentration less than 0.059 ng/L. This indicates that some discharges, though they contribute methylmercury loading to the Delta, may act as dilution because of their low methylmercury concentration.

As proposed in the 2010 TMDL Staff Report, Board staff recommends that the facilities with median methylmercury concentrations below the proposed aqueous MeHg implementation goal be considered dilution, be assigned a pre-determined allocation based on their median annual methylmercury load, and be allotted an additional waste load allocation to accommodate future growth. To calculate the additional waste load allocation for future growth, Board staff used the specific facility's estimated methylmercury concentration and assumed that the median flow may increase up to 50%[130]. Thus, the facilities listed in Table 8.12 were given a future growth methylmercury allocation equivalent to half of their assigned waste load allocation, except for the DVI and City of Lathrop CTF.

As discussed in Section 6.2.4.3, the DVI plans to remain minimally staffed without inmates for an estimated five years and then move towards complete closure. Accordingly, the DVI was not given a future growth allocation.

The City of Lathrop CTF previously discharged to land but was given an NPDES permit in 2022 (Central Valley Water Board Order R5-2022-0004) allowing discharge to the San Joaquin River. At the time of the DMCP Review, the facility had not begun discharging to the San Joaquin River and did not have corresponding monitoring or flow data. Therefore, methylmercury loading for the City of Lathrop CTF was determined using the effluent aqueous methylmercury concentrations discharged to land provided in the NPDES permit application effluent characterization study, and the NPDES permitted flow of 2.5 MGD. The facility's median methylmercury concentration was less than the aqueous MeHg implementation goal and Board staff assumed the effluent methylmercury concentrations historically discharged to land will be representative of the effluent concentrations when surface water discharge begins. Because the City of

[129] The CDOF predicts the following population increases by 2060: Alameda County - 17%, Contra Costa County - 18%, Sacramento County - 27%, San Joaquin County - 28%, Solano County - 24%, and Yolo County - 43% (CDOF c2023).

[130] The median predicted population growth of 25% was doubled to obtain 50%.

Lathrop CTF's median effluent methylmercury concentration was below the aqueous MeHg implementation goal, the facility was also given a methylmercury allocation for future growth. However, this allocation was calculated based on a future expansion permitted flow limit of 6 MGD, as evaluated in their antidegradation analysis. Therefore, the flow volume used for their future growth allocation is 3.5 MGD (6 MGD minus 2.5 MGD), rather than 50% of their estimated flow.

8.1.3.2.3 Facilities with a Median Methylmercury Concentration Greater than the Proposed Aqueous MeHg Implementation Goal of 0.059 ng/L

To calculate allocations for NPDES WWTFs with effluent methylmercury concentrations greater than 0.059 ng/L, Board staff used the median methylmercury concentration, median effluent flow, and percent allocation calculation method described in Section 8.1.3.4.

Although these facilities may need to increase their effluent volume due to future population growth, an effluent volume increase at their effluent concentration would increase their methylmercury load and potentially worsen the methylmercury impairment. The discharge volume from a NPDES WWTF that has a median effluent methylmercury concentration greater than the aqueous MeHg implementation goal could increase their flow volume so long as its methylmercury load does not increase. This approach is consistent with State Water Board Resolution No. 2005-0060, which required the San Francisco Bay Water Board to incorporate provisions in the San Francisco Bay Mercury TMDL and associated implementation plan 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. Thus, methylmercury allocations for these WWTFs listed in Table 8.3 through Table 8.9 include expected future population growth and associated increase of effluent volume.

The City of Sacramento CWWCTS is the only NPDES WWTF to discharge at two locations within the Delta MeHg TMDL Boundary. The 2010 TMDL Staff Report concluded the methylmercury concentrations for the two discharge locations (EFF-002 and EFF-006) were not statistically different and used the average methylmercury concentration and average annual flow volume to determine the methylmercury load. In the DMCP Review, Board staff used a significance level of 0.05 ($\alpha = 0.05$) to determine that the median methylmercury concentrations of the two discharge locations also were not significantly different ($p = 1$), but the annual flow volumes were statistically different ($p = 0.047$). Therefore, the methylmercury concentration and flow data were not pooled as in the 2010 TMDL Staff Report. Instead, methylmercury loading was determined by calculating the methylmercury load for each discharge location and adding the methylmercury loads together.

8.1.3.2.4 Unassigned NPDES WWTF Methylmercury Allocations

Consistent with the 2010 TMDL Staff Report, Board staff calculated unassigned NPDES methylmercury allocations for each Delta TMDL subarea (Table 8.13) to account for any

NPDES WWTFs that are not listed in Table 8.3 through Table 8.9. These WWTFs are expected to be designed to discharge effluent with methylmercury concentrations equal to or less than 0.059 ng/L, the aqueous MeHg implementation goal. Annual effluent volumes were estimated based on the median predicted population growth of counties within the Delta MeHg TMDL Boundary from 2020 to 2060, which is 25% (Section 8.1.3.2.1). The unassigned NPDES methylmercury allocations for WWTFs were calculated by multiplying the predicted annual effluent volumes shown in Table 8.13 by 0.059 ng/L of methylmercury.

Table 8.12: Calculation of Future Growth Methylmercury Allocations Allowed for Dischargers with a Median Methylmercury Concentration Less than the Aqueous MeHg Implementation Goal

Delta TMDL Subarea	Discharger	Facility	Median MeHg Conc. (ng/L)	Effluent Volume (MGD)	Projected Effluent Volume for Future Growth (MGD)	MeHg Allocation for Future Growth (g/yr)
Central Delta	Discovery Bay CSD, Town of	Discovery Bay WWTP	0.026	1.107	0.554	0.020
Central Delta	Lodi, City of	White Slough Water Pollution Control Facility	0.020	1.561	0.780	0.022
Marsh Creek	Brentwood, City of	Wastewater Treatment Plant	0.020	3.227	1.613	0.045
Sacramento River	Rio Vista, City of	Beach Wastewater Treatment Facility	0.030	0.399	0.200	0.008
Sacramento River	Rio Vista, City of	Northwest WWTF	0.020	0.259	0.130	0.004
San Joaquin River	CA Dept of Corrections and Rehabilitation	Deuel Vocational Institution	0.023	0.476	NA	NA
San Joaquin River	Lathrop, City of	Consolidated Treatment Facility	0.020	2.500	3.5000	0.097
San Joaquin River	Manteca, City of	Wastewater Quality Control Facility	0.020	5.571	2.785	0.077
San Joaquin River	Mountain House CSD	Wastewater Treatment Plant	0.020	0.900	0.450	0.012
San Joaquin River	Tracy, City of	Wastewater Treatment Plant	0.020	9.588	4.794	0.132
West Delta	Ironhouse SD	Water Recycling Facility	0.020	2.592	1.296	0.036
Yolo Bypass - North	Woodland, City of	Water Pollution Control Facility	0.020	3.524	1.762	0.049

Table 8.13: Calculation of Unassigned NPDES Methylmercury Allocations for NPDES WWTFs Not Assessed in the DMCP Review

Delta TMDL Subarea	Total Effluent Volume of Assessed NPDES WWTFs (MGD)	Projected Total Effluent Volume for NPDES WWTFs Not Assessed in DMCP Review (MGD)	Unassigned NPDES WWTFs MeHg Allocation (g/yr)
Central Delta	2.668	0.667	0.054
Marsh Creek	3.227	0.807	0.066
Sacramento River	124.310	31.077	2.533
San Joaquin River	42.407	10.602	0.864
West Delta	2.592	0.648	0.053
Yolo Bypass - North	4.108	1.027	0.084
Total	**179.311**	**44.828**	**3.654**

8.1.3.3 NPDES MS4 & Urban Runoff (Nonpoint Source) Methylmercury Allocations

The 2010 TMDL Staff Report used the wet weather average concentration of 0.241 ng/L, rounded to 0.24 ng/L, as the average annual methylmercury concentration for all MS4s and nonpoint source urban runoff (see Table 6.11 of the 2010 TMDL Staff Report). For the DMCP Review, Board staff used the weighted annual median methylmercury concentrations estimated in Section 6.2.6.5. These concentrations were weighted by the number of days per annual dry and wet weather periods that were used to estimate runoff volumes: 305 days of dry weather and 60 days of wet weather. To maintain consistency, Board staff calculated MS4 and nonpoint source urban runoff allocations using similar methods as NPDES WWTFs allocations (Section 8.1.3.2). This section describes how Board staff calculated NPDES MS4 waste load allocations and nonpoint source urban runoff load allocations for the DMCP Review.

8.1.3.3.1 MS4s & Urban Runoff (Nonpoint Source) with a Median Methylmercury Concentration Less than the Proposed Aqueous MeHg Implementation Goal of 0.059 ng/L

Neither MS4s, nor nonpoint source urban runoff, had a weighted annual median methylmercury concentration less than 0.059 ng/L, so no pre-determined or future growth allocations were assigned.

8.1.3.3.2 MS4s & Urban Runoff (Nonpoint Source) with a Median Methylmercury Concentration Greater than the Proposed Aqueous MeHg Implementation Goal of 0.059 ng/L

Allocations for MS4s and nonpoint source urban runoff with weighted annual median methylmercury concentrations greater than 0.059 ng/L were calculated using methods described in Section 8.1.3.4.

Population growth is expected to expand urban areas in the Delta and increase urban runoff volumes; therefore, additional runoff volumes at the estimated annual median methylmercury concentration would increase the methylmercury load and potentially worsen the methylmercury impairment in the Delta. However, urban runoff volumes may increase so long as the methylmercury load does not increase. Thus, the methylmercury allocations for MS4s and nonpoint source urban runoff listed in Table 8.3 through Table 8.9 include expected future urbanization and associated increase of urban runoff.

8.1.3.3.3 Unassigned NPDES Methylmercury Allocations for MS4s not Assessed in DMCP Review

The 2010 TMDL Staff Report did not include an unassigned allocation for MS4s. Anticipated population growth could result in additional methylmercury loading to the Delta by increasing urban acreage and associated runoff for MS4s not assessed in the DMCP Review.

Since adoption of the 2010 TMDL Staff Report, urban expansion has occurred in the Delta resulting in new urban areas within jurisdictional areas of three Phase II MS4s that were not assessed or assigned an allocation. To incorporate expansions of other MS4s not currently assigned waste load allocations in the DMCP Review, Board staff estimated expected urbanization by comparing the urban acreages from the 2010 TMDL Staff Report and DMCP Review datasets.

The 2010 TMDL Staff Report estimated approximately 55,603 acres of urban land cover in the Delta using DWR land use surveys from 1993 to 2003. In the DMCP Review, Board staff reevaluated land cover using land cover data from 1993 to 2021 and determined about 65,237 acres of urban lands within the Delta MeHg TMDL Boundary, similarly excluding the CCSB. This is a difference of 9,634 acres.

Using the end dates of both datasets, Board staff assumed urban growth occurred linearly in the Delta from 2003 to 2021. Meaning, the 17.33% increase of urban area from the 2003 dataset of 9,634 acres was created evenly over the 18-year period at a rate of 0.96% increase each year. Board staff used this rate to calculate the anticipated urbanization of 24,490 acres within the Delta MeHg TMDL Boundary by 2060.

Board staff used the ratio of Phase II MS4 urban areas to all urban areas within each Delta TMDL subarea to estimate the expected urban area growth of about 7,092 acres for MS4s not evaluated in the DMCP Review (Table 8.14). Using this expected urban area growth acreage and the aqueous MeHg implementation goal of 0.059 ng/L, Board staff updated the dry weather and wet weather loads from Section 6.2.6.5.

The expected dry weather load was calculated to be about 0.043 g/yr by using Equation 6.2, the new urban acreage estimate, and the aqueous MeHg implementation goal.

In Section 6.2.6.4, wet weather urban runoff was estimated using precipitation gages and urban land cover type runoff coefficients. Since urban land cover type of future urban growth is unknown, Board staff used the aqueous MeHg implementation goal and the wet weather runoff volume for Phase II MS4s estimated in Table 6.27 to determine what the WYs 2000-2019 annual loads would be if concentrations were at the aqueous MeHg implementation goal. This load was then divided by their individual urban acreage per Delta TMDL subarea to create a methylmercury load rate per acre. This rate was multiplied by the new urban acreage growth expected in Delta TMDL subareas that have Phase II MS4s to get the expected methylmercury wet weather load of about 0.202 g/yr within the Delta MeHg TMDL Boundary by 2060.

In total, Board staff estimates loading of any MS4 not assessed in the DMCP Review by 2060 to be about 0.244 grams of methylmercury per year. These loads per subarea were used for the unassigned NPDES methylmercury allocations for MS4s and added to the Unassigned NPDES methylmercury Allocations listed in Table 8.3 through Table 8.9.

Table 8.14: Calculation of Unassigned Methylmercury Allocations for MS4s not Assessed in the DMCP Review

Delta TMDL Subarea	Expected Urban Area Growth of MS4s not Assessed in DMCP Review (ac)	Expected MeHg Dry Weather Load by 2060 (g/yr)	Expected MeHg Wet Weather Load by 2060 (g/yr)	Expected Annual MeHg Load by 2060 (g/yr)
Central Delta	30.285	0.000	0.002	0.002
Sacramento River	1,176.684	0.007	0.069	0.076
San Joaquin River	4,891.860	0.029	0.071	0.100
Yolo Bypass - North	981.771	0.006	0.059	0.065
Yolo Bypass - South	12.234	0.000	0.001	0.001
Total	**7,092.835**	**0.043**	**0.202**	**0.244**

8.1.3.4 Remaining Sources Percent Allocations

This section details how percent allocations were calculated for each Delta TMDL subarea. Percent allocations were assigned to sources of methylmercury in the Delta that did not have a pre-determined allocation (Section 8.1.3.1), were not an NPDES WWTF with a median annual methylmercury concentration less than the aqueous MeHg implementation goal (Section 8.1.3.2.2), were not an NPDES MS4 or nonpoint source urban runoff with a median annual methylmercury concentration less than the aqueous MeHg implementation goal (Section 8.1.3.3.1), or were not an Unassigned NPDES allocation (Sections 8.1.3.2.4 and 8.1.3.3.3).

Equation 8.5: First Iteration of Percent Allocation

$$\begin{matrix}\textit{Percent Allocation}\\ (\textit{first iteration})\end{matrix} = \frac{\begin{matrix}\textit{Assimilative}\\ \textit{Capacity}\ (g/yr)\end{matrix} - \sum \begin{matrix}\textit{Pre-Determined MeHg}\\ \textit{Allocations}\ (g/yr)\end{matrix}}{\sum \begin{matrix}\textit{All Median Annual}\\ \textit{MeHg Loads}\ (g/yr)\end{matrix} - \sum \begin{matrix}\textit{Median Annual MeHg Loads}\\ \textit{of Pre-Determined}\\ \textit{MeHg Allocations}\ (g/yr)\end{matrix}} \times 100\%$$

Where:

Assimilative Capacity = A subarea's maximum pollutant loading capacity without violating water quality standards, calculated using Equation 8.3 (g/yr)
Σ Pre-Determined MeHg Allocations = Sum of all pre-determined methylmercury allocations per subarea, calculated using Equation 8.4 (g/yr)
Σ All Median Annual MeHg Loads = Sum of median annual methylmercury loads of all sources per subarea (g/yr)
Σ Median Annual MeHg Loads of Pre-Determined Allocations = Sum of median annual methylmercury loads of sources with a pre-determined allocation (g/yr)
100% = Conversion factor from decimal to percent (%)

Consistent with the 2010 TMDL Staff Report, sources without a pre-determined allocation were assigned a percent allocation determined by Equation 8.5. This is the first iteration of the percent allocation calculation for each Delta TMDL subarea and the results were used to calculate the methylmercury allocation concentration and methylmercury allocation.

Equation 8.6: Methylmercury Allocation Concentration

$$\begin{matrix}\textit{MeHg Allocation}\\ \textit{Conc.}\ (ng/L)\end{matrix} = \begin{matrix}\textit{Median Annual}\\ \textit{MeHg Conc.}\ (ng/L)\end{matrix} \times \begin{matrix}\textit{Percent}\\ \textit{Allocation}\end{matrix}$$

Where:

Median Annual MeHg Conc. = A source's median annual methylmercury concentration from WYs 2000-2009 (ng/L)
Percent Allocation = Percentage resulting from Equation 8.5 for the first iteration or Equation 8.9 for subsequent iterations (%)

Board staff used the resulting percent allocation to calculate a source's methylmercury allocation concentration in Equation 8.6, if applicable. The methylmercury allocation concentration is the estimated concentration the source needs at their median annual flow to achieve the assigned methylmercury allocation. Sources like agricultural returns and nontidal wetlands do not have a median annual methylmercury concentration specific to each subarea and therefore do not have a methylmercury allocation concentration.

Consistent with the 2010 TMDL Staff Report, neither NPDES WWTFs, nor MS4 are required to reduce their median annual methylmercury concentrations to less than the aqueous MeHg implementation goal of 0.059 ng/L. For the DMCP Review, Board staff extended this to also include urban runoff nonpoint sources. Thus, if Equation 8.6 resulted in a concentration less than 0.059 ng/L for an NPDES WWTF, MS4, or urban runoff nonpoint source, Board staff set the methylmercury allocation concentration at 0.059 ng/L. The percent allocation for these sources was delimited (i.e., having a fixed limit) at the aqueous MeHg implementation goal, described below.

Equation 8.7: Delimited Percent Allocation

$$\begin{matrix} Delimited \\ Percent\ Allocation \end{matrix} = \begin{matrix} Proposed\ Aq\ MeHg \\ Imp\ Goal\ (ng/L) \end{matrix} \div \begin{matrix} Median\ Annual \\ MeHg\ Conc.\ (ng/L) \end{matrix} \times 100\%$$

Where:

Proposed Aq MeHg Imp Goal = 0.059 ng/L
Median Annual MeHg Conc. = A source's median annual methylmercury concentration from WYs 2000-2009 (ng/L)
100% = Conversion factor from decimal to percent (%)

Using the aqueous MeHg implementation goal as the methylmercury allocation concentration for these sources, Board staff determined a delimited percent allocation using Equation 8.7. The delimited percent allocation was used to calculate these source's methylmercury allocation, as detailed below.

Equation 8.8: Methylmercury Allocation for Sources with Delimited Percent Allocation

$$\begin{matrix} MeHg \\ Allocation\ (g/yr) \end{matrix} = \begin{matrix} Median\ Annual \\ MeHg\ Load\ (g/yr) \end{matrix} \times \begin{matrix} Delimited \\ Percent\ Allocation \end{matrix}$$

Where:

Median Annual MeHg Load = Median annual methylmercury load of source (g/yr)
Delimited Percent Allocation = Percentage resulting from Equation 8.7 (%)

Board staff applied the delimited percent allocation to the source's median annual methylmercury load to determine the methylmercury allocation using Equation 8.8. This ensures that the ratio of the methylmercury allocation concentration to the median annual methylmercury concentration is the same ratio for the methylmercury allocation to the median annual methylmercury load. This requires these sources to reduce their methylmercury concentration to the aqueous MeHg implementation goal and thereby reduce their methylmercury loading to the methylmercury allocation.

Because some sources received methylmercury allocations based on a delimited percent allocation and not the percent allocation determined in the first iteration, Board staff repeated the percent allocation equation and included the delimited percent allocations as described below.

Equation 8.9: Subsequent Iterations of Percent Allocation

$$\begin{matrix}\text{Percent Allocation} \\ \text{(subsequent iterations)}\end{matrix} = \frac{\begin{matrix}\text{Assimilative} \\ \text{Capacity (g/yr)}\end{matrix} - \sum \begin{matrix}\text{Pre-Determined and Delimited} \\ \text{MeHg Allocations (g/yr)}\end{matrix}}{\sum \begin{matrix}\text{All Median Annual} \\ \text{MeHg Loads (g/yr)}\end{matrix} - \sum \begin{matrix}\text{Median Annual MeHg Loads of} \\ \text{Pre-Determined and Delimited} \\ \text{MeHg Allocations (g/yr)}\end{matrix}} \times 100\%$$

Where:

Assimilative Capacity = A subarea's maximum pollutant loading capacity without violating water quality standards, calculated using Equation 8.3 (g/yr)

Σ Pre-Determined and Delimited MeHg Allocations = Sum of all pre-determined and delimited percent allocations per subarea, calculated using Equation 8.4 and Equation 8.7 (g/yr)

Σ All Median Annual MeHg Loads = Sum of median annual methylmercury loads of all sources per subarea (g/yr)

Σ Median Annual MeHg Loads of Pre-Determined and Delimited MeHg Allocations = Sum of median annual methylmercury loads of sources with a pre-determined or delimited percent allocation (g/yr)

100% = Conversion factor from decimal to percent (%)

To determine the next iteration of percent allocations for each TMDL Delta subarea, Board staff used Equation 8.9. This equation is similar to Equation 8.5 with the differences being: (1) the methylmercury allocations of sources with a delimited percent allocation were added to the sum of the pre-determined methylmercury allocations, and (2) the median annual methylmercury loads of sources with a delimited percent allocation were added to the sum of the median annual methylmercury loads of sources with pre-determined allocations.

Equation 8.6 through Equation 8.9 were repeated until: (1) all sources requiring a delimited percent allocation were identified, and (2) the sum of all source's methylmercury allocations for the subarea equaled the subarea's assimilative capacity.

The resulting percent and proposed methylmercury allocations for sources per Delta TMDL subarea[131] are listed in Table 8.15 through Table 8.21. The NPDES WWTF, and MS4 median annual methylmercury loads and proposed methylmercury allocations presented in Table 8.15 through Table 8.21 are also depicted in Figure 8.1 through

[131] Consistent with the 2010 TMDL Staff Report, the Yolo Bypass - North and Yolo Bypass - South subareas were combined for assigning source methylmercury allocations.

Figure 8.4. Please note that these graphs are not intended to demonstrate compliance with proposed WLAs.

Figure 8.1 shows the DMCP Review's median loads and proposed WLAs for NPDES WWTFs, which includes the future growth WLA for applicable WWTFs. Thirteen of the 17 facilities, nearly 80%, have a median load less than or approximately equal to the proposed WLA.

As shown in Figure 8.2, Board staff compared the DMCP Review NPDES WWTF data to the 2010 TMDL Staff Report average annual loads and 2010 WLAs to evaluate if WWTFs have reduced methylmercury loading. To make the evaluation comparable, the methods described in Section 6.2.4.2 were used to calculate an average load from the DMCP Review NPDES WWTF data instead of a median load. In the 2010 TMDL Staff Report, nine of the 16 WWTFs had an average load less than or equal to the 2010 WLA, which was approximately 56% of the WWTFs. Notably, two of the nine WWTFs, Discovery Bay WWTP and Lodi White Slough WPCF, had a methylmercury allocation equal to their average annual load even though their average annual methylmercury concentration was greater than the methylmercury implementation goal. This was because the Central Delta subarea did not require a load reduction for any sources in 2010. At the time of the DMCP Review, 11 of the 16 WWTFs evaluated in 2010 had a DMCP Review average load less than either the 2010 average load or the 2010 WLA. Additionally, the percentage of WWTFs with a methylmercury load less than or equal to their allocation has increased from 56%, or 44% if the Discovery Bay WWTP and Lodi White Slough WPCF are excluded, to 76%. This suggests that existing WWTFs have reduced their methylmercury loads and that it is possible for those that have not to reduce their methylmercury loads. Furthermore, new NPDES WWTFs can be designed to meet the proposed WLAs.

Figure 8.3 displays the DMCP Review's median annual methylmercury loads and proposed methylmercury WLAs for NPDES MS4s. Of the 25 MS4 median loads evaluated in the DMCP Review, 0% have a median load less than or equal to the proposed WLA.

To evaluate whether MS4s have reduced methylmercury loading, Figure 8.4 compares DMCP Review MS4 data to the 2010 TMDL Staff Report annual loads and 2010 WLAs. To make an equal comparison, the methods described in Section 6.2.6.5 were used to calculate an average load with the DMCP Review MS4 data rather than a median load. In the 2010 TMDL Staff Report, five of the 15 MS4 average loads were less than the 2010 WLA, which was approximately 33% of the MS4 average loads. At the time of the DMCP Review, 10 of the 15 MS4 average loads were less than either the 2010 average load or the 2010 WLA. While the number of MS4 average loads lower than the 2010 WLA increased from five to 10, the percentage of MS4 annual loads lower than the 2010 WLA versus the proposed WLA decreased from 33% to 0%. This suggests that MS4s have reduced their methylmercury loads and can further reduce their current or future methylmercury load, but reductions are needed by all MS4s to meet the proposed WLAs.

Table 8.15: Allocations for Methylmercury Sources to the Central Delta Subarea

MeHg Source	Specific Source	Allocation Type	Median Annual MeHg Conc. (ng/L)	Median Annual MeHg Load (g/yr)	Percent Allocation	MeHg Allocation Conc. (ng/L)	MeHg Allocation (g/yr)
Agricultural Returns		Load Allocation	NA	234.578	24.39%	NA	57.211
Atmospheric Deposition		Load Allocation	NA	54.660	100%	NA	54.660
Open Water Sediment Flux		Load Allocation	NA	171.314	100%	NA	171.314
Nontidal Wetlands		Load Allocation	NA	12.720	24.39%	NA	3.102
Tidal Wetlands		Load Allocation	NA	90.973	100%	NA	90.973
Tributary Inflows	Bear/Mosher Creeks (includes Fivemile Creek and White Slough)	Load Allocation	0.336	13.698	24.39%	0.082	3.341
Tributary Inflows	Calaveras River (includes Stockton Diversion Canal)	Load Allocation	0.127	7.309	24.39%	0.031	1.783
Urban Runoff (nonpoint source)		Load Allocation	0.180	0.109	32.83%	0.059	0.036
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	Waste Load Allocation	NA	28.807	100%	NA	28.807
NPDES WWTFs	City of Lodi White Slough WCPF	Waste Load Allocation	0.020	0.043	100%	0.020	0.043
NPDES WWTF	City of Lodi White Slough WCPF (future growth)	Waste Load Allocation	NA	NA	100%	0.026	0.022
NPDES WWTF	Discovery Bay WWTP	Waste Load Allocation	0.026	0.040	100%	0.026	0.040
NPDES WWTF	Discovery Bay WWTP (future growth)	Waste Load Allocation	NA	NA	100%	0.026	0.020
NPDES WWTF	Lincoln Center GWTS	Waste Load Allocation	0.095	0.007	62.11%	0.059	0.004
NPDES MS4	Caltrans	Waste Load Allocation	0.180	0.100	32.83%	0.059	0.033
NPDES MS4	City of Lodi	Waste Load Allocation	0.180	0.020	32.83%	0.059	0.007
NPDES MS4	Contra Costa County	Waste Load Allocation	0.093	0.262	63.25%	0.059	0.166
NPDES MS4	Port of Stockton	Waste Load Allocation	0.087	0.150	67.75%	0.059	0.102
NPDES MS4	San Joaquin County and City of Stockton	Waste Load Allocation	0.077	1.299	76.16%	0.059	0.990
NPDES WWTF & MS4	Unassigned NPDES Allocation (future growth)	Waste Load Allocation	NA	NA	100%	0.059	0.057
Central Delta Subarea Total:			**0.088**	**616.090**	**66.99%**	**0.059**	**412.709**

Table 8.16: Allocations for Methylmercury Sources to the Marsh Creek Subarea

MeHg Source	Specific Source	Allocation Type	Median Annual MeHg Conc. (ng/L)	Median Annual MeHg Load (g/yr)	Percent Allocation	MeHg Allocation Conc. (ng/L)	MeHg Allocation (g/yr)
Agricultural Returns		Load Allocation	NA	11.036	21.81%	NA	2.407
Atmospheric Deposition		Load Allocation	NA	0.818	100%	NA	0.818
Open Water Sediment Flux		Load Allocation	NA	0.080	100%	NA	0.080
Nontidal Wetlands		Load Allocation	NA	0.050	21.81%	NA	0.011
Tributary Inflows	Marsh Creek	Load Allocation	0.237	1.231	21.81%	0.052	0.269
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	Waste Load Allocation	NA	0.003	100%	NA	0.003
NPDES WWTF	City of Brentwood WWTP	Waste Load Allocation	0.020	0.089	100%	0.020	0.089
NPDES WWTF	City of Brentwood WWTP (future growth)	Waste Load Allocation	NA	NA	100%	0.020	0.045
NPDES MS4	Contra Costa County	Waste Load Allocation	0.093	0.658	63.25%	0.059	0.416
NPDES WWTF & MS4	Unassigned NPDES Allocation (future growth)	Waste Load Allocation	NA	NA	100%	0.059	0.066
Marsh Creek Subarea Total:			**0.196**	**13.965**	**30.10%**	**0.059**	**4.204**

Table 8.17: Allocations for Methylmercury Sources to the Mokelumne/Cosumnes Rivers Subarea

MeHg Source	Specific Source	Allocation Type	Median Annual MeHg Conc. (ng/L)	Median Annual MeHg Load (g/yr)	Percent Allocation	MeHg Allocation Conc. (ng/L)	MeHg Allocation (g/yr)
Agricultural Returns		Load Allocation	NA	8.948	53.17%	NA	4.758
Atmospheric Deposition		Load Allocation	NA	1.286	100%	NA	1.286
Open Water Sediment Flux		Load Allocation	NA	1.362	100%	NA	1.362
Nontidal Wetlands		Load Allocation	NA	5.749	53.17%	NA	3.057
Tidal Wetlands		Load Allocation	NA	2.783	100%	NA	2.783
Tributary Inflows	Mokelumne River (includes Cosumnes River and Dry Creek)	Load Allocation	Depends on tributary[132]	156.614	53.17%	Depends on tributary[133]	83.279
Urban Runoff (nonpoint source)		Load Allocation	0.180	0.020	53.17%	0.096	0.011
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	Waste Load Allocation	NA	0.062	100%	NA	0.062
NPDES MS4	Caltrans	Waste Load Allocation	0.180	0.005	53.17%	0.096	0.003
Mokelumne/ Cosumnes Rivers Subarea Total:			**0.108**	**176.830**	**54.63%**	**0.059**	**96.601**

[132] The median annual MeHg concentration of Mokelumne River is 0.025 ng/L and Cosumnes River is 0.376 ng/L. No methylmercury concentration data were available for Dry Creek in the DMCP Review; Board staff used the Cosumnes River methylmercury concentration to calculate the methylmercury load for Dry Creek.

[133] The MeHg allocation concentration for Mokelumne River is 0.013 ng/L, for Cosumnes River is 0.200 ng/L, and for Dry Creek is 0.200 ng/L.

Table 8.18: Allocations for Methylmercury Sources to the Sacramento River Subarea

MeHg Source	Specific Source	Allocation Type	Median Annual MeHg Conc. (ng/L)	Median Annual MeHg Load (g/yr)	Percent Allocation	MeHg Allocation Conc. (ng/L)	MeHg Allocation (g/yr)
Agricultural Returns		Load Allocation	NA	220.948	63.92%	NA	141.221
Atmospheric Deposition		Load Allocation	NA	22.966	100%	NA	22.966
Open Water Sediment Flux		Load Allocation	NA	64.787	100%	NA	64.787
Nontidal Wetlands		Load Allocation	NA	16.438	63.92%	NA	10.507
Tidal Wetlands		Load Allocation	NA	20.984	100%	NA	20.984
Tributary Inflows	Morrison Creek (includes Laguna Creek and Florin/Elder Creek)	Load Allocation	0.102	7.501	63.92%	0.065	4.794
Tributary Inflows	Sacramento River (includes American River and Steelhead Creek)	Load Allocation	Depends on tributary[134]	1,551.921	63.92%	Depends on tributary[135]	991.920
Urban Runoff (nonpoint source)		Load Allocation	0.180	0.166	63.92%	0.115	0.106
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	Waste Load Allocation	NA	7.126	100%	NA	7.126
NPDES WWTF	City of Rio Vista Beach WWTF	Waste Load Allocation	0.030	0.017	100%	0.030	0.017
NPDES WWTF	City of Rio Vista Beach WWTF (future growth)	Waste Load Allocation	NA	NA	100%	0.030	0.008
NPDES WWTF	City of Rio Vista Northwest WWTF	Waste Load Allocation	0.020	0.007	100%	0.020	0.007
NPDES WWTF	City of Rio Vista Northwest WWTF (future growth)	Waste Load Allocation	NA	NA	100%	0.020	0.004
NPDES WWTF	City of Sacramento CWWCTS	Waste Load Allocation	Depends on discharge location[136]	2.363	63.92%	Depends on discharge location[137]	1.511
NPDES WWTF	Sacramento Regional WWTP	Waste Load Allocation	0.180	28.858	63.92%	0.115	18.445
NPDES MS4	Caltrans	Waste Load Allocation	0.180	0.212	63.92%	0.115	0.135
NPDES MS4	City of Rio Vista	Waste Load Allocation	0.180	0.031	63.92%	0.115	0.020
NPDES MS4	City of West Sacramento	Waste Load Allocation	0.180	0.643	63.92%	0.115	0.411
NPDES MS4	Sacramento Stormwater Quality Partnership	Waste Load Allocation	0.252	1.041	63.92%	0.161	0.666
NPDES WWTF & MS4	Unassigned NPDES Allocation (future growth)	Waste Load Allocation	NA	NA	100%	0.059	2.609
Sacramento River Subarea Total:			**0.089**	**1,946.011**	**66.20%**	**0.059**	**1,288.243**

[134] The pooled median annual MeHg concentration of Sacramento River above Steelhead Creek confluence is 0.095 ng/L, of American River is 0.054 ng/L, and of Steelhead Creek is 0.253 ng/L.

[135] The MeHg allocation concentration for Sacramento River above Steelhead Creek confluence is 0.061 ng/L, for American River is 0.035 ng/L, and for Steelhead Creek is 0.162 ng/L.

[136] The median annual MeHg concentration for the City of Sacramento CWWCTS EFF-002 is 0.220 ng/L and for EFF-006 is 0.230 ng/L.

[137] The MeHg allocation concentration for the City of Sacramento CWWCTS EFF-002 is 0.141 ng/L and EFF-006 is 0.147 ng/L.

Table 8.19: Allocations for Methylmercury Sources to the San Joaquin River Subarea

MeHg Source	Specific Source	Allocation Type	Median Annual MeHg Conc. (ng/L)	Median Annual MeHg Load (g/yr)	Percent Allocation	MeHg Allocation Conc. (ng/L)	MeHg Allocation (g/yr)
Agricultural Returns		Load Allocation	NA	132.209	38.06%	NA	50.317
Atmospheric Deposition		Load Allocation	NA	9.586	100%	NA	9.586
Open Water Sediment Flux		Load Allocation	NA	22.771	100%	NA	22.771
Nontidal Wetlands		Load Allocation	NA	4.779	38.06%	NA	1.819
Tidal Wetlands		Load Allocation	NA	9.516	100%	NA	9.516
Tributary Inflows	French Camp Slough (includes Duck Creek, Littlejohns Creek, and Walker Slough)	Load Allocation	0.139	12.225	38.06%	0.053	4.653
Tributary Inflows	San Joaquin River	Load Allocation	0.144	260.056	38.06%	0.055	98.974
Urban Runoff (nonpoint source)		Load Allocation	0.180	0.324	38.06%	0.068	0.123
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	Waste Load Allocation	NA	0.962	100%	NA	0.962
NPDES WWTF	City of Lathrop CTF	Waste Load Allocation	0.020	0.069	100%	0.020	0.069
NPDES WWTF	City of Lathrop CTF (future growth)	Waste Load Allocation	NA	NA	100%	0.020	0.097
NPDES WWTF	City of Manteca WWQCF	Waste Load Allocation	0.020	0.154	100%	0.020	0.154
NPDES WWTF	City of Manteca WWQCF (future growth)	Waste Load Allocation	NA	NA	100%	0.020	0.077
NPDES WWTF	City of Stockton Regional WWCF	Waste Load Allocation	0.061	1.970	96.72%	0.059	1.905
NPDES WWTF	City of Tracy WWTP	Waste Load Allocation	0.020	0.265	100%	0.020	0.265
NPDES WWTF	City of Tracy WWTP (future growth)	Waste Load Allocation	NA	NA	100%	0.020	0.132
NPDES WWTF	Deuel Vocational Institution WWTP	Waste Load Allocation	0.023	0.015	100%	0.023	0.015
NPDES WWTF	Mountain House CSD WWTP	Waste Load Allocation	0.020	0.025	100%	0.020	0.025
NPDES WWTF	Mountain House CSD WWTP (future growth)	Waste Load Allocation	NA	NA	100%	0.020	0.012
NPDES MS4	Caltrans	Waste Load Allocation	0.180	0.064	38.06%	0.068	0.024
NPDES MS4	City of Lathrop	Waste Load Allocation	0.180	0.434	38.06%	0.068	0.165
NPDES MS4	City of Manteca	Waste Load Allocation	0.180	0.015	38.06%	0.068	0.006
NPDES MS4	City of Tracy	Waste Load Allocation	0.180	1.606	38.06%	0.068	0.611
NPDES MS4	Deuel Vocational Institution	Waste Load Allocation	0.180	0.029	38.06%	0.068	0.011
NPDES MS4	Mountain House Community Services District	Waste Load Allocation	0.180	0.184	38.06%	0.068	0.070
NPDES MS4	Port of Stockton	Waste Load Allocation	0.087	0.001	67.75%	0.059	0.0007
NPDES MS4	San Joaquin County	Waste Load Allocation	0.180	0.464	38.06%	0.068	0.177
NPDES MS4	San Joaquin County and City of Stockton	Waste Load Allocation	0.077	0.274	76.16%	0.059	0.209
NPDES WWTF & MS4	Unassigned NPDES Allocation (future growth)	Waste Load Allocation	NA	NA	100%	0.059	0.965
San Joaquin River Subarea Total:			**0.133**	**457.996**	**44.48%**	**0.059**	**203.711**

Table 8.20: Allocations for Methylmercury Sources to the West Delta Subarea

MeHg Source	Specific Source	Allocation Type	Median Annual MeHg Conc. (ng/L)	Median Annual MeHg Load (g/yr)	Percent Allocation	MeHg Allocation Conc. (ng/L)	MeHg Allocation (g/yr)
Agricultural Returns		Load Allocation	NA	21.800	69.32%	NA	15.112
Atmospheric Deposition		Load Allocation	NA	25.882	100%	NA	25.882
Open Water Sediment Flux		Load Allocation	NA	83.128	100%	NA	83.128
Nontidal Wetlands		Load Allocation	NA	11.146	69.32%	NA	7.726
Tidal Wetlands		Load Allocation	NA	102.375	100%	NA	102.375
Urban Runoff (nonpoint source)		Load Allocation	0.180	0.007	69.32%	0.125	0.005
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	Waste Load Allocation	NA	10.867	100%	NA	10.867
NPDES WWTF	Ironhouse SD WRF	Waste Load Allocation	0.020	0.072	100%	0.020	0.072
NPDES WWTF	Ironhouse SD WRF (future growth)	Waste Load Allocation	NA	NA	100%	0.020	0.036
NPDES MS4	Caltrans	Waste Load Allocation	0.180	0.018	69.32%	0.125	0.013
NPDES MS4	Contra Costa County	Waste Load Allocation	0.093	1.319	69.32%	0.065	0.914
NPDES WWTF & MS4	Unassigned NPDES Allocation (future growth)	Waste Load Allocation	NA	NA	100%	0.059	0.053
West Delta Subarea Total:			**0.062**	**256.614**	**95.93%**	**0.059**	**246.183**

Table 8.21: Allocations for Methylmercury Sources to the Yolo Bypass - North & - South Subareas

MeHg Source	Specific Source	Allocation Type	Median Annual MeHg Conc. (ng/L)	Median Annual MeHg Load (g/yr)	Percent Allocation	MeHg Allocation Conc. (ng/L)	MeHg Allocation (g/yr)
Agricultural Returns		Load Allocation	NA	140.990	6.79%	NA	9.575
Atmospheric Deposition		Load Allocation	NA	25.419	100%	NA	25.419
Open Water Sediment Flux		Load Allocation	NA	47.902	100%	NA	47.902
Nontidal Wetlands		Load Allocation	NA	66.131	6.79%	NA	4.491
Tidal Wetlands		Load Allocation	NA	55.479	100%	NA	55.479
Cache Creek Settling Basin		Load Allocation	Depends on waterway[138]	69.931	6.79%	Depends on waterway[139]	69.931
Tributary Inflows	Cache Creek (above Cache Creek Settling Basin)	Load Allocation	0.252	22.605	6.79%	0.035	4.981
Tributary Inflows	Dixon Area	Load Allocation	0.176	2.287	6.79%	0.024	0.155
Tributary Inflows	Fremont Weir	Load Allocation	0.082	174.201	6.79%	0.011	11.831
Tributary Inflows	Putah Creek	Load Allocation	0.131	36.199	6.79%	0.018	2.458
Tributary Inflows	Ridge Cut Slough (Knights Landing)	Load Allocation	0.198	117.887	6.79%	0.027	8.447
Tributary Inflows	Sacramento Weir	Load Allocation	0.123	18.608	6.79%	0.008	1.264
Tributary Inflows	Willow Slough	Load Allocation	0.176	9.825	6.79%	0.024	0.168
Tributary Inflows	Upper Lindsey/Cache Slough Area (includes Barker Slough)	Load Allocation	0.176	2.467	6.79%	0.024	0.552
Tributary Inflows	Ulatis Creek	Load Allocation	0.176	8.134	6.79%	0.024	0.667
Urban Runoff (nonpoint source)		Load Allocation	0.180	0.022	32.83%	0.059	0.007
Dredging	Deep Water Ship Channel Dredging and Smaller Dredging Projects	Waste Load Allocation	NA	6.325	100%	NA	6.325
NPDES WWTF	City of Davis WWTP	Waste Load Allocation	0.760	0.614	7.76%	0.105	0.048
NPDES WWTF	City of Woodland WPCF	Waste Load Allocation	0.020	0.097	100%	0.020	0.097
NPDES WWTF	City of Woodland WPCF (future growth)	Waste Load Allocation	NA	NA	100%	0.020	0.049
NPDES MS4	Caltrans	Waste Load Allocation	0.180	0.039	32.83%	0.059	0.013
NPDES MS4	City of Rio Vista	Waste Load Allocation	0.180	0.008	32.83%	0.059	0.003
NPDES MS4	City of West Sacramento	Waste Load Allocation	0.180	0.574	32.83%	0.059	0.188
NPDES WWTF & MS4	Unassigned NPDES Allocation (future growth)	Waste Load Allocation	NA	NA	100%	0.059	0.149
Yolo Bypass - North & South Subareas Total:			**0.204**	**862.975**	**28.99%**	**0.059**	**250.199**

[138] The pooled median annual MeHg concentration of the CCSB Outflow is 0.296 ng/L and the CCSB Overflow Weir is 0.333 ng/L.

[139] The MeHg allocation concentration for the CCSB Outflow is 0.296 ng/L and the CCSB Overflow Weir is 0.333 ng/L.

Table 8.22: Methylmercury Load and Waste Load Allocation for Each Delta TMDL Subarea by Source Category

Allocation Type	Source	Central Delta Median Annual MeHg Load (g/yr)	Central Delta MeHg Allocation (g/yr)	Marsh Creek Median Annual MeHg Load (g/yr)	Marsh Creek MeHg Allocation (g/yr)	Moke./ Cos. Rivers Median Annual MeHg Load (g/yr)	Moke./ Cos. Rivers MeHg Allocation (g/yr)	Sac. River Median Annual MeHg Load (g/yr)	Sac/ River MeHg Allocation (g/yr)	San Joaquin River Median Annual MeHg Load (g/yr)	San Joaquin River MeHg Allocation (g/yr)	West Delta Median Annual MeHg Load (g/yr)	West Delta MeHg Allocation (g/yr)	YB - North & South Median Annual MeHg Load (g/yr)	YB - North & South MeHg Allocation (g/yr)
Load	Agricultural Returns	234.578	57.211	11.036	2.407	8.948	4.758	220.948	141.221	132.209	50.317	21.800	15.112	140.990	9.575
Load	Atmospheric Deposition	54.660	54.660	0.818	0.818	1.286	1.286	22.966	22.966	9.586	9.586	25.882	25.882	25.419	25.419
Load	Open Water Sediment Flux	171.314	171.314	0.080	0.080	1.362	1.362	64.787	64.787	22.771	22.771	83.128	83.128	47.902	47.902
Load	Nontidal Wetlands	12.720	3.102	0.050	0.011	5.749	3.057	16.438	10.507	4.779	1.819	11.146	7.726	66.131	4.491
Load	Tidal Wetlands	90.973	90.973	NA	NA	2.783	2.783	20.984	20.984	9.516	9.516	102.375	102.375	55.479	55.479
Load	Cache Creek Settling Basin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	69.931	69.931
Load	Tributary Inflows	21.007	5.123	1.231	0.269	156.614	83.279	1,559.422	996.714	272.281	103.627	NA	NA	449.444	30.523
Load	Urban Runoff (Nonpoint Source)	0.109	0.036	NA	NA	0.020	0.011	0.166	0.106	0.324	0.123	0.007	0.005	0.022	0.007
Waste Load	Dredging	28.807	28.807	0.003	0.003	0.062	0.062	7.126	7.126	0.962	0.962	10.867	10.867	6.325	6.325
Waste Load	NPDES WWTFs	0.090	0.087	0.089	0.089	NA	NA	31.245	19.979	2.498	2.433	0.072	0.072	0.711	0.145
Waste Load	NPDES WWTFs Future Growth	NA	0.041	NA	0.045	NA	NA	NA	0.012	NA	0.319	NA	0.036	NA	0.049
Waste Load	NPDES MS4	1.833	1.297	0.658	0.416	0.005	0.003	1.928	1.232	3.071	1.274	1.337	0.927	0.622	0.204
Waste Load	Unassigned NPDES WWTF & MS4	NA	0.057	NA	0.066	NA	NA	NA	2.609	NA	0.965	NA	0.053	NA	0.149
Total		**616.090**	**412.709**	**13.965**	**4.204**	**176.830**	**96.601**	**1,946.011**	**1,288.243**	**457.996**	**203.711**	**256.614**	**246.183**	**862.975**	**250.199**

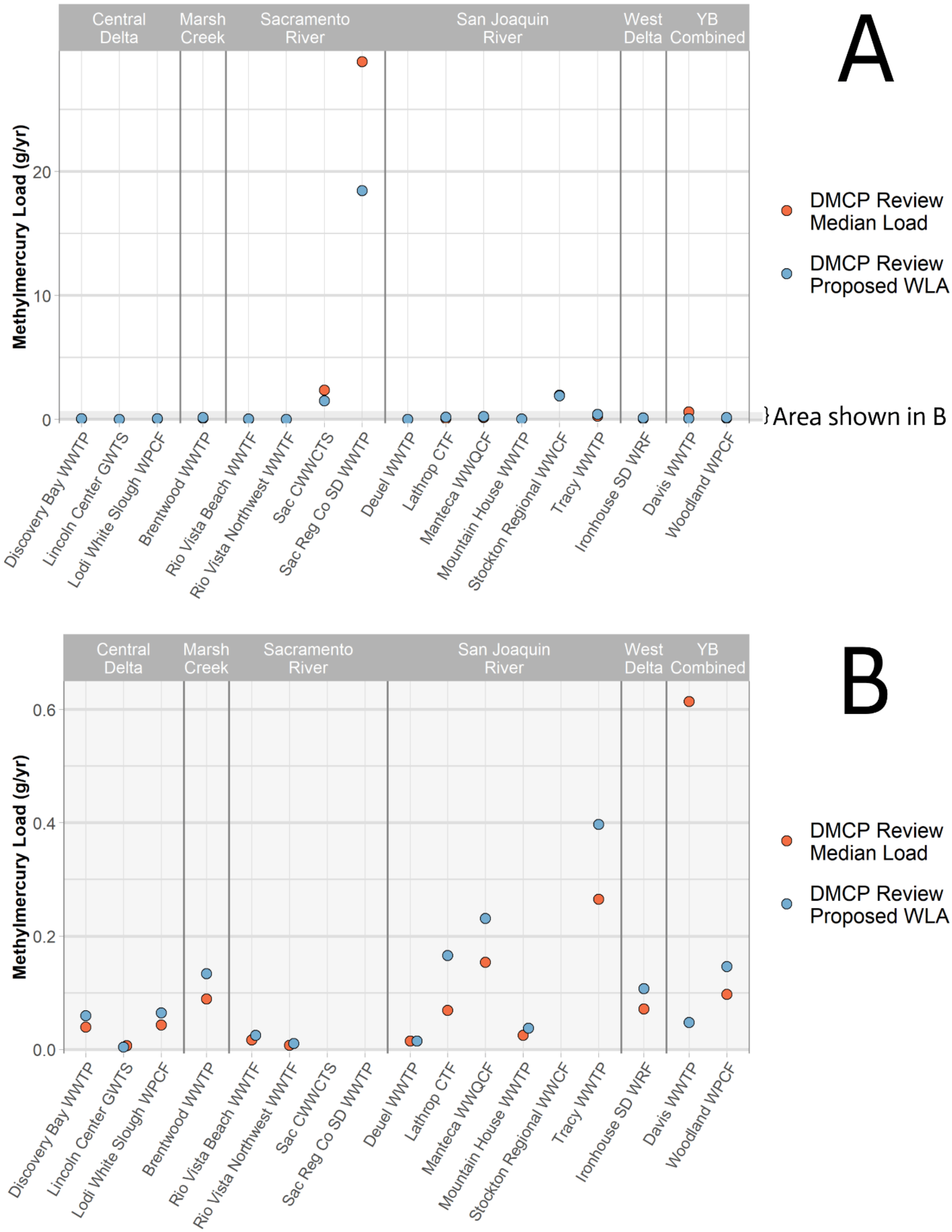

Figure 8.1: (A) DMCP Review NPDES WWTF Median Methylmercury Loads and Proposed Waste Load Allocations, **(B)** Zoomed Scale of Gray Highlighted Area in (A)

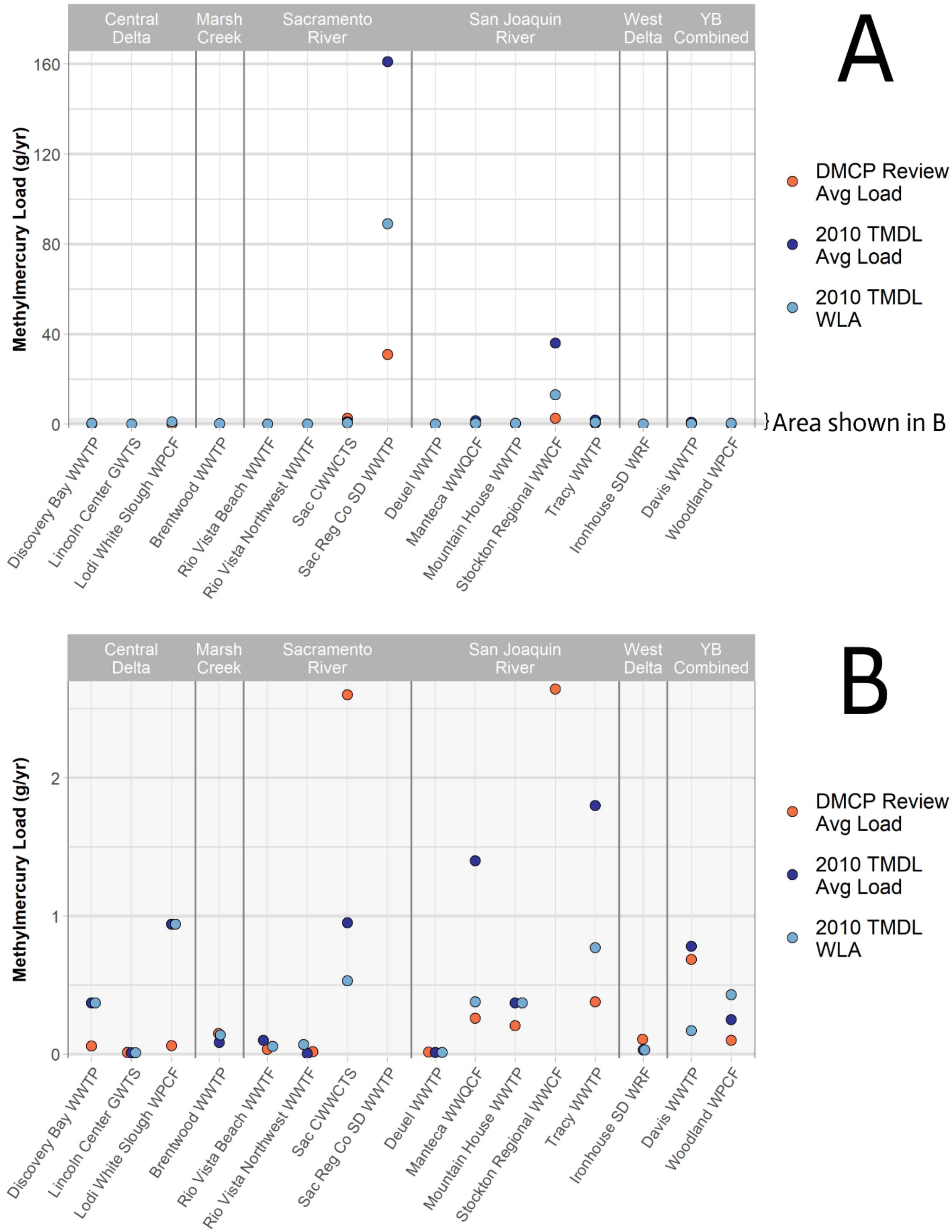

Figure 8.2: (A) DMCP Review NPDES WWTF Average Methylmercury Loads Compared to the 2010 TMDL Staff Report Average Loads and Waste Load Allocations, **(B)** Zoomed Scale of Gray Highlighted Area in (A)

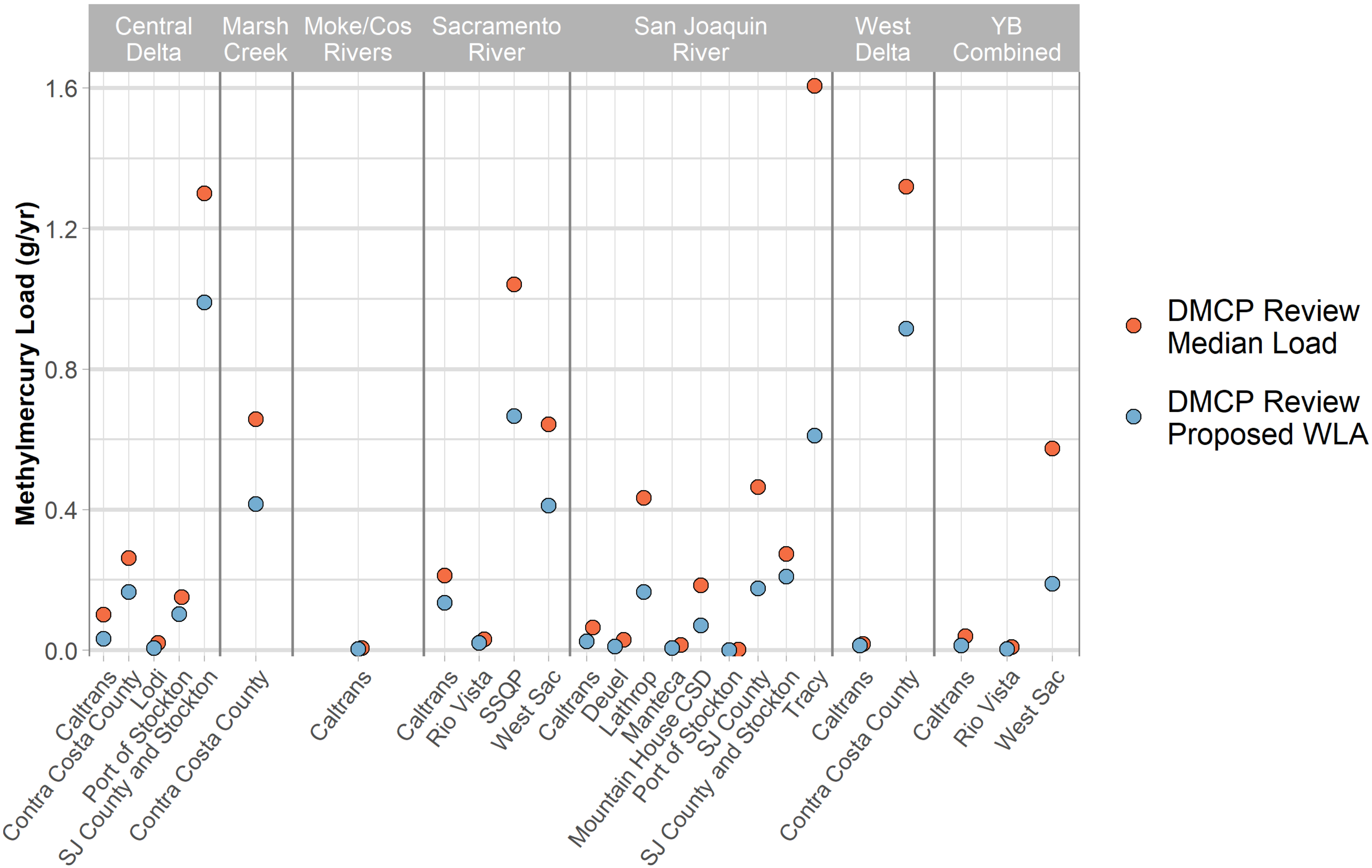

Figure 8.3: DMCP Review NPDES MS4 Median Methylmercury Loads and Proposed Waste Load Allocations

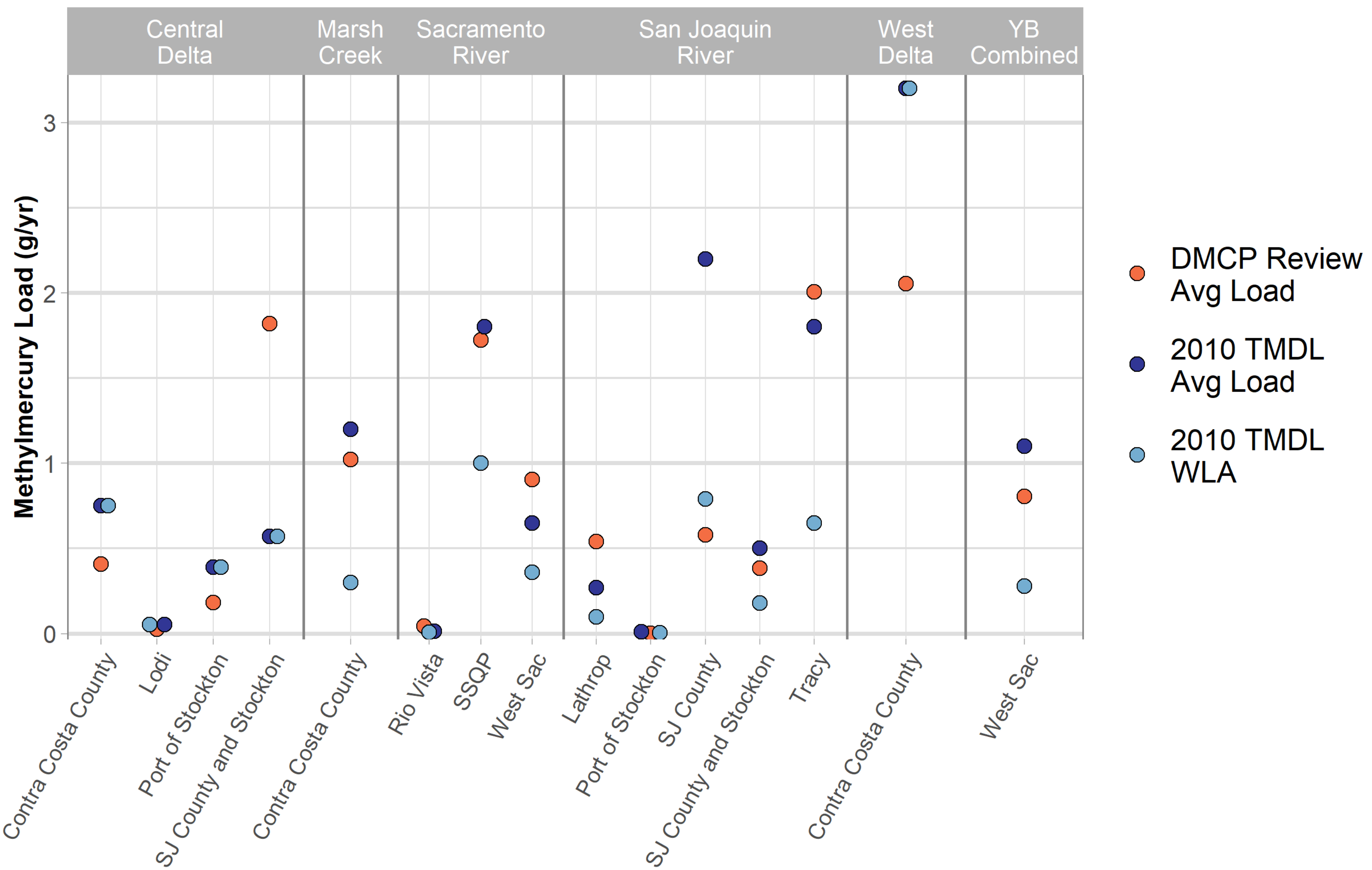

Figure 8.4: DMCP Review NPDES MS4 Average Methylmercury Loads Compared to the 2010 TMDL Staff Report Average Loads and Waste Load Allocations

8.1.4 Compliance with Methylmercury Allocations

This section describes how Board staff recommends determining compliance with the methylmercury allocations for the DMCP Review.

8.1.4.1 All Dischargers

In the 2010 TMDL Staff Report, Board staff recommended that load allocation compliance for the atmospheric deposition, open-water habitat, tributary inputs, urban areas outside of MS4 service areas, and waste load allocations for the MS4s be based on a five-year average annual load. Compliance for NPDES WWTFs were to be based on a one-calendar year average annual load[140]. Time frame recommendations for calculating agricultural drainage and wetland habitat loads were not specified.

Equation 8.10: How to Calculate the Methylmercury Load to Determine Compliance with Allocations in Table 8.15 through Table 8.21

$$\frac{MeHg}{Allocation\ (g/yr)} \geq \frac{Annual\ MeHg}{Load\ (g/yr)} = \frac{Median\ MeHg}{Conc.(ng/L)} \times \frac{Median\ Flow}{Volume\ (L)} \times 10^{-9}(g/ng)$$

Where:

Median MeHg Conc. = Median of the previous, consecutive five years of pooled methylmercury concentrations (ng/L)

Median Flow Volume = Median of the previous, consecutive five annual flow volumes (L)

10^{-9} = Conversion factor of nanogram to gram (g/ng)

For the DMCP Review, Board staff recommends that compliance for all methylmercury source allocations be based on a rolling five-year median, which is calculated using the median methylmercury concentration from the previous, consecutive five years of data pooled together, and the median of the previous, consecutive five annual flow volumes (Equation 8.10). At a minimum, two aqueous unfiltered methylmercury samples representative of the discharge need to be collected annually: at least one sample in the dry weather period, and one sample in the wet weather period[141]. This way of determining compliance mimics the methods used to determine the aqueous MeHg implementation goal (Section 5.3); is similar to the 2010 TMDL Staff Report's recommended allocation compliance calculation method for atmospheric deposition, open water, tributaries, urban runoff, and MS4s; accounts for hydrologic variability; and provides each methylmercury source the same statistical basis for determining compliance. While this is a minimum recommendation for determining compliance with WLAs, Board staff continues to recommend additional monitoring to characterize

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[140] Except for Oakwood Lake Subdivision Mining Reclamation that was to be assessed as a five-year average annual methylmercury load because its discharges resulted from flood-control pumping that can fluctuate with short-term and long-term precipitation patterns.

[141] Wet and dry weather periods as defined in individual permits or otherwise determined to be representative of the and approved by the Executive Officer on a discharger-specific basis.

methylmercury production throughout the year to best implement mercury reduction management practices.

The allocation for each source applies to its gross load within the Delta TMDL subarea boundaries and any future expansions. Future expansions include population growth, regional water management changes, and wetland restoration efforts, which may result in increased methylmercury loading to the Delta. For compliance assessment purposes, Board staff recommends that all loads be rounded to at least three decimal places for consistency with the allocations and aqueous MeHg implementation goal. The methylmercury concentration used to calculate the allocation (Table 8.15 through Table 8.21) should not be used as an effluent limit to assess compliance with the allocations.

For example, to determine compliance in 2025, the Median MeHg Conc. would be the median of pooled methylmercury concentrations from WY 2021, 2022, 2023, 2024, and 2025. If two methylmercury samples were collected each year and if these values, in increasing order, were a nondetectable concentration, 0.07 ng/L, 0.17 ng/L, 0.21 ng/L, 0.21 ng/L, 0.21 ng/L, 0.49 ng/L, 0.50 ng/L, 0.80 ng/L, 0.80 ng/L, 0.91 ng/L, and 0.98 ng/L, the Median MeHg Conc. would equal 0.35 ng/L. Likewise, if the flow volumes for the same water years were 2.624×10^9 liters (L), 2.763×10^9 L, 3.453×10^9 L, 3.868×10^9 L, and 4.420×10^9 L, the Median Annual Flow Volume would equal 3.453×10^9 L. Plugging the Median MeHg Conc. and Median Annual Flow Volume into Equation 8.10 results in a Compliance MeHg Load of 1.21 g/yr. If five years of previous, consecutive five years of data are not available, compliance should be based on the most recent available data within the last five years until five years of annual data are collected.

8.1.4.2 Agricultural Returns

Agricultural returns load allocations apply to the methylmercury discharges of agricultural lands in the Delta MeHg TMDL Boundary, excluding the CCSB.

8.1.4.3 Atmospheric Deposition

Atmospheric deposition load allocations apply to precipitation loading over all land cover types except urban in the Delta MeHg TMDL Boundary, excluding the CCSB.

8.1.4.4 Open Water Sediment Flux

Open water sediment flux load allocations apply to the sediment flux rate in all open water habitat in the Delta, excluding the CCSB. These allocations apply to current and future projects that create additional open water habitat.

8.1.4.5 Nontidal & Tidal Wetlands

Nontidal and tidal wetland allocations apply to the gross loading of all nontidal and tidal wetland habitat in the Delta, excluding the CCSB. These allocations apply to current and future wetland restoration projects.

8.1.4.6 Cache Creek Settling Basin

The CCSB load allocation applies to the cumulative methylmercury discharges from the CCSB Outflow and Overflow Weir to the Yolo Bypass.

8.1.4.7 Tributary Inflows

Tributary load allocations apply to methylmercury loads from incoming flows to the Delta at the Delta MeHg TMDL Boundary.

8.1.4.8 Urban Runoff (Nonpoint Source)

Nonpoint source urban runoff load allocations apply to urban areas not encompassed by an MS4 jurisdictional area, consistent with USEPA's requirements and guidance for establishing waste load allocations for storm water sources (USEPA 2002).

If an NPDES MS4 not listed in Table 8.15 through Table 8.21 is given an NPDES MS4 permit for stormwater dischargers from urban areas identified as urban runoff (nonpoint source) within a Delta TMDL subarea, a portion of the subarea-specific Urban Runoff (Nonpoint Source) load allocation may be allotted to the NPDES MS4 as a waste load allocation in the permit (USEPA 2014).

8.1.4.9 Dredging

Dredging waste load allocations apply to the methylmercury discharges from DMPSs for permitted dredging activities, such as DWSCs and smaller dredging projects.

8.1.4.10 NPDES WWTFs

NPDES WWTFs listed in Table 8.15 through Table 8.21 could be allowed to increase their effluent volume so long as the methylmercury load does not increase above the assigned waste load allocation. An increase in volume would necessitate a decrease in methylmercury concentration to maintain compliance with the assigned waste load allocation.

8.1.4.10.1 Facilities with a Median Methylmercury Concentration Less than the Proposed Aqueous MeHg Implementation Goal of 0.059 ng/L

For NPDES WWTFs with two allocations (current and future growth) listed in Table 8.15 through Table 8.21, the two allocations should be summed for compliance purposes.

8.1.4.10.2 NPDES WWTFs Not Assessed in DMCP Review

If an NPDES WWTF not listed in Table 8.15 through Table 8.21 is given an NPDES permit for discharge within a Delta TMDL subarea, a portion of the subarea-specific Unassigned NPDES Methylmercury Allocation may be allotted to the WWTF.

Equation 8.11: How to Calculate a New NPDES Methylmercury Allocation for a NPDES WWTF not Listed in Table 8.15 through Table 8.21

$$\begin{matrix} New\ NPDES\ WWTF \\ MeHg\ Allocation\ (g/yr) \end{matrix} = \begin{matrix} Proposed\ Aq\ MeHg \\ Imp\ Goal\ (ng/L) \end{matrix} \times \begin{matrix} Annual\ Permitted \\ Flow\ (L) \end{matrix} \times 10^{-9}(\text{g/ng})$$

Where:

Proposed Aq MeHg Imp Goal = 0.059 ng/L

Annual Permitted Flow = Annual permitted flow for the NPDES WWTF not listed in Table 8.15 through Table 8.21 (L)

10^{-9} = Conversion factor of nanogram to gram (g/ng)

The methylmercury allocation would be equal to the product of the aqueous MeHg implementation goal and the NPDES annual permitted flow (Equation 8.11). All methylmercury allocations provided in this way must be subtracted from the subarea-specific Unassigned NPDES Methylmercury Allocation, which cannot go below zero.

8.1.4.10.3 Regionalization of NPDES WWTFs

NPDES WWTFs listed in Table 8.15 through Table 8.21 could be allowed to increase their effluent volume for the purposes of regionalization.

Equation 8.12: How to Calculate a New NPDES Methylmercury Allocation for Regionalization of WWTFs

$$\begin{matrix} Regionalized \\ NPDES\ WWTF \\ MeHg\ Allocation \\ (g/yr) \end{matrix} = \sum \begin{matrix} Existing\ MeHg \\ Allocations \\ (g/yr) \end{matrix} + \left(\begin{matrix} Proposed\ Aq \\ MeHg\ Imp\ Goal \\ (ng/L) \end{matrix} \times \begin{matrix} Net\ Flow \\ Increase \\ (L) \end{matrix} \times \begin{matrix} 10^{-9} \\ (g/ng) \end{matrix} \right)$$

Where:

Existing MeHg Allocations = Sum of NPDES WWTF methylmercury allocations from WWTFs that are regionalizing and listed in Table 8.15 through Table 8.21 (g/yr)

Proposed Aq MeHg Imp Goal = 0.059 ng/L

Net Flow Increase = Additional flow from NPDES WWTF(s) not listed in Table 8.15 through Table 8.21; enter 0 if only listed WWTFs are regionalizing (L)

10^{-9} = Conversion factor of nanogram to gram (g/ng)

If NPDES WWTFs listed in Table 8.15 through Table 8.21 regionalize or otherwise consolidate, their waste load allocations should be summed for compliance purposes (Equation 8.12).

If an NPDES WWTF listed in Table 8.15 through Table 8.21 regionalizes with a facility not listed in those tables, the regionalized facility would have a methylmercury waste load allocation equal to the NPDES WWTF’s assigned waste load allocation in those tables plus a portion of the Unassigned NPDES Methylmercury Allocation for WWTFs (Equation 8.12). The portion of Unassigned NPDES Methylmercury Allocation for

WWTFs is calculated in Equation 8.12 by the terms in parentheses, which equals the product of the net flow increase due to regionalization and the aqueous MeHg implementation goal. The portion of Unassigned NPDES Methylmercury Allocation assigned to the regionalized WWTF must be subtracted from the subarea-specific Unassigned NPDES Methylmercury Allocation for WWTFs, which cannot go below zero.

8.1.4.11 NPDES MS4s

NPDES MS4 waste load allocations apply to all urban lands within MS4 jurisdictional areas within each Delta TMDL subarea at the time of the DMCP Review. These allocations also apply to future loading from expanded urban areas within the listed MS4 jurisdictional areas. MS4s that span several Delta TMDL subareas have multiple subarea-specific allocations.

The MS4 waste load allocations do not apply to non-urban land covers within MS4 jurisdictional areas or to MS4 jurisdictional areas outside of the Delta MeHg TMDL Boundary.

8.1.4.11.1 NPDES MS4s Not Assessed in DMCP Review

If urban area is developed within the Delta MeHg TMDL Boundary and within an MS4 jurisdiction not listed in Table 8.15 through Table 8.21, a portion of the subarea-specific Unassigned NPDES Methylmercury Allocation may be allotted to the MS4.

Equation 8.13: How to Calculate a New NPDES Methylmercury Allocation for an MS4 not Listed in Table 8.15 through Table 8.21

$$\begin{matrix} New\ NPDES\ MS4 \\ MeHg\ Allocation\ (g/yr) \end{matrix} = \begin{matrix} Proposed\ Aq\ MeHg \\ Imp\ Goal\ (ng/L) \end{matrix} \times \begin{matrix} Urban\ Runoff \\ Volume\ (L) \end{matrix} \times 10^{-9} (g/ng)$$

Where:

Proposed Aq MeHg Imp Goal = 0.059 ng/L
Urban Runoff Volume = Annual urban runoff volume for the NPDES MS4 not listed in Table 8.15 through Table 8.21 (L)
10^{-9} = Conversion factor of nanogram to gram (g/ng)

The MS4 would have a methylmercury allocation equal to the product of the estimated urban runoff volume and aqueous MeHg implementation goal (Equation 8.13). All methylmercury allocations provided in this way must be subtracted from the subarea-specific Unassigned NPDES Methylmercury Allocation, which cannot go below zero.

8.2 Total Mercury Load Reduction Requirement for Tributary Watersheds

Board staff reviewed Section 8.2 of the 2010 TMDL Staff Report and determined that revision of the total mercury load reduction requirement for tributary watersheds was not necessary in the DMCP Review. As described in Section 7, Board staff did not evaluate available data for the THg/TSS analysis to revise the total mercury loading in the DMCP

Review. Board staff maintains the conclusions and recommendations of 2010 TMDL Staff Report Section 8.2.

8.3 Margin of Safety

In the 2010 TMDL Staff Report, the protective aqueous methylmercury goal was determined to be 0.066 ng/L and Board staff set the aqueous methylmercury goal at 0.060 ng/L. The difference between the protective aqueous methylmercury concentration and the aqueous methylmercury goal resulted in 0.006 ng/L, which equates to an explicit margin of safety of approximately 10%.

For the DMCP Review, the protective aqueous methylmercury concentration was determined to be 0.061 ng/L and Board staff set the aqueous MeHg implementation goal at the 5^{th} percentile of the protective aqueous methylmercury concentration probability distribution (Figure 5.4). This resulted in the aqueous MeHg implementation goal of 0.059 ng/L and an explicit margin of safety of 3.3% (Section 5.3).

8.4 Seasonal & Inter-annual Variability

After evaluation of Section 8.4 Seasonal and Inter-annual Variability of the 2010 TMDL Staff Report, Board staff determined that no update to the section is needed for the DMCP Review. Board staff maintains the information and conclusions in Section 8.4 of the 2010 TMDL Staff Report and any updated information relevant to the section are already incorporated in other sections of the DMCP Review, as described below.

Seasonal and inter-annual variability in methylmercury loads is accounted for in the methylmercury source analysis Section 6 and methylmercury allocations Section 8.1 by evaluating annual median loads for Delta sources and losses for WYs 2000-2019. As mentioned in the water balance Section 6.1, this 20-year period includes a mix of wet and dry years.

Board staff did not update the THg/TSS source analysis in the DMCP Review, for reasons described in Section 7. Therefore, there are no total mercury variability or sediment load updates for this section.

Seasonal and inter-annual variability in black bass is accounted for in Section 4 Numeric Targets and Section 5 Linkage Analysis by using data collected over multiple years.

Regional and global changes may affect methylmercury loading to and within the Delta. Future conditions and the effects of climate change were evaluated in Section 6.1.13 and Section 6.4.1. Population growth is accounted for in the methylmercury allocations, as described in Section 8.1.3.2 and Section 8.1.3.3. Changes in methylmercury loads due to wetland restoration projects are evaluated in Section 6.2.3, Section 6.3.6, and Appendix D.

The 2010 TMDL Staff Report’s Section 8.4.3.3 described state and federal projects that had the potential to affect the transport of mercury, transport of methylmercury, and production of methylmercury in the Delta. Though the specific list of projects that may affect total mercury and methylmercury loading to or within the Delta has changed since adoption of the DMCP, the types of projects have not. These project types include water infrastructure development for deliveries, diversions, storage, and flood conveyance, and dredging for channel maintenance.

State and federal agencies were required to participate in DMCP Phase 1 Control Studies and DWR conducted the DWR Open Water Report, a characterization and control study of mercury in open water in the Delta (DiGiorgio *et al.* 2020). Flood conveyance and water management projects have the potential to increase ambient mercury and methylmercury levels within the Delta MeHg TMDL Boundary. However, some projects also have the potential to decrease ambient mercury and methylmercury levels by limiting water flows to the Delta or increasing water flows out of the Delta, thereby reducing total mercury and methylmercury loading to the Delta and increasing methylmercury exports from the Delta.

Modifications in water management activities will change residence time of water in the Delta, which may affect rates of photodegradation, sediment deposition, and uptake by biota. As stated in the 2010 TMDL Staff Report, 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 DMCP Review's linkage analysis, methylmercury source analysis, and methylmercury allocations described in this TMDL are based on present water management practices and channel configurations. However, there are current and future projects being evaluated and developed that will change water management practices and channel configurations, which may influence methylmercury concentrations and cycling in Delta fish and water. These projects include, but are not limited to:

- 2023 State of California Orders for Changes to Reservoir Storage and Outflow Requirements:
    - State of California Executive Order N-3-23 (https://www.gov.ca.gov/wp-content/uploads/2023/02/Feb-13-2023-Executive-Order.pdf?emrc=b12708): An order by Governor Newsom for the State Water Board to consider modifying outflow requirements from reservoirs to the Delta and diversion limitations to SWP and CVP facilities in order to increase reservoir storage and water diversions. The order also suspends Water Code § 13247, which requires state agencies to comply with water quality control plans adopted or approved by State Water Board when conducting activities that may affect water quality, and California Public Resources Code, Division 13, which details the CEQA requirements of environmental quality assessment and mitigation for impacts of a project.
    - State Water Board's Order Approving Temporary Urgency Changes to Water Right License and Permit Terms Relating to Delta Water Quality

[Objectives](https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/tucp/docs/2023/20230221-final-tuco.pdf) (https://www.waterboards.ca.gov/waterrights/water_issues /programs/drought/tucp/docs/2023/20230221-final-tuco.pdf): In response to a joint petition from DWR and United States Bureau of Reclamation (USBR), the State Water Board issued the order to temporarily modify water right permit and license conditions that would suspend existing minimum outflow requirements for Port Chicago in February and March 2023. This order would then allow reduced reservoir discharges and increased diversions to SWP and CVP facilities during these months.

- California EcoRestore: A multi-agency initiative to create and restore wildlife habitat in the Delta to mitigate long–term operations and impacts from the SWP and CVP. Currently, there are 32 EcoRestore projects in various stages of construction. In total, final EcoRestore projects should restore and protect approximately 30,000 acres of habitat in the Delta by creating 3,500 acres of managed wetlands, restoring 9,000 acres of tidal habitat, restoring over 17,500 acres of floodplain habitat, and enhancing over 1,000 acres of habitat not associated with mitigation requirements. For more information on EcoRestore, see DWR's California EcoRestore website (https://water.ca.gov/Programs/All-Programs/EcoRestore). DWR has participated in the Delta RMP for the duration of the 401 Water Quality Certifications for several EcoRestore projects.
- Centennial Reservoir Project: A proposed surface water reservoir that is intended to store up to 110,000 ac-ft of water from Bear River between the Rollins and Combie Reservoirs, west of Colfax, California. The project was deemed ineligible for Water Storage Investment Funding by the California Water Commission (https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Centennial-Water-Supply-Project) in 2018. The Nevada Irrigation District's Centennial Water Supply Project website (https://www.nidwater.com/centennial-water-supply-project) states the project is currently on hold and property purchases have been suspended.
- Delta Conveyance Project: A proposed project to build new water infrastructure to convey and divert water from the north Delta to the SWP and CVP delivery facilities south of the Delta. The proposed project alternative described in the 2022 Draft Environmental Impact Report (DEIR; https://www.deltaconveyanceproject.com/draft-eir) includes the construction of two new intakes, each with the capacity of up to 3,000 cfs, in the Sacramento River on the east and south side of Merritt Island near Hood and Courtland, California. The project also proposes the construction of a single tunnel, aqueduct, and pumping plant near Mountain House, California to deliver water to the Bethany Reservoir.
- Los Vaqueros Reservoir Expansion Project: A proposed expansion of the existing off-stream surface water Los Vaqueros Reservoir from 160,000 ac-ft to 275,000 ac-ft storage capacity, diverting water from the Delta, and delivering water to agencies and wildlife refuges. Current project timeline includes construction beginning in 2024 and operations beginning in 2029; see the California Water Commission's Los Vaqueros Reservoir Expansion Project

website (https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Los-Vaqueros-Reservoir-Expansion-Project) for more information.

- Operations and Maintenance Dredging of Stockton and Sacramento Deep Water Ship Channels Memorandum of Understanding, Central Valley Water Board Order R5-2019-0041 (Dredging MOU): A resolution between the Central Valley Water Board and the USACE, San Francisco District to allow annual operations and maintenance dredging of the Sacramento and Stockton DWSCs by USACE. The resolution is effective for 10 years with the expiration date of 2029. Under the MOU, the USACE agreed to participate in the Delta RMP, conduct pre-dredge sediment and leachate monitoring, dredge site receiving water monitoring, DMPS effluent and receiving water monitoring, notify the Central Valley Water Board in advance of dredging activities, and submit annual monitoring reports.
- Pacheco Reservoir Expansion Project: A proposed expansion of the existing surface water reservoir from 6,000 ac-ft to 141,600 ac-ft storage capacity, sourcing water from Pacheco Creek and San Luis Reservoir, and delivering water to local water districts and several wildlife refuges. This project is located within the Central Coast Regional Water Quality Control Board but is included in this list due to sourcing water from the Delta via the CVP and the San Luis Reservoir. Current project timeline includes construction beginning in 2027 and operations beginning in 2030; see the California Water Commission's Pacheco Reservoir Expansion Project website (https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Pacheco-Reservoir-Expansion-Project) for more details.
- Sites Reservoir Project: A proposed off-stream surface water reservoir that is intended to divert excess storm water from the Sacramento River, Funks Creek, and Stone Creek; store up to 1.5 million ac-ft of water west of Maxwell, California; and release water to the Sacramento River during dry periods. See the Sites Reservoir Authority's main webpage (https://sitesproject.org/) and the Revised DEIR/Supplemental Draft Environmental Impact Statement webpage (https://sitesproject.org/revised-draft-environmental-impact-report-supplemental-draft-environmental-impact-statement/) for more project information. The California Water Commission's Sites Project website (https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Sites-Project) states the current project timeline includes construction beginning in 2025 and operations beginning in 2030.
- Willow Springs Water Bank Conjunctive Use Project: A proposed project to use existing groundwater storage facilities to store up to 500,000 ac-ft of surface water diverted from the SWP during wet years and recovered when needed. The project is located within the Lahontan Regional Water Quality Control Board but is included in this list due to sourcing water from the Delta via the SWP's California Aqueduct. See the project's DEIR (https://img1.wsimg.com/blobby/go/5d9ba30a-393d-4213-b97e-e1e678db29b6/downloads/1_EIR-Vol%20I%20(2006)%20-%20Chapters%201-3.pdf?ver=1635445244354) for more details. The California Water Commission's Willow Springs Water Bank

Conjunctive Use Project website (https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Willow-Springs-Water-Bank-Conjunctive-Use-Project) currently lists the project timeline with construction beginning in 2025 and operations beginning in 2026.

- Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (also known as the Big Notch Project): Project to construct a new Fremont Weir structure, outlet channel, and other channel improvements in the Yolo Bypass to improve fish passage and rearing habitat; see DWR's Riverine Habitat Restoration Projects website (https://water.ca.gov/Programs/Integrated-Science-and-Engineering/Restoration-Mitigation-Compliance/Yolo-Bypass-Projects) for more details. The project is expected to inundate up to 20,000 acres of floodplain habitat more frequently and for longer periods of time and is conducted in accordance with the National Marine Fisheries Service's (NMFS) 2009 Biological Opinion and Conference Opinion on the Long Term Operations of the CVP and the SWP, the 2012 Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan, the NMFS 2019 Biological Opinion on Long Term Operation of the CVP and the SWP, and California Department of Fish and Wildlife's (CDFW) 2020 Incidental Take Permit for Long Term Operation of the SWP in the Sacramento-San Joaquin Delta (Central Valley Water Board Clean Water Act Section 401 Water Quality Certification and Order WDID# 5A57CR00195). The project is currently under construction, with in water work expected to be completed in 2023 (Central Valley Water Board Order Amendment WDID# 5A57CR00195A1).

In addition to these listed projects, Board staff will continue to coordinate with state and federal agencies to evaluate the potential effects of future water management, flood management, and dredging projects.

8.4.1 Critical Conditions

Critical conditions were incorporated in the development of the aqueous methylmercury implementation goal and margin of safety (Section 5.3), methylmercury source load analysis (Section 6), and Delta TMDL subarea-specific percent reduction requirements (Section 8.1.1.1) because data used for these assessments include a variety of wet and critically dry water year types (Table 6.1). The TMDL accounted for critical conditions for flow, loading, and methylmercury parameters by using the median of available flow and methylmercury data from WYs 2000-2019, or as described in Sections 4, 5, 6, and 8.1.

8.5 Key Points

- Consistent with the 2010 TMDL Staff Report, methylmercury allocations are divided among waste load allocations for point sources and load allocations for nonpoint sources. The Sacramento-San Joaquin Delta Methylmercury TMDL is the sum of these components.
- Methylmercury allocations were made in terms of specific Delta TMDL subareas assimilative capacity using available data from WYs 2000-2019. The

recommended aqueous methylmercury implementation goal is a median annual methylmercury concentration of 0.059 ng/L in unfiltered water (Section 5). This goal describes the assimilative capacity of Delta waters in terms of methylmercury concentration and encompasses a margin of safety of about 3.3%. Board staff anticipates that as the median concentration of methylmercury in each Delta TMDL subarea decreases to the aqueous methylmercury implementation goal, the targets for fish tissue will be attained.

- To determine necessary reductions, the median annual methylmercury concentrations in ambient water in the Delta TMDL subareas were compared to the aqueous methylmercury implementation goal. The amount of reduction needed in each subarea is expressed as a percent of the median annual methylmercury concentration from available data during WYs 2000-2019. Percent reductions required to meet the aqueous methylmercury implementation goal range from 4.07% in the West Delta subarea to 71.01% in the Yolo Bypass - North and - South cumulative subareas.
- The allocation strategy described in Section 8.1.2 is based on Board staff's recommendations, similar to the 2010 TMDL Staff Report's allocation strategy, and designed to remedy the beneficial use impairment in all Delta TMDL subareas.
- Board staff did not update total mercury limits in the DMCP Review and maintain the 2010 TMDL Staff Report's total mercury limits to maintain compliance with the USEPA's CTR for total mercury in the water column, to achieve the San Francisco Bay Water Board's mercury control program's total mercury allocation for the Central Valley, and to help enable methylmercury reductions in Delta water and fish.
- Board staff maintains the 110 kg total mercury reduction allocated by the San Francisco Bay Water Board's mercury control program to the Central Valley be met by reduction in total mercury entering the Delta from tributary inputs, for reasons described in the 2010 TMDL Staff Report.

9 REFERENCES

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Appendix A – Data Relied Upon & Considered

A.1 Fish Tissue & Aqueous Concentration Data for the TLG Evaluation & Linkage Analysis

Board staff compiled and evaluated aqueous methylmercury and fish mercury concentration data for reevaluating implementation goals (Section 4) and the linkage analysis (Section 5).

For the trophic level group evaluation (Section 4.1) and black bass evaluation (Section 4.2), Board staff evaluated 3,784 reported fish mercury concentration results collected from Delta waterways between 1998 and 2019. In total, these results were collected from 9,311 fish with some of the results being a composite sample of more than one fish. Of the total fish collected, 1,920 were black bass.

For the linkage analysis (Section 5), Board staff also evaluated 2,053 reported aqueous methylmercury concentration results and 1,076 reported black bass total mercury tissue concentration results collected from Delta waterways between 2000 and 2019. In total, the black bass results were collected from 1,112 fish, with some of the results being a composite sample of more than one fish.

Because of the extensive nature of the data used for these evaluations, a paper copy of the data set is not included in this report. Instead, the data are available in the "Appendix A.1 - Data for BB Eval & Linkage Analysis.xlsx" Microsoft Excel workbook.

The Microsoft Excel workbook includes multiple tabs labeled to distinguish references for data, data considered for evaluations, and data relied upon for final evaluation calculations.

A.2 Concentration & Flow Data for the Source Analysis

Board staff compiled and evaluated aqueous methylmercury, total mercury, NTU, and evaporation data results for thousands of water and effluent samples characterizing ambient aqueous concentrations and volumes of Delta inputs and exports. Evaporation, precipitation (see Appendix A.3), and flow gage (see Appendix A.4) data were compiled to estimate the Delta water balance and methylmercury loads. The data sets in this appendix were used for calculations and may not be the same as the original data source due to the reporting of censored (i.e., ND and DNQ) data. Additionally, certain data sets provided in this appendix contain imputed ND and DNQ values fitted to a distribution (e.g., Burr, gamma, log-logistic, log normal, Pareto, Weibull) using maximum likelihood estimation.

Because of the extensive nature of the data used for these evaluations, a paper copy of the data set is not included in this report. Instead, the data are available in the "Appendix A.2 - Data for Source Analysis.xlsx" Microsoft Excel workbook.

The Microsoft Excel workbook includes multiple tabs labeled to distinguish references for data relied upon, references for data considered, and data relied upon for final evaluation calculations.

A.3 Precipitation Data for the Source Analysis

Board staff compiled and evaluated precipitation data for several precipitation stations in watersheds that drain to the Delta for WYs 2000-2019 to estimate land cover runoff volumes. Precipitation data were compiled to estimate the Delta water balance, methylmercury loads, and were used in conjunction with GIS land cover type and boundaries (see Appendix D).

Because of the extensive nature of the data used for these evaluations, a paper copy of the data set is not included in this report. Instead, the data are available in the "Appendix A.3 - Precipitation Data.xlsx" Microsoft Excel workbook.

The Microsoft Excel workbook includes multiple tabs labeled to distinguish references and data for each precipitation station.

A.4 Flow Gage Data for the Source Analysis

Board staff compiled and evaluated flow gage data for several waterways that drain to the Delta for WYs 2000-2019 to estimate tributary flow volumes and Cache Creek Settling Basin outflows. Flow gage data were compiled to estimate the Delta water balance and methylmercury loads.

Because of the extensive nature of the data used for these evaluations, a paper copy of the data set is not included in this report. Instead, the data are available in the "Appendix A.4 - Flow Gage Data.xlsx" Microsoft Excel workbook.

The Microsoft Excel workbook includes multiple tabs labeled to distinguish references and data for each flow gage station.

APPENDIX B – ALTERNATIVES CONSIDERED FOR THE TLG EVALUATION & DETERMINATION OF THE BLACK BASS IMPLEMENTATION GOAL

The following sections describe the data analysis options Board staff considered in developing the proposed black bass implementation goal. Section B.1 describes the methods considered in calculating the 350 mm standardized total mercury concentration in black bass using multiple years of data. Section B.2 describes the year ranges of fish tissue total mercury data that were considered to determine the proposed black bass implementation goal.

B.1 Pooling Black Bass Data Versus the Annual Weighted Average to Determine the 350 mm Standardize Black Bass Total Mercury Concentration for Each Delta TMDL Subarea

As discussed in Section 0, the 2010 TMDL Staff Report proposed a largemouth bass implementation goal based on the 350 mm standardized largemouth bass total mercury concentration for each Delta TMDL subarea using data from calendar year 2000. The DMCP Review used three species of black bass rather than only the largemouth bass species and evaluated black bass data from calendar years 2000 through 2019.

Having more years of data provided more options to determine the 350 mm standardized black bass total mercury concentration for each subarea. The methodology details and calculation results are provided in the R Script “1.TEST TLG 1998-2019 & BB 2000-2019_pooled vs wt avg.Rmd”. Board staff compared the following two options:

- Option 1.A pooled all years of black bass data in each subarea and then determined the 350 mm standardized black bass total mercury concentration
- Option 1.B determined the 350 mm standardized black bass total mercury concentration for each calendar year and then averaged these concentrations for each subarea, weighted by annual sample size

Black bass mercury concentrations were standardized to 350 mm using regression models as described in Section 4.2.1 The resulting 350 mm standardized black bass total mercury concentrations for each option are shown in Table B.1.

Regressions models were used to evaluate the relationship between the weighted average mercury concentration for each TLG from years 1998-2019 (Table B.2, calculated as described in Section 4.1.1) and the standardized 350 mm black bass mercury concentrations from years 2000-2019 (Table B.1). Board staff found that the regression models using Option 1.B had the lowest average SER (Table B.3). Board staff provided an overview of Option 1.B during the 19 May 2021 Delta Tributaries Mercury Council (DTMC) meeting, which was supported by participants because it uses a weighted annual average that represents annual variation and accounts for differences in the number of black bass samples collected each year. Therefore, Board staff selected Option 1.B to use in the next evaluation step of selecting the year range of fish data (Section B.2).

Table B.1: Standardized 350 mm Black Bass Mercury Concentrations using 2000-2019 Data

Delta TMDL Subarea	Option 1.A Pooled (mg/kg)	Option 1.B Weighted Annual Average (mg/kg)
Central Delta	0.259	0.265
Mokelumne/ Cosumnes Rivers	1.109	1.119
Sacramento River	0.597	0.587
San Joaquin River	0.510	0.490
West Delta	0.307	0.314
Yolo Bypass - North	0.637	NA
Yolo Bypass - South	0.461	0.463

Table B.2: Weighted Average Fish Tissue Mercury Concentrations (mg/kg) by Trophic Level Group and Delta TMDL Subarea from 1998-2019

Trophic Level Group	Central Delta	Mokelumne/ Cosumnes Rivers	Sacramento River	San Joaquin River	West Delta	Yolo Bypass - North	Yolo Bypass - South
TL4 Fish (150-500 mm)	0.231	1.032	0.507	0.459	0.274	0.492	0.423
TL4 Fish (150-350 mm)	0.187	0.962	0.412	0.370	0.227	0.518	0.362
TL3 Fish (150-500 mm)	0.086	0.372	0.214	0.156	0.113	0.214	0.218
TL3 Fish (150-350 mm)	0.082	0.385	0.154	0.121	0.073	0.222	0.234
TL3 Fish (50 - <150 mm)	0.027	0.105	0.043	0.039	0.037	0.239	0.067
TL3 Fish (<50 mm)	0.024	0.114	0.034	0.037	0.034	NA	0.049

Table B.3: Option 1.A and 1.B Average SER of Regression Models

Evaluation Options to Calculate 350 mm Standardized MeHg Concentrations in Black Bass	Average SER of TLG and Black Bass Regression Models (mg/kg)
Option 1.A: Pooled	0.106
Option 1.B: Weighted Annual Average	0.078

B.2 Year Range for TLG Evaluation & Determining the Black Bass Implementation Goal

This section describes the evaluation of year ranges for TLG mercury tissue concentrations and 350 mm standardized black bass concentrations to determine the black bass implementation goal.

The 2010 TMDL Staff Report used fish data from 1998 through 2001 to calculate TLG total mercury concentrations and largemouth bass data from the year 2000 to determine the 350 mm standardized largemouth bass total mercury concentrations. For the DMCP Review, Board staff evaluated three year ranges to calculate TLG total mercury concentrations and to determine the weighted annual average 350 mm standardized black bass total mercury concentrations. The methodology details and calculation results are provided in the R Script “2.TEST TLG & BB_wt avg_year ranges.Rmd”.

Board staff considered the following options, which are summarized in Table B.4:

- Option 2.A uses all complied fish data: 1998 through 2019 for TLGs and 2000 through 2019 for black bass
- Option 2.B uses the data from the 2010 TMDL Staff Report: 1998 through 2001 for TLG and 2000 for black bass
- Option 2.C matching years of newly compiled data: 2002 through 2019 for TLG and black bass.

Regressions models were used to evaluate the relationship between the weighted average mercury concentration for each TLG (calculated as described in Section 4.1.1) and weighted annual average standardized 350 mm black bass mercury concentration for each option. Table B.5 summarizes the results of evaluating the year range options and provides values from the 2010 TMDL Staff Report for comparison. All three options resulted in humans being the most protective target. Options 2.A and 2.B both resulted in using TLG TL4 150-500 mm in the final regression model and humans as the most protective target to determine the black bass mercury implementation goal. Option 2.C resulted using TLG TL3 150-500 mm in the final regression model and humans as the most protective target, the same TLG and protective target used in the 2010 TMDL Staff Report.

Board staff decided to use Option 2.C, which is described in Sections 4.1 and 4.2, because it provided the regressions with the lowest average SER. Notably, Option 2.C does not include data for TLG TL3 fish less than 50 mm, which were only sampled in 1998 and 1999. Board staff found that although Option 2.A included TLG TL3 < 50 mm data, neither the California least tern nor Western snowy plover, the piscivorous species in that group, were chosen to be the most protective target. Additionally, the black bass implementation goal of Option 2.A was more protective than Option 2.C. Therefore, Board staff conclude the Black Bass Implementation Goal determined in Option 2.C is also protective of the TLG TL3 < 50 mm. This TLG will also be protected by the WQO of

0.03 mg/kg for TL2 and TL3 fish less than 50 mm that is being proposed to remain in place as part of the DMCP review.

After completing the linkage analysis (Section 5) that used black bass data from 2016 through 2019, Board staff considered using the same year range for the TLG evaluation and black bass implementation goal determination. This year range may be more representative of current fish tissue conditions. However, most of the TLG TL3 fish data was sampled before 2008, so excluding older data limited the lower trophic level data available for the DMCP Review and was not considered further.

Table B.4: Year Range Evaluation Options for TLG and Black Bass Regression Models

Evaluation Options for TLG and Black Bass Regression Models	Year Range for TLGs	Year Range for Black Bass
Option 2.A: All Compiled Fish Data	1998 - 2019	2000 - 2019
Option 2.B: 2010 TMDL	1998 - 2001	2000
Option 2.C: Newly Compiled Fish Data	2002 - 2019	2002 - 2019

Table B.5: Comparing Year Range Results to Calculate the Black Bass Implementation Goal

Evaluation Options for TLG and Black Bass Regression Models	Average SER of TLG and Black Bass Regression Models	TLG Used in Final Regression Model	Final Regression Model SER (Model Type)	Most Protective Target (Hg mg/kg)	Black Bass Implementation Goal (mg/kg)
Option 2.A: All Fish Data	0.0780	TL4 150-500 mm	0.0170 (NLS)	Human (0.24)	0.272
Option 2.B: 2010 TMDL	0.1898	TL4 150-500 mm	0.0931 (Log)	Human (0.24)	0.215
Option 2.C: Only New Fish Data	0.0571	TL3 150-500 mm	0.0513 (Exp)	Human (0.08)	0.258
2010 TMDL Staff Report	NA	TL3 150-500 mm[142]	NA (Linear)	Human (0.08)	0.24[143]

[142] The 2010 TMDL Staff Report regression models evaluated the total mercury concentration relationship between TLGs and largemouth bass.

[143] The largemouth bass methylmercury goal.

APPENDIX C – ALTERNATIVES CONSIDERED FOR THE LINKAGE ANALYSIS

The following sections describe the data analysis options Board staff considered in developing the proposed linkage model and aqueous MeHg implementation goal. Section C.1 Year Ranges. Section C.2 Data Pairing Methods the different methods that were considered to pair multiple years of black bass and aqueous data for each Delta TMDL subarea. The calculation and methodology details are provided in the R script "1.TEST_Linkage Analysis_Aq & BB_Year Pairings.Rmd".

C.1 Year Ranges

The 2010 TMDL Staff Report conducted the linkage analysis using aqueous methylmercury data and largemouth bass mercury data sampled in the year 2000.

For the DMCP Review, Board staff evaluated three different periods: 2000-2019, 2012-2019, and 2016-2019. For each year range, black bass data were selected based on calendar year and aqueous data were selected based on a seasonal year that extends from 1 November through 31 October. The seasonal year for aqueous data includes months November through April, which had an average rainfall[144] greater than 1-inch, as the wet season, and May through October, which had an average rainfall less than 1-inch, as the dry season. The seasonal year was designated by the calendar year in which it ends. For example, the 2010 seasonal aqueous year started on 1 November 2009 and ended on 31 October 2010. Due to time constraints, Board staff did not evaluate different year designations (i.e., data sets being selected both by calendar year or water year, or combinations of different year designations).

The year range 2000-2019 was chosen to include 2010 TMDL Staff Report linkage model data and the most recent year of the DMCP Review data compilation. The year range 2016-2019 was chosen to only include Delta RMP data, which involved a focused sampling plan to collect black bass mercury and aqueous methylmercury data at representative locations. The seasonal year range of 2012-2019 was also selected for aqueous data with black bass being selected from years 2016-2019. This allowed each year of black bass data to be paired with five years of preceding aqueous data.

Table C.1 summarizes the year ranges Board staff evaluated for the linkage analysis. The table also shows the lowest SER achieved for different analysis methods, which are discussed in the next section.

C.2 Data Pairing Methods

Two methods to pair black bass mercury data with aqueous methylmercury data were evaluated for the three periods (Table C.1): (1) pairing aqueous methylmercury data and black bass mercury data by both Delta TMDL subarea and year, and (2) pairing aqueous and black bass data by subarea only. Both methods used seven different

[144] Monthly precipitation averages were calculated using 2000 through 2019 monthly accumulation rainfall data from CDEC precipitation stations Sacramento WB City (SCR) and Los Banos (LSB).

summary statistics to measure central tendency (Table C.2) and nine regression models. The regressions used were linear, exponential, logarithmic, NLS, and GAM (using a smoothing dimension term 1, 2, 3, or 4), and power models. This resulted in 63 potential linkage models for each evaluation method. Because each year range was evaluated using the two methods, 378 potential linkage models were evaluated.

The lowest regression model SER for the year range and pairing method is listed in Table C.1. The lowest SER overall, 0.0195, occurred when using black bass and aqueous data within the 2016-2019 period and grouping the data by subarea only. This year range and analysis method was selected to develop the final linkage model described in Section 5.

C.2.1 Pairing Data by Delta TMDL Subarea & Year

Every year of black bass mercury data was standardized to a fish length of 350 mm as described in Section 4.2.1. Consistent with the 2010 TMDL Staff Report's assumption that a 350 mm bass is three to five years old (see Section 4.8.1 of the 2010 TMDL Staff Report), Board staff paired five years of aqueous data with each standardized 350 mm bass mercury concentration. This allowed the incorporation of more data because some years that black bass data were sampled did not have corresponding aqueous data, and vice versa (Figure C.1). The five seasonal years of aqueous data included the year black bass were sampled and allowed overlap with the black bass lifespan. For example, the standardized 350 mm mercury concentration for black bass sampled in 2005 was paired with available aqueous methylmercury data collected in seasonal years 2005, 2004, 2003, 2002, and 2001. In contrast, the 2010 TMDL Staff Report paired aqueous data with only the last eight months of the sampled largemouth bass lifespan (see Section 5.1 of the 2010 TMDL Staff Report).

Seven aqueous methylmercury data summary statistics were calculated to evaluate the best way to pair the data with 350 mm standardized black bass (Table C.2). The median, average, and geomean of the five years of aqueous data were calculated by pooling the data and by grouping by seasonal year. The average was also calculated by seasonal year and weighted by sample size. Each aqueous methylmercury concentration summary statistic was paired with a standardized 350 mm black bass concentration by subarea and year and regressed using a linear, power, exponential, NLS, GAM (using a smoothing dimension term 1, 2, 3, or 4), and logarithmic model.

C.2.2 Pairing by Delta TMDL Subarea

The median, average, geomean, and weighted average were calculated for 350 mm standardized black bass mercury concentrations in each subarea. The same was done for the aqueous methylmercury data summary statistics shown in Table C.2. The weighted average of 350 mm standardized black bass was weighted by the number of black bass samples collected during the year. The weighted average of aqueous methylmercury concentration was weighted by the number of samples collected during the 5-seasonal year period. Table C.3 shows how aqueous summary statistics were matched with 350 mm standardized black bass summary statistics. Aqueous methylmercury concentrations and standardized 350 mm black bass concentrations were paired by subarea and regressed using a linear, power, exponential, NLS, GAM (using a smoothing dimension term 1, 2, 3, or 4), and logarithmic model.

C.2.3 Other Options Considered

In addition to the methods described above, aqueous methylmercury data and black bass mercury data, not standardized to 350 mm, were pooled for year range 2000 - 2019 by Delta TMDL subarea. The median, average, and geomean were calculated for each pooled dataset. Matching summary statistics for aqueous and black bass data were paired by subarea and regressed using a linear, power, exponential, NLS, GAM (using a smoothing dimension term 1, 2, 3, or 4), and logarithmic model. This resulted in 27 potential linkage models.

The lowest SER achieved was 0.0253 using medians and a logarithmic regression model. Because the lowest SER was higher than pairing data by subarea for year rang 2000 – 2019 (Table C.1), Board staff did not apply this method to the other year ranges due to limited time.

There were other alternatives that Board staff did not investigate. For example, one option could be to perform a linkage analysis for each subarea. This was not an option for the 2010 TMDL Staff Report because at that time Board staff only had data available from one year. Thus, there was only one data point per subarea for the linkage analysis. However, with more data available during the DMCP Review, multiple data points were available when data was summarized by year and subarea, as described above. This option was not evaluated due to limited time.

C.3 Final Results

In total, Board staff evaluated 405 potential linkage models and choose the year range and evaluation method that resulted in the regression model with the lowest SER. Table C.1 shows that the lowest SER of 0.0195 occurred when using the Delta RMP sampling years 2016 - 2019 for both aqueous methylmercury concentrations and standardized 350 mm black bass mercury concentrations summarized by Delta TMDL subarea. This is likely because the Delta RMP sampling plan collected data at locations determined to be representative of the Delta TMDL subareas.

The regression model that provided the lowest SER was selected as the proposed linkage model (Section 5). In summary, each year of black bass mercury concentrations were standardized to a fish length of 350 mm. For each year a standardized 350 mm black bass mercury concentration was available, preceding seasonal years of aqueous methylmercury concentrations were pooled and the median concentration was calculated. For each Delta TMDL subarea, the median 350 mm standardized black bass was paired with the median of the pooled aqueous methylmercury medians (Table C.3). Regressing these data points using a logarithmic model provided the lowest SER of

0.0195. The calculation and methodology details are provided in the R script "3.FINAL_Linkage Analysis_DRMP Aq & BB 2016-2019.Rmd".

Table C.1: Year Range and Minimum Standard Error of Regression for Different Data Pairing Methods

Black Bass Calendar Year Range	Aqueous Seasonal Year Range	Paired by Subarea & Year Lowest SER	Paired by Subarea Lowest SER	Pooled by Subarea Lowest SER
2000-2019	2000-2019	0.0505	0.0232	0.0251
2016-2019	2012-2019	0.0259	0.0229	NA
2016-2019	2016-2019	0.0236	0.0195	NA

Table C.2: Summary Statistics of Aqueous Methylmercury Concentrations Paired with Standardized 350 mm Black Bass Concentrations by Subarea and Year

Aqueous Methylmercury Data Summary Statistic	Description
Pooled Median	Calculated the median of the pooled five years of aqueous methylmercury data
Seasonal Year Median	Calculated the median for each seasonal year, then calculated the median of those medians
Pooled Average	Calculated the average of the pooled five years of aqueous methylmercury data
Seasonal Year Average	Calculated the average for each seasonal year, then calculated the average of those averages
Pooled Geomean	Calculated the geomean of the pooled five years of aqueous methylmercury data
Seasonal Year Geomean	Calculated the geomean for each seasonal year, then calculated the geomean of those geomeans
Weighted Average	Calculated the average for each seasonal year, then calculated the average of those averages weighted by sample size

Table C.3: Summary Statistics for Standardized 350 mm Black Bass and Aqueous Methylmercury Data Paired by Subarea

Std. 350 mm Black Bass Summary Statistic	Aqueous Methylmercury Data Summary Statistic
Median	Median of Pooled Medians & Median of Seasonal Year Medians
Average	Average of Pooled Averages & Average of Seasonal Year Averages
Geomean	Geomean of Pooled Geomeans & Geomean of Seasonal Year Geomeans
Weighted Average	Weighted Average of Weighted Averages

Figure C.1: Monthly Average and Sample Size of Aqueous Methylmercury (ng/L) and Black Bass Mercury (mg/kg) Concentrations in each Subarea

APPENDIX D – GIS, LAND COVER, & RUNOFF COEFFICIENTS

D.1 Introduction

To estimate methylmercury source loading in the 2010 TMDL Staff Report, Board staff relied on DWR's 1993-2003 land use survey geospatial data within the Region 5 jurisdictional boundary to acquire land cover acreages and calculate runoff volumes representative of WYs 1984-2003.

To reevaluate runoff volumes and methylmercury loading for the DMCP Review, Board staff updated land cover using available data from WYs 2000-2019. Areas that were reevaluated are within the Delta MeHg TMDL Boundary and within the tributary watershed boundaries. Sources of land cover layers used in the DMCP Review include more recent DWR county land use surveys (CNRA c2021c-g; CNRA c2022a-g), city and county general use maps (Borelli 2022; Brooke 2022; Bruce 2022; CCC c2021; Fairfield c2022; Patel 2022; Valenzuela 2022), DWR agricultural crop mapping (CNRA c2021a-b), USFWS NWI (USFWS n.d.), Caltrans State Highways (Caltrans c2022), Port of Stockton (Bedore 2022), and layers created for the 2010 TMDL Staff Report (Wood *et al.* 2010). Table D.1 provides the metadata crosswalk of attributes assigned in source layers to Central Valley Water Board land cover terms for consistency.

References relied upon are listed in Appendix D.11. For more information on references for geospatial data, including a list of references considered, are available see the "Appendix D - List of References.xlsx" Microsoft Excel workbook.

Board staff used NAD 83 California Teale Alpers coordinate system in ArcMap for geospatial processing and reprojected layers, as needed, to this coordinate system to ensure acreage accuracy. Steps taken by Board staff to process the geospatial data for the DMCP Review are described in the following sections.

Because of the extensive nature of the final geospatial datasets used for these evaluations, a paper copy of the datasets is not included in this report. Instead, the layers are available electronically in the "DMCP Review GIS Layers" zip file.

D.2 Layering

To prevent double counting of areas, Board staff layered shapefiles from top to bottom and removed overlap from underlying layers in the following order:

- Port of Stockton (Bedore 2022)
- State Highways (Caltrans c2022)
- Wetland (USFWS n.d.)
- Open Water
    - 2010 TMDL Staff Report Figure 6.7 open water layer for within the Delta TMDL Boundary (Wood *et al*. 2010)

    - USFWS NWI layer for within the tributary watershed boundary (USFWS n.d.)
- 2018 Crop Mapping (CNRA c2021a)
- 2015 Delta Crop Mapping (CNRA c2021b)
- Urban
    - Cities (Antioch, Brentwood, Oakley, Fairfield, and Pittsburg)[145]
    - Counties (Contra Costa and Solano)[146]
    - DWR county land use surveys (Alameda, Butte, Calaveras, El Dorado, Nevada, Sacramento, San Joaquin, Stanislaus, Sutter, Tuolumne, Yolo, Yuba)[147]
    - Urban attribute in 2018 Crop Mapping for within the tributary watershed boundary (CNRA c2021a)
- Land cover layer from Figure 6.7 of the 2010 TMDL Staff Report (Wood *et al*. 2010)

Board staff compared Delta subarea acreages (Table D.2) and land cover used in the DMCP Review within each Delta subarea were (Table D.3) to check that acreage within the Delta MeHg TMDL Boundary was assigned a land cover type. By comparing the total acreage in Table D.2 and Table D.3, 100% of the Delta MeHg TMDL Boundary area was assigned a land cover type.

The following sections provide more detail about the GIS layers used in the DMCP Review.

D.3 Port of Stockton

Port of Stockton provided land cover information to Board staff with submission and post-submission discussions of their Control Study (Appendix E.11). Board staff reviewed the land cover information and noted parcel outlines were outdated compared to the San Joaquin County Land Use Survey layer downloaded from the California Natural Resources Agency's (CNRA) Natural Resources Spatial Data website (https://gis.data.cnra.ca.gov/). Board staff notified Port of Stockton consultants on 25 January 2022 of the discrepancy and provided the Port of Stockton the opportunity to submit updated land cover geospatial data. After multiple discussions with the Port of Stockton's consultant, Board staff received revised layers on 25 February, 3 March, and 11 March of 2022. The layer used in the DMCP Review is the delineated version received on 11 March 2022 (Bedore 2022). Board staff reassigned a few land cover types so that similar areas based on satellite imagery had consistent land cover designations across the Delta (Table D.1). Since this layer was the smallest, most

[145] References for city geospatial data are Borelli 2022, Brooke 2022, Valenzuela 2022, Fairfield c2022, and Patel 2022, respectively.

[146] References for county geospatial data are CCC c2021 and Bruce 2022, respectively.

[147] References for DWR county land use surveys area CNRA c2021c, CNRA c2022a, CNRA c2022b, CNRA c2022c, CNRA c2022d, CNRA c2021d, CNRA c2021e, CNRA c2022e, CNRA c2021f, CNRA c2022f, CNRA c2021g, CNRA c2022g, respectively.

detailed, and had a variety of land cover types, Board staff decided to use it as the top most layer, erasing any overlapping areas of the layers below.

D.4 State Highways

Board staff requested geospatial data of jurisdictional areas from Caltrans staff several times in 2021 and 2022, but the requested layers were not received during the DMCP Review.[148] Board staff acquired the State Highways polyline layer, which included a usage License (Caltrans c2023) from Caltrans' GIS Data website (https://gisdata-caltrans.opendata.arcgis.com/) on 12 January 2022 (Caltrans c2022). Metadata for the layer states polylines were based on an October 2021 Caltrans data extraction. Because the layer downloaded was a polyline layer and not a polygon layer, acreage data was not included. Board staff assigned each polyline a uniform width of 75 feet to incorporate lanes, highway medians, shoulders, and right of ways. For highways with left and right highway polylines, any overlap of the two 75-foot-wide lanes were removed. Board staff confirmed several lane width estimates with comparisons to satellite imagery.

No overlap of the State Highway layer and Port of Stockton layer occurred. Any overlap of the state highway area with underlying layers were erased from the underlying layers. Note that because land cover acreages were assessed in 2D, land cover area below bridges were also deleted from that associated layer type (e.g., wetlands, open water), which underestimates the area of that layer.

D.5 Wetland

Board staff found several options to update wetland land cover layers, including the USFWS NWI (USFWS n.d.; https://www.fws.gov/wetlands/Data/Data-Download.html) and CDFW's Delta Vegetation and Land Use Update from 2016 (https://gis.data.cnra.ca.gov/datasets/CDFW::vegetation-delta-vegetation-and-land-use-update-2016-ds2855-1). The dataset from CDFW was highly detailed and included polygons assigned to specific plant type. This was more comprehensive than the purposes of the DMCP Review and would have taken a considerable amount of time to research plant species names to reassign to the appropriate land cover. Board staff decided to use USFWS NWI to update wetland acreages because the Delta and Yolo Bypass Wetlands and Open Water Habitat map in the 2010 TMDL Staff Report's Figure 6.4 displays wetland geospatial data from USFWS NWI, other sources evaluated were not as useful, and wetlands were identified by wetland type which included tidal and nontidal.

Data downloaded from USFWS's NWI included: wetlands polygon data, wetlands project metadata, wetlands historic map information, historic wetlands, and historic wetlands project metadata. Based on information within the metadata details, the geospatial layers were last updated on 22 May 2018. Categories that were included in the dataset were: Estuarine and Marine Deepwater, Estuarine and Marine Wetland,

[148] Board staff requested GIS layers from Caltrans staff on 24 November 2021, 14 December 2021, 30 November 2022, and 9 December 2022 but did not receive a response or the requested data.

Freshwater Emergent Wetland, Freshwater Forested/Shrub Wetland, Freshwater Pond, Lake, Other, and Riverine. Board staff excluded Estuarine and Marine Deepwater, Freshwater Pond, Lake, Other, and Riverine because these categories are accounted for in the open water, agriculture, or urban land cover layers. Attributes for Estuarine and Marine Wetland, Freshwater Emergent Wetland, and Freshwater Forested/Shrub Wetland were grouped together and relabeled as Wetland and Marsh (Figure 6.1). Tidal and nontidal wetland were separated based on classifications provided by USFWS in the NWI shapefile's attribute table, which classified a wetland as either Nontidal, Freshwater Tidal, or Saltwater Tidal. Board staff grouped Freshwater Tidal and Saltwater Tidal together and labeled them Tidal Wetlands (Figure 6.8).

Overlapping areas with the Port of Stockton and State Highway layers were erased, and polygon geospatial geometry were recalculated.

Board staff acknowledges that newer wetland restoration projects are not included in the layer shown in Figure 6.8 because the projects were not completed by 2018. Table D.4 provides Board staff's compiled list of known permitted projects that plan to convert primarily agricultural land cover to wetland habitat and were not completed as of October 2021. The list of projects primarily includes EcoRestore projects within the Yolo Bypass, Sherman Island, and Decker Island. The list may not be comprehensive but provides a glimpse of future land use acreages for wetland and agricultural land covers. Information on these permitted projects were gathered from project files, Central Valley Water Board's 401 Water Quality Certifications webpage (https://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/401_wqcerts/), and State Water Board's ArcGIS Online CIWQS 2020 Application[149] (https://gispublic.waterboards.ca.gov/portal/apps/webappviewer/index.html?id=f1835bcdaed04cd298d6b19cf7c0a0d0).

EcoRestore projects were developed in order to offset impacts to special status species in the Delta from the SWP and CVP, the USFWS and NMFS issued Biological Opinions in 2008 and 2009, respectively. These Biological Opinions required improvement of the overall health of the Delta ecosystem, prompting the development of California EcoRestore projects to create and restore at least 30,000 acres of critical habitat in the Delta (for more details, see DWR's EcoRestore website (https://water.ca.gov/Programs/All-Programs/EcoRestore)). In 2016, USBR and DWR requested re-initiation of Endangered Species Act consultation based on newer information on the long-term operations of the SWP and CVP. USFWS and NWFS released separate Biological Opinions in October 2019 for the 2016 request (see the USFWS CVP and California SWP website (https://www.fws.gov/project/central-valley-project-and-california-state-water-project-consultation) and the NOAA's Biological Opinion for the Reinitiation of Consultation on the Long-Term Operation of the CVP and SWP website (https://www.fisheries.noaa.gov/resource/document/biological-opinion-reinitiation-consultation-long-term-operation-central-valley) for more information). In September 2021, USBR and DWR again requested re-initiation of consultation based on project

[149] Wetland restoration project information was found on the CIWQS 2020 Application webpage by filtering permits to Facility Subtype Dredge/Fill Site and searching for projects with "restoration" in name.

modification impacts that were not analyzed in the 2019 Biological Opinions (for more details, see the USBR's [2021 Consultation on the Coordinated Long-Term Operation of the CVP and SWP website](https://www.usbr.gov/mp/bdo/lto/) (https://www.usbr.gov/mp/bdo/lto/)). It is expected that both USFWS and NWFS will issue Biological Opinions in the future based on the 2021 consultation request and mitigation requirements, such as additional habitat restoration projects, but are not known at the time of DMCP Review.

Several levee reconstruction projects are occurring or are planned to occur within the Delta that include creating wetland habitat on the waterside section of the levees. With concerns on the effectiveness of existing levees in current and future conditions, many are required to be reconstructed. Waterside sections of levees in the Delta are typically sloped, packed earth and rock, containing little to no vegetation or shady habitat. The Delta Stewardship Council was tasked to create the Delta Levee Investment Strategy (https://deltacouncil.ca.gov/dlis/) to ensure levee reconstructions in the Delta meets requirements set in the 2009 Delta Reform Act (https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200920107AB12) and the 2013 Delta Plan (https://deltacouncil.ca.gov/delta-plan/). In 2016, the Delta Stewardship Council issued the document *Improving Habitats Along Delta Levees; A Review of Past and Recommended Next Steps* (https://cawaterlibrary.net/wp-content/uploads/2017/10/Improving-Habitats-Along-Delta-Levees-Issue-Paper.pdf), which analyzes and provides suggestions for habitat benches as an option for levee reconstruction projects. Some of these projects involving levee reconstruction with habitat bench creation in and near the Delta include:

- Northwest Levee Improvements and Stone Road Levee Seepage Reduction Project, Waste Discharger Identification (WDID) # 5B07CR00211
- Sacramento River Erosion Control and Habitat Enhancement Project, WDID # 5A34CR00817
- Grand Island Levee Erosion Repair Project, WDID # 5A34CR00790
- Huff's Corner Levee Raise and Channel Reconfiguration Project, WDID # 5A57CR00203 & R5-2018-0085-0074
- Grand Island Levee Maintenance Project, WDID # 5A34CR00839
- Twitchell Island Levee Improvement Project-San Joaquin River Reach, WDID # 5B34CR00065
- Southport Levee Improvement Project/Southport Early Implementation Project, WDID # 5A57CR00140
- Lower Elkhorn Basin Levee Setback Project, WDID # 5A57CR00182A1

D.6 Open Water

Board staff considered water surface layers from the following data sources to update the area of open water in the Delta: (1) USFWS NWI; (2) 2014 Crop Mapping (https://data.cnra.ca.gov/dataset/i15-crop-mapping-2014) ; (3) 2015 Crop Mapping (https://data.cnra.ca.gov/dataset/i15-crop-mapping-delta-2015); (4) USEPA's

Watershed Index Online (https://www.epa.gov/wsio); (5) USGS's National Hydrography Dataset; and (6) State Water Board's Gallery for California Water Resources Control Board Portal (GIS Portal; https://gispublic.waterboards.ca.gov/portal/home/gallery.html?view=grid&sortOrder=asc&sortField=title). None of these layers were as comprehensive as the open water layer used in the 2010 TMDL Staff Report, except for the USFWS NWI. Specifically, the 2014 and 2015 Crop Mapping layers included agricultural ditches and canals that were not hydrologically connected to free-flowing rivers and streams and would have taken an exorbitant amount of time to remove. USEPA's Watershed Index Online lacked attributes and other details needed to accurately identify open water areas. USGS's National Hydrography Dataset did not include important waterbodies such as lakes. The State Water Board's GIS Portal did not include some sections of rivers and streams. The USFWS NWI layer classified many Delta island surface waters as "Riverine", including hundreds of individual agricultural drains, which are accounted for in the source analysis for agricultural returns (Section 6.2.5) and are not counted as Open Water for the purposes of the open water sediment flux source analysis (Section 6.2.2). Thus, use of the USFWS NWI layer would have required removal of the agricultural drain polygons from "Riverine" to ensure double counting did not occur. As this would have taken more time, and river and stream channels were not dissimilar to the layer used in the 2010 TMDL Staff Report, Board staff decided not to use the USFWS NWI open water layer.

Ultimately, the 2010 Open Water layer was used for the DMCP Review. Changes to the 2010 Open Water layer include removal of waterbodies labeled "Other" and removal of overlaps with the 2018 Wetlands layer, since overlapped areas were already reclassified from "Riverine", "Estuarine and Marine Deepwater", and "Lake" to wetland. To ensure these reclassifications were accurate, Board staff verified several of the overlapping areas on GIS with satellite images. Overlap with the Port of Stockton and State Highway layers were also erased from the Open Water layer.

D.7 Agriculture

Board staff used the Crop Mapping 2018 and 2015 found on the CNRA Open Data website (https://data.cnra.ca.gov/dataset/) to update agricultural geospatial data for the DMCP Review (CNRA c2021a-b). Figure 6.12 is a result of merging the following layers: Crop Mapping 2018, Crop Mapping Delta 2015, and 2010 TMDL Staff Report Figure 6.7. The Crop Mapping 2018 data set is a mapping of all agricultural crops in California but includes other land cover types, as well. The Crop Mapping Delta 2015 was specific to the Sacramento-San Joaquin Delta area and did not include the upper portion of the Yolo Bypass. Board staff selected agricultural use attributes and relabeled them to Central Valley Water Board land cover terms, as needed (Table D.5). Overlap of the Crop Mapping 2018 layer with the Crop Mapping 2015 layer was erased from the less recent but more detailed Crop Mapping 2015 layer. Board staff then backfilled any additional agricultural land cover areas that were not in either Crop Mapping layer using the 2010 TMDL Staff Report Figure 6.7 layer as a base layer, after removing overlap of the Crop Mapping 2018 and 2015 layers. In addition to erasing overlaps of the three agricultural layers, Board staff removed overlaps of Port of Stockton, State Highways, Wetland, and Open Water layers from the agricultural attributes of the 2018 and 2015 Cropping Mapping layers.

As discussed in Appendix D.5, several large wetland restoration projects have been constructed, are under construction, or are planned to be constructed in the Delta. Many of these projects are converting agricultural lands to wetland and riparian habitat, which Board staff expects will change runoff volumes for wetland and agriculture lands by thousands of acres, most notably in the Yolo Bypass - South subarea.

D.8 Urban

Board staff downloaded DWR county land use survey data from the CNRA Spatial Data website for Alameda, Butte, Calaveras, El Dorado, Nevada, Sacramento, San Joaquin, Stanislaus, Sutter, Tuolumne, Yolo, and Yuba counties.[150] Board staff also downloaded, but ultimately did not use, the Urban and Built-Up Land layer from the California Important Farmland: Most Recent map. At the time of the DMCP Review, Board staff was unable to obtain DWR county land use surveys for Contra Costa and Solano counties.[151] In order to include urban land cover for those counties, Board staff acquired general plan or zoning map layers from Contra Costa County, Solano County, City of Antioch, City of Brentwood, City of Fairfield, City of Oakley, and the City of Pittsburg.[152]

Board staff downloaded Contra Costa County general plan land use data, which included a GIS Data Disclaimer (Contra Costa County n.d.a) and Disclaimer of Liability and Warranties (Contra Costa County n.d.b) from the Contra Costa County GIS website (https://www.contracosta.ca.gov/1818/GIS) on 15 December 2021. Board staff contacted Solano County staff via email to request a copy of the County's General Plan Land Use Diagram data in shapefile format, which was provided in a reply email on 13 January 2022. Board staff reached out to City of Antioch staff to obtain a copy of the shapefile used to create the City's General Plan Land Use Map and received a reply email with the data on 18 January 2022. City of Brentwood staff provided copies of the City's General Plan Land Use map in shapefile format to Board staff via email on 27 January 2022. City of Fairfield staff requested that Board staff submit a Public Record's Act request for the release of the layers used for the City's land use maps. The Public Record Act request was submitted on 20 January 2022 and the shapefiles were posted in the response to the request on their website on 28 January 2022. The files downloaded for the City of Fairfield were copies of the parcels layer joined with the Assessor's designated land use information and zoning layer. City of Oakley staff emailed a copy of the City's General Plan Land Use and Zoning shapefiles to Board staff on 19 January 2022. City of Pittsburg staff provided a copy of the City's General

[150] References for DWR county land use surveys area CNRA c2021c, CNRA c2022a, CNRA c2022b, CNRA c2022c, CNRA c2022d, CNRA c2021d, CNRA c2021e, CNRA c2022e, CNRA c2021f, CNRA c2022f, CNRA c2021g, CNRA c2022g, respectively.

[151] Board staff asked managers of the Open Data website if they were able to find the land surveys for Solano and Contra Costa County and the managers replied that they were unable to find these land surveys.

[152] References are CCC c2021, Bruce 2022, Borelli 2022, Brooke 2022, Fairfield c2022, Valenzuela 2022, and Patel 2022, respectively.

Plan shapefiles and a GIS Data Disclaimer (City of Pittsburg n.d.) to Board staff via email on 19 January 2022.

It should be noted that files provided by the counties and cities listed above are not considered land use surveys and varied in descriptions of parcels. Board staff renamed parcel descriptions to Central Valley Water Board land cover terms either by names provided in the attribute tables of each file or by checking unnamed parcels with satellite images to approximate the best term for parcels (Table D.5). No urban areas in the City of Fairfield, Solano County, or DWR county land use surveys for Butte, Calaveras, El Dorado, Nevada, Stanislaus, Sutter, Tuolumne, and Yuba counties were found to be within the Delta MeHg TMDL Boundary. However, the urban areas from these datasets were included in the tributary watershed land cover assessment.

Any overlap of the cities and counties were removed from the county layers. Overlap of the Port of Stockton, State Highways, Wetland, Open Water, agriculture from the 2018 Crop Mapping, and agriculture from the 2015 Delta Crop Mapping layers were then removed from all urban geospatial data.

D.9 2010 TMDL Staff Report Land Cover

The 2010 TMDL Staff Report land cover map is shown in Figure 6.7 of the 2010 TMDL Staff Report (Wood *et al.* 2010). Overlap of the layers discussed above were removed from the 2010 TMDL Staff Report layer. These include Port of Stockton, State Highways, Wetland, Open Water, agriculture from the 2018 Crop Mapping, and agriculture from the 2015 Delta Crop Mapping, cities, counties, and DWR county land use survey layers. As mentioned previously, what remained of the 2010 TMDL Staff Report land cover map was used to backfill any blank areas within the Delta MeHg TMDL Boundary that were not identified by newer geospatial data. Board staff noted that areas not included were mostly native vegetation, previously identified as Rangeland in the 2010 TMDL Staff Report map.

D.10 Tributary Watersheds

To assess methylmercury loading to the Delta from tributaries without streamflow gage data, Board staff relied upon precipitation runoff volumes to estimate flow volumes (Section 6.2.1). Consistent with the 2010 TMDL Staff Report, precipitation runoff volumes were calculated for tributary watershed areas upstream of the Delta MeHg TMDL Boundary and downstream of major dams or reservoirs (Figure 6.7; Table D.6).

Board staff used available geospatial data, described below, to update land cover in each tributary watershed (Table D.7). Board staff layered datasets in the following order from top to bottom: State Highways, wetland and open water, agriculture, urban, and the 2010 TMDL Staff Report map.

Board staff used the same State Highway layer described in Appendix D.4 for the tributary watersheds. Though Board staff assumed the width of 75ft was appropriate for estimating Caltrans jurisdictional areas within the Delta MeHg TMDL Boundary, this width may be an underestimate for areas outside the Delta MeHg TMDL Boundary. This is because highways have more width in more urbanized areas and the State Highway layer does not include on and off ramps.

The USFWS NWI dataset was used for the wetland and open water land cover within the tributary watershed. Board staff assigned the attributes “Freshwater Emergent Wetland,” “Freshwater Forested/Shrub Wetland,” and “Estuarine and Marine Wetland” as Wetland and “Estuarine and Marine Deepwater”, “Freshwater Pond”, “Lake”, and “Riverine” as Open Water. Overlaps with the State Highway layer were erased.

The 2018 Crop Mapping layer described in Section 6.2.5 was also used for identifying agricultural areas in the tributary watersheds. The 2015 Delta Crop Mapping layer was not used for the tributary watersheds because it detailed areas only within the Legal Delta Boundary.

Board staff used the DWR county land use surveys and methods described in Section 6.2.6 for the urban land cover in the tributary watersheds. Some counties did not have available land use surveys from the Open Data website. To fill in the missing urban data for these counties, Board staff used the urban attribute in the 2018 Agricultural Crop Mapping.

Lastly, the 2010 TMDL Staff Report map was used to fill in any gaps in geospatial data.

D.11 References

References listed below were relied upon in the text of Appendix D. For more information on references, including a list of references considered, see the “Appendix D – List of References.xlsx” Microsoft Excel workbook.

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Table D.1: Metadata Crosswalk of Land Cover Terms.

Layer	Original Land Cover Term	Assigned Land Cover Term
2010 TMDL Staff Report Land Cover	Forrest	Native Vegetation - uncategorized
2010 TMDL Staff Report Land Cover	Rangeland	Native Vegetation - uncategorized
2015 Delta Crop Mapping	Citrus and Subtropical	Orchard
2015 Delta Crop Mapping	Deciduous Fruits and Nuts	Orchard
2015 Delta Crop Mapping	Field Crops	Row and Field Crops
2015 Delta Crop Mapping	Idle	Row and Field Crops
2015 Delta Crop Mapping	Native Vegetation	Native Vegetation – uncategorized
2015 Delta Crop Mapping	Pasture	Pasture
2015 Delta Crop Mapping	Rice	Rice Fields
2015 Delta Crop Mapping	Riparian Vegetation	Native Vegetation – uncategorized
2015 Delta Crop Mapping	Truck Nursery and Berry Crops	Row and Field Crops
2015 Delta Crop Mapping	Vineyard	Vineyard
2018 Crop Mapping	Citrus and Subtropical (C)	Orchard
2018 Crop Mapping	Deciduous Fruits and Nuts (D)	Orchard
2018 Crop Mapping	Field Crops (F)	Row and Field Crops
2018 Crop Mapping	Grain and Hay Crops (G)	Crop and Pasture – uncategorized
2018 Crop Mapping	Idle (I)	Row and Field Crops
2018 Crop Mapping	Pasture (P)	Pasture
2018 Crop Mapping	Rice (R)	Rice Fields
2018 Crop Mapping	Truck Nursery and Berry Crops (T)	Row and Field Crops
2018 Crop Mapping	Unclassified (X)	Agricultural – Other, Mixed, or Uncategorized
2018 Crop Mapping	Urban (U)	Urban unclassified (includes mixed use) (U)
2018 Crop Mapping	Vineyard (V)	Vineyard
2018 Crop Mapping	Young Perennial (YP)	Row and Field Crops
Alameda County	NR	Native Vegetation - uncategorized
Alameda County	NV	Native Vegetation - uncategorized
Alameda County	U	Urban unclassified (includes mixed use) (U)
Alameda County	UC	Commercial (UC)
Alameda County	UI	Industrial (UI)
Alameda County	UL	Landscaped (irrigated lawns, cemeteries, parks)
Alameda County	UR	Residential (UR)
Alameda County	UV	Transportation, Communication, Utilities (T)
Butte County	NB	Barren
Butte County	NR	Native Vegetation - uncategorized
Butte County	NV	Native Vegetation - uncategorized
Butte County	U	Urban unclassified (includes mixed use) (U)
Butte County	UC	Commercial (UC)
Butte County	UI	Industrial (UI)
Butte County	UL	Landscaped (irrigated lawns, cemeteries, parks)
Butte County	UR	Residential (UR)

Layer	Original Land Cover Term	Assigned Land Cover Term
Butte County	UV	Transportation, Communication, Utilities (T)
Calaveras County	NB	Barren
Calaveras County	NR	Native Vegetation - uncategorized
Calaveras County	NV	Native Vegetation - uncategorized
Calaveras County	U	Urban unclassified (includes mixed use) (U)
Calaveras County	UC	Commercial (UC)
Calaveras County	UI	Industrial (UI)
Calaveras County	UL	Landscaped (irrigated lawns, cemeteries, parks)
Calaveras County	UR	Residential (UR)
Calaveras County	UV	Transportation, Communication, Utilities (T)
City of Antioch	Business Park	Residential (UR)
City of Antioch	Commercial	Commercial (UC)
City of Antioch	Commercial/Office	Commercial (UC)
City of Antioch	Commercial/Office	Residential (UR)
City of Antioch	Community Retail	Commercial (UC)
City of Antioch	Convenience Commercial	Commercial (UC)
City of Antioch	High Density Residential	Residential (UR)
City of Antioch	Industrial	Industrial (UI)
City of Antioch	Light Industrial	Industrial (UI)
City of Antioch	Light Industrial	Commercial (UC)
City of Antioch	Light Industrial	Residential (UR)
City of Antioch	Low Density Residential	Residential (UR)
City of Antioch	Marina	Open Recreation
City of Antioch	Marina/ Support Uses	Open Recreation
City of Antioch	Medium Density Residential	Residential (UR)
City of Antioch	Medium Low Density Residential	Residential (UR)
City of Antioch	Medium Low Density Residential/ Open Space	Residential (UR)
City of Antioch	Mixed Use	Urban unclassified (includes mixed use) (U)
City of Antioch	Mixed Used Residential/ Commercial	Urban unclassified (includes mixed use) (U)
City of Antioch	Neighborhood Community Commercial	Commercial (UC)
City of Antioch	Office	Commercial (UC)
City of Antioch	Open Space	Barren
City of Antioch	Open Space	Urban unclassified (includes mixed use) (U)
City of Antioch	Open Space	Open Recreation
City of Antioch	Public/Institutional	Urban unclassified (includes mixed use) (U)
City of Antioch	Rail Served Industrial	Industrial (UI)
City of Antioch	Regional Commercial	Commercial (UC)
City of Antioch	Regional Commercial	Residential (UR)
City of Antioch	Regional Retail	Commercial (UC)
City of Antioch	Regional Retail/Employment Generating Lands	Commercial (UC)
City of Antioch	Residential	Residential (UR)
City of Antioch	Residential TOD	Residential (UR)
City of Antioch	Residential/ Open Space	Urban unclassified (includes mixed use) (U)

Layer	Original Land Cover Term	Assigned Land Cover Term
City of Antioch	Water	Commercial (UC)
City of Antioch	Business Park	Commercial (UC)
City of Brentwood	BBSP	Urban unclassified (includes mixed use) (U)
City of Brentwood	BP	Commercial (UC)
City of Brentwood	CC	Commercial (UC)
City of Brentwood	DSP	Urban unclassified (includes mixed use) (U)
City of Brentwood	GC	Commercial (UC)
City of Brentwood	I	Industrial (UI)
City of Brentwood	P	Landscaped (irrigated lawns, cemeteries, parks)
City of Brentwood	PA-1	Transitional (UT)
City of Brentwood	PD	Urban unclassified (includes mixed use) (U)
City of Brentwood	PF	Urban unclassified (includes mixed use) (U)
City of Brentwood	PO	Commercial (UC)
City of Brentwood	P-OS	Barren
City of Brentwood	RC	Commercial (UC)
City of Brentwood	RE	Residential (UR)
City of Brentwood	R-HD	Residential (UR)
City of Brentwood	R-LD	Residential (UR)
City of Brentwood	R-MD	Residential (UR)
City of Brentwood	R-VHD	Residential (UR)
City of Brentwood	R-VLD	Residential (UR)
City of Brentwood	SCH	Commercial (UC)
City of Brentwood	SPA 2	Transitional (UT)
City of Brentwood	SPF	Landscaped (irrigated lawns, cemeteries, parks)
City of Brentwood	UR	Residential (UR)
City of Fairfield	Community Commercial	Commercial (UC)
City of Fairfield	Downtown Commercial	Commercial (UC)
City of Fairfield	Downtown Commercial Core	Commercial (UC)
City of Fairfield	General Industrial	Industrial (UI)
City of Fairfield	Industrial and Business Park	Industrial (UI)
City of Fairfield	Light Industrial	Industrial (UI)
City of Fairfield	Limited Industrial	Industrial (UI)
City of Fairfield	Limited Industrial (Prezone)	Industrial (UI)
City of Fairfield	Mixed Commercial	Commercial (UC)
City of Fairfield	Mixed-Use Office	Urban unclassified (includes mixed use) (U)
City of Fairfield	Neighborhood Commercial	Commercial (UC)
City of Fairfield	Office Commercial	Commercial (UC)
City of Fairfield	Open Space Conservation	Native Vegetation - uncategorized
City of Fairfield	Open Space Conservation (Prezone)	Native Vegetation - uncategorized
City of Fairfield	Public Facility	Urban unclassified (includes mixed use) (U)
City of Fairfield	Public Facility (Prezone)	Urban unclassified (includes mixed use) (U)
City of Fairfield	Recreation	Open Recreation
City of Fairfield	Regional Commercial	Commercial (UC)
City of Fairfield	Residential- High Density	Residential (UR)

Layer	Original Land Cover Term	Assigned Land Cover Term
City of Fairfield	Residential- Low Density	Residential (UR)
City of Fairfield	Residential- Low Medium Density	Residential (UR)
City of Fairfield	Residential- Low Medium Density (Prezone)	Residential (UR)
City of Fairfield	Residential- Medium Density	Residential (UR)
City of Fairfield	Residential- Medium Density (Prezone)	Residential (UR)
City of Fairfield	Residential- Very High Density	Residential (UR)
City of Fairfield	Residential- Very Low Density	Residential (UR)
City of Fairfield	Service Commercial	Commercial (UC)
City of Fairfield	Thoroughfare Commercial	Commercial (UC)
City of Oakley	Business Park	Commercial (UC)
City of Oakley	Commercial	Commercial (UC)
City of Oakley	Commercial Downtown	Commercial (UC)
City of Oakley	Commercial Recreation	Commercial (UC)
City of Oakley	Delta Recreation	Open Recreation
City of Oakley	Light Industrial	Industrial (UI)
City of Oakley	Mobile Home	Residential (UR)
City of Oakley	Multi-Family High	Residential (UR)
City of Oakley	Multi-Family Low	Residential (UR)
City of Oakley	Parks and Recreation	Open Recreation
City of Oakley	Public and Semi-Public	Urban Unclassified (includes mixed use) (U)
City of Oakley	Single Family High	Residential (UR)
City of Oakley	Single Family Low	Residential (UR)
City of Oakley	Single Family Medium	Residential (UR)
City of Oakley	Single Family Very Low	Residential (UR)
City of Oakley	SP-4	Residential (UR)
City of Oakley	Utility Energy	Transportation, Communication, Utilities (T)
City of Pittsburg	Business Commercial	Commercial (UC)
City of Pittsburg	Community Commercial	Commercial (UC)
City of Pittsburg	Downtown Commercial	Commercial (UC)
City of Pittsburg	Downtown High Density Residential	Residential (UR)
City of Pittsburg	Downtown Low Density Residential	Residential (UR)
City of Pittsburg	Downtown Medium Density Residential	Residential (UR)
City of Pittsburg	High Density Residential	Residential (UR)
City of Pittsburg	Hillside Low Density Residential	Residential (UR)
City of Pittsburg	Industrial	Industrial (UI)
City of Pittsburg	Landfill	Urban Unclassified (includes mixed use) (U)
City of Pittsburg	Low Density Residential	Residential (UR)
City of Pittsburg	Marine Commercial	Commercial (UC)
City of Pittsburg	Medium Density Residential	Residential (UR)
City of Pittsburg	Mixed Use	Urban Unclassified (includes mixed use) (U)

Layer	Original Land Cover Term	Assigned Land Cover Term
City of Pittsburg	Park	Open Recreation
City of Pittsburg	Public/Institutional	Urban Unclassified (includes mixed use) (U)
City of Pittsburg	Regional Commercial	Commercial (UC)
City of Pittsburg	Roadway	Transportation, Communication, Utilities (T)
City of Pittsburg	Service Commercial	Commercial (UC)
City of Pittsburg	Utility/ROW	Transportation, Communication, Utilities (T)
Contra Costa County	ACO	Transportation, Communication, Utilities (T)
Contra Costa County	BP	Commercial (UC)
Contra Costa County	CC	Residential (UR)
Contra Costa County	CO	Commercial (UC)
Contra Costa County	CR	Commercial (UC)
Contra Costa County	DR	Open Recreation
Contra Costa County	HI	Industrial (UI)
Contra Costa County	LF	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	LI	Industrial (UI)
Contra Costa County	M-1	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-10	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-11	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-12	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-13	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-14	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-15	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-2	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-3	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-4	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-5	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-6	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-8	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	M-9	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	MH	Residential (UR)
Contra Costa County	ML	Residential (UR)
Contra Costa County	MM	Residential (UR)
Contra Costa County	MO	Residential (UR)
Contra Costa County	MS	Residential (UR)
Contra Costa County	MV	Residential (UR)
Contra Costa County	OF	Commercial (UC)

Layer	Original Land Cover Term	Assigned Land Cover Term
Contra Costa County	OS	Open Recreation
Contra Costa County	PR	Landscaped (irrigated lawns, cemeteries, parks)
Contra Costa County	PS	Urban Unclassified (includes Mixed Use) (U)
Contra Costa County	SH	Residential (UR)
Contra Costa County	SL	Residential (UR)
Contra Costa County	SM	Residential (UR)
Contra Costa County	SV	Residential (UR)
El Dorado County	NB	Barren
El Dorado County	NR	Native Vegetation - uncategorized
El Dorado County	NV	Native Vegetation - uncategorized
El Dorado County	UC	Commercial (UC)
El Dorado County	UI	Industrial (UI)
El Dorado County	UL	Landscaped (irrigated lawns, cemeteries, parks)
El Dorado County	UR	Residential (UR)
El Dorado County	UV	Transportation, Communication, Utilities (T)
Nevada County	NR	Native Vegetation - uncategorized
Nevada County	NV	Native Vegetation - uncategorized
Nevada County	U	Urban unclassified (includes mixed use) (U)
Nevada County	UC	Commercial (UC)
Nevada County	UI	Industrial (UI)
Nevada County	UL	Landscaped (irrigated lawns, cemeteries, parks)
Nevada County	UR	Residential (UR)
Nevada County	UV	Transportation, Communication, Utilities (T)
Port of Stockton	Industrial	Industrial (UI)
Port of Stockton	Landscaped	Landscaped (irrigated lawns, cemeteries, parks)
Port of Stockton	Native Vegetation	Native Vegetation - uncategorized
Port of Stockton	Rangeland	Barren
Port of Stockton	Row and Field Crops	Row and Field Crops
Port of Stockton	Urban Unclassified	Urban unclassified (includes mixed use) (U)
Port of Stockton	Water	Industrial (UI)
Port of Stockton	Wetland and Marsh	Wetland and Marsh
Sacramento County	E	Entry Denied
Sacramento County	NR	Native Vegetation - uncategorized
Sacramento County	NV	Native Vegetation - uncategorized
Sacramento County	U	Urban unclassified (includes mixed use) (U)
Sacramento County	UC	Commercial (UC)
Sacramento County	UI	Industrial (UI)
Sacramento County	UL	Landscaped (irrigated lawns, cemeteries, parks)
Sacramento County	UR	Residential (UR)
Sacramento County	UV	Transportation, Communication, Utilities (T)
San Joaquin County	NB	Barren
San Joaquin County	NR	Native Vegetation - uncategorized
San Joaquin County	NV	Native Vegetation - uncategorized

Layer	Original Land Cover Term	Assigned Land Cover Term
San Joaquin County	U	Urban unclassified (includes mixed use) (U)
San Joaquin County	UC	Commercial (UC)
San Joaquin County	UI	Industrial (UI)
San Joaquin County	UL	Landscaped (irrigated lawns, cemeteries, parks)
San Joaquin County	UR	Residential (UR)
San Joaquin County	UV	Transportation, Communication, Utilities (T)
Stanislaus County	NR	Native Vegetation - uncategorized
Stanislaus County	NV	Native Vegetation - uncategorized
Stanislaus County	U	Urban unclassified (includes mixed use) (U)
Stanislaus County	UC	Commercial (UC)
Stanislaus County	UI	Industrial (UI)
Stanislaus County	UL	Landscaped (irrigated lawns, cemeteries, parks)
Stanislaus County	UR	Residential (UR)
Stanislaus County	UV	Transportation, Communication, Utilities (T)
Sutter County	NR	Native Vegetation - uncategorized
Sutter County	NV	Native Vegetation - uncategorized
Sutter County	U	Urban unclassified (includes mixed use) (U)
Sutter County	UC	Commercial (UC)
Sutter County	UI	Industrial (UI)
Sutter County	UL	Landscaped (irrigated lawns, cemeteries, parks)
Sutter County	UR	Residential (UR)
Sutter County	UV	Transportation, Communication, Utilities (T)
Tuolumne County	NR	Native Vegetation - uncategorized
Tuolumne County	NV	Native Vegetation - uncategorized
Tuolumne County	U	Urban unclassified (includes mixed use) (U)
Tuolumne County	UC	Commercial (UC)
Tuolumne County	UI	Industrial (UI)
Tuolumne County	UR	Residential (UR)
Tuolumne County	UV	Transportation, Communication, Utilities (T)
Yolo County	NR	Native Vegetation - uncategorized
Yolo County	NV	Native Vegetation - uncategorized
Yolo County	U	Urban unclassified (includes mixed use) (U)
Yolo County	UC	Commercial (UC)
Yolo County	UI	Industrial (UI)
Yolo County	UL	Landscaped (irrigated lawns, cemeteries, parks)
Yolo County	UR	Residential (UR)
Yolo County	UV	Transportation, Communication, Utilities (T)
Yuba County	NB	Barren
Yuba County	NR	Native Vegetation - uncategorized
Yuba County	NV	Native Vegetation - uncategorized
Yuba County	U	Urban unclassified (includes mixed use) (U)
Yuba County	UC	Commercial (UC)
Yuba County	UI	Industrial (UI)
Yuba County	UL	Landscaped (irrigated lawns, cemeteries, parks)

Layer	Original Land Cover Term	Assigned Land Cover Term
Yuba County	UR	Residential (UR)
Yuba County	UV	Transportation, Communication, Utilities (T)

Table D.2: Delta Subarea Acreage and Percentage of Total Delta Methylmercury TMDL Boundary Acreage

Delta TMDL Subarea	Acres	% of Total with Cache Creek Settling Basin	% of Total without Cache Creek Settling Basin
Central Delta	227,832.284	30.55%	30.67%
Mokelumne/Cosumnes Rivers	9,650.622	1.29%	1.30%
Marsh Creek	16,127.666	2.16%	2.17%
Sacramento River	185,030.200	24.81%	24.91%
San Joaquin River	120,481.515	16.16%	16.22%
West Delta	50,183.342	6.73%	6.75%
Yolo Bypass - North	36,941.382	4.95%	4.97%
Yolo Bypass - South	99,494.299	13.34%	13.39%
Total with Cache Creek Settling Basin	**745,741.311**	**100.00%**	**NA**
Cache Creek Settling Basin	2,822.213	0.38%	NA
Total without Cache Creek Settling Basin	**742,919.098**	**NA**	**100.00%**

Table D.3: Land Cover Acreages in Each Delta TMDL Subarea

Land Cover	Central Delta	Marsh Creek	Mokelumne/ Cosumnes Rivers	Sacramento River	San Joaquin River	West Delta	Yolo Bypass - North[153]	Yolo Bypass - South	Total w/out CCSB
Agriculture - Other, mixed, or uncategorized	22,842	2,264	1,551	22,235	18,322	1,441	2,644	8,401	79,701
Barren	269	9	0	0	13	5	0	0	296
Commercial (UC)	198	566	0	149	546	1,945	17	0	3,421
Crop & Pasture - uncategorized	15,104	370	538	19,580	7,741	1,187	195	3,540	48,256
Entry Denied	0	0	0	0	0	0	0	7	7
Industrial (UI)	1,612	29	38	369	1,358	763	125	0	4,294
Landscaped (irrigated lawns, cemeteries, parks)	1,652	427	0	535	993	6	45	0	3,659
Native Vegetation - uncategorized	22,801	2,129	2,239	14,111	10,172	5,263	10,687	18,947	86,348
Open Recreation	378	161	0	13	28	478	4	0	1,062
Orchard	7,239	1,150	141	9,550	16,873	72	365	1,950	37,339
Orchard & Vineyard - uncategorized	0	0	0	5	0	0	0	0	5
Pasture	33,620	286	591	16,716	14,138	9,582	812	35,921	111,666
Residential (UR)	2,097	4,331	13	1,781	1,975	5,443	49	9	15,698
Rice Fields	1,811		463	1,648	1	0	9,144	501	13,567
Row and Field Crops	68,981	2,726	602	46,026	28,756	1,485	3,748	11,887	164,211
Strip Mine or Quarry	0	0	0	0.428	0	0	0	0	0.428
Transitional (UT)	0	4	0	1	0	92	0	0	97
Transportation, Communication, Utilities (T)	1,239	92	51	2,832	1,816	508	560	178	7,276
Urban unclassified (includes mixed use) (U)	11,117	1,068	21	5,723	11,592	2,872	2,053	5	34,452
Vineyard	5,332	493	2,024	30,169	1,487	631		241	40,375
Water	25,772	12	205	9,746	3,426	12,506	1,350	5,857	58,873
Wetland and Marsh	5,771	9	1,173	3,842	1,245	5,905	2,323	12,050	32,318
Total	**227,834**	**16,128**	**9,651**	**185,030**	**120,482**	**50,184**	**34,119**	**99,494**	**742,921**

[153] Acreage of land cover in Yolo Bypass - North Delta Subarea does not include land cover within the Cache Creek Settling Basin

Table D.4: Recent, Current, or Future Wetland Restoration Projects in the Delta

Project Name[154]	WDID	Delta TMDL Subarea	Post-Project Acreage	Restoration Type	Land Cover	Permit Date	EcoRestore Project
Yolo Bypass Salmonid Habitat Restoration and Fish Passage	5A57CR00195A1	Yolo Bypass - North	115.8	Re-establish or enhance	Wetland and Open Water	12/23/2022	Yes
Decker Island Restoration	5A48CR00149	West Delta	140	Re-establish	Wetland	3/1/2018	Yes
Dutch Slough Tidal Marsh Restoration	5B07CR00131A2	West Delta	759	Re-establish or enhance	Wetland	7/9/2021	Yes
Fremont Weir Adult Fish Passage Modification	5A57CR00153	Yolo Bypass - North	2.17	Re-establish	Wetland and Open Water	8/30/2017	Yes
Grizzly Slough Floodplain Restoration	5A34CR00782	Mokelumne/ Cosumnes Rivers	37.2	Re-establish	Wetland and Open Water	12/14/2020	Yes
Lower Yolo Ranch Restoration	5A57CR00185	Yolo Bypass - South	1,716	Re-establish or enhance	Wetland and Open Water	5/1/2020	Yes
McCormack-Williamson Tract Levee Modification and Habitat Enhancement	5B34CR00072	Mokelumne/ Cosumnes Rivers and Sacramento River	105	Establish	Wetland	5/27/2016	Yes
Prospect Island Tidal Restoration	5A48CR00156	Sacramento River	1,529.3	Establish or re-establish	Wetland and Open Water	10/30/2020	Yes
Sherman Island Whale's Belly Wetland	5A34CR00765	West Delta	990	Establish or re-establish	Wetland	5/29/2019	Yes
Twitchell Island San Joaquin Setback Levee Restoration	5B34CR00065	Central Delta	47.78	Establish	Wetland and Open Water	7/27/2015	Yes
Twitchell Island East End Wetland Restoration	5A34CR00572	Central Delta	740	Re-establish or rehabilitate	Wetland	3/1/2013	Yes
Lindsey Slough Freshwater Tidal Marsh Enhancement	5A48CR00113	Yolo Bypass - South	211	Establish or enhance	Wetland	9/17/2013	Yes

[154] Project information from issued 401 Water Quality Certifications or from 401 application documents.

Project Name[154]	WDID	Delta TMDL Subarea	Post-Project Acreage	Restoration Type	Land Cover	Permit Date	EcoRestore Project
Sherman Island Whale's Mouth	5B34CR00057	West Delta	601.4	Establish or re-establish	Wetland and Open Water	8/28/2014	Yes
Lower Elkhorn Basin Levee Setback	5A57CR00182A1	Yolo Bypass - North	129.6	Establish, re-establish, or enhance	Open Water	8/4/2020	Yes
Yolo Flyway Farms	5A57CR00169A1	Yolo Bypass - South	278	Re-establish or enhance	Wetland	7/27/2018	Yes
Lookout Slough Tidal Habitat Restoration and Flood Improvement	5A48CR00175	Yolo Bypass - South	3,394	Re-establish	Wetland and Open Water	2/5/2021	Yes
Three Creeks Parkway Restoration	5B07CR00187	Marsh Creek	4.9	Re-establish	Wetland and Open Water	3/16/2018	Yes
Sacramento River Erosion Control and Habitat Enhancement	5A34CR00817	Sacramento River	3.62	Establish	Wetland and Open Water	4/29/2021	Yes
Stone Lakes Restoration Project, Serra Property	5A34CR00867	Sacramento River	47.69	Establish or enhance	Wetland and Open Water	3/24/2023	No
Stone Lakes Restoration Project, Sun River and Headquarters Unites	5A34CR00865	Sacramento River	304.88	Establish or enhance	Wetland and Open Water	2/3/2023	No

Table D.5: Land Cover Terms, Land Cover Classification, and Runoff Coefficients[155]

Land Cover Term	Land Cover Classification	Runoff Coefficient
Agriculture - Other, mixed, or uncategorized	Agriculture	0.175
Barren	Open Space	0.300
Commercial (UC)	Urban	0.71
Crop & Pasture - uncategorized	Agriculture	0.175
Entry Denied	Open Space	0.175
Industrial (UI)	Urban	0.70
Landscaped (irrigated lawns, cemeteries, parks)	Open Space	0.22
Native Vegetation - uncategorized	Open Space	0.150
Open Recreation	Open Space	0.175
Orchard	Agriculture	0.200
Orchard & Vineyard - uncategorized	Agriculture	0.200
Pasture	Agriculture	0.175
Residential (UR)	Urban	0.50
Rice Fields	Agriculture	0.175
Row and Field Crops	Agriculture	0.175
Strip Mine or Quarry	Open Space	0.3
Transitional (UT)	Urban	0.70
Transportation, Communication, Utilities (T)	Urban	0.700
Urban unclassified (includes mixed use) (U)	Urban	0.56
Vineyard	Agriculture	0.200
Water	Open Water	1.000
Wetland and Marsh	Wetland and Marsh	0.150

[155] Land cover terms and runoff coefficients from Table E.5 of the 2010 TMDL Staff Report.

Table D.6: Tributary Watershed Acreage

Tributary Watershed Name	Acreage
American River below Nimbus Dam	51,139
Antioch Area	8,824
Bear Creek & Mosher Creek	100,268
Bethany Reservoir Area	25,094
Butte Creek/Sutter Bypass	818,269
Cache Creek	352,169
Colusa Basin	1,103,545
Cosumnes River	809,614
Dixon Area	34,277
Feather River below Oroville Dam	393,169
French Camp Slough / Lone Tree Creek	256,851
Lower Calaveras River & Mormon Slough	149,463
Lower Mokelumne River	83,448
Manteca-Escalon Area	108,398
Marsh Creek below M.C. Reservoir	33,353
Montezuma Hills Area	17,439
Morrison Creek	116,225
Natomas East Main Drain/Arcade Creek	147,688
Putah Creek below Lake Berryessa	86,939
Rio Vista Area	5,228
Sacramento River above Colusa	2,944,097
San Joaquin River above Vernalis	2,980,493
Ulatis Creek	94,698
Upper Lindsay/Cache Slough Area	42,216
Willow Slough	146,222
Total	**11,727,029**

Table D.7: Tributary Watershed Land Cover Acreage

Tributary Watershed Land Cover	Acreage
Agriculture - Other, mixed, or uncategorized	268,648
Barren	18,070
Commercial (UC)	16,201
Crop & Pasture - uncategorized	437,364
Entry Denied	477
Industrial (UI)	53,564
Landscaped (irrigated lawns, cemeteries, parks)	37,480
Native Vegetation - uncategorized	5,986,816
Open Recreation	8,458
Open Water	231,918
Orchard	1,487,736
Orchard & Vineyard - uncategorized	5,658
Pasture	410,657
Residential (UR)	201,269
Rice Fields	530,529
Row and Field Crops	848,911
Strip Mine or Quarry	10,159
Transitional (UT)	5,900
Transportation, Communication, Utilities (T)	87,555
Urban unclassified (includes mixed use) (U)	446,843
Vineyard	230,431
Wetland and Marsh	402,384
Total	**11,727,029**

APPENDIX E – CHARACTERIZATION AND CONTROL STUDY SUMMARIES

The first phase of the DMCP required discharging entities to develop characterization and control studies to evaluate approaches for managing methylmercury. The DMCP named entities responsible to conduct control studies. The control studies were required to include the following:

- Evaluation of existing control methods and, as needed, additional control methods that could be implemented to achieve LAs and WLAs[156]
- Evaluation of feasibility of reducing sources more than the minimum amount needed to achieve allocations
- Description of methylmercury or inorganic mercury, or both, management practices identified in Phase 1
- Evaluation of the effectiveness, costs, potential environmental effects, and overall feasibility of control actions
- Proposed implementation plans and schedules to comply with allocations as soon as possible

If the control study results indicated that achieving a given methylmercury allocation was infeasible, then the entity was required to provide detailed information on why full compliance was not achievable, what methylmercury load reduction was achievable, and an implementation plan and schedule to achieve partial compliance.

Control study workplans were required to be submitted to the Central Valley Water Board for review and approval by 20 April 2012. Progress reports were required by 20 October 2015, and final reports were required by 20 October 2018. Certain entities conducting control studies requested extensions to submit final reports after the 2018 deadline and were granted by the Central Valley Water Board Executive Officer.

As part of the DMCP Review, Board staff considered applicable new data and information from control study findings. Recommendations from the characterization and control study final reports for Board staff to evaluate in the Phase 1 DMCP Review include the following:

- Utilize a Climate Change Model to account for future climatic and hydrologic changes
- Maintain the current Facility-Based WLA Values but allow for an aggregate NPDES WWTP WLA
- Storm water and publicly owned treatment works methylmercury loads should be considered *de minimis* or an Insignificant Discharge
- Change mass based WLAs to a goal

[156] Any allocations and associated compliance evaluations described this appendix refer to the allocations set by Phase 1 of the DMCP. Allocations were reevaluated and modified as part of the DMCP Review in Section 8.

- Allow storm water agencies to demonstrate load reductions in other jurisdictional urban areas
- Recalculate the Linkage Analysis using an improved mercury cycling analysis and new data
- Conduct a Use Attainability Analysis
- Develop a reasonable mercury offset program to allow feasible methylmercury reductions
- Coordinate compliance approaches with stakeholders for Delta tributary waterbodies
- Reevaluate the delineations of Marsh Creek and San Joaquin River Delta TMDL subareas
- Continue to support the Delta RMP
- Stormwater compliance should be determined from implementation of LID or similar controls
- Reevaluate methylmercury loading from wetland habitats to incorporate tidal wetland data

An independent expert Technical Advisory Committee (TAC) was convened to provide scientific and technical peer review of the control study workplans and results, advise the Central Valley Water Board, and provide recommendations for additional studies and implementation alternatives.

The Delta Science Program of the Delta Stewardship Council convened an ISRP to evaluate Control Studies for scientific validity, effectiveness of proposed controls, and adherence to Workplans. Information on the ISRP and copies of the ISRP reports can be found on the Delta Stewardship Council's Independent Scientific Review of the Delta Mercury Control Program Phase 1 website (https://deltacouncil.ca.gov/delta-science-program/independent-science-review-of-the-delta-mercury-control-program). The ISRP provided an overall and individual assessment of the studies, in two parts.[157] The first part was published in 2019 and focused on point source control and characterization studies conducted by municipal wastewater and urban stormwater dischargers (Branfireun *et al.* 2019). Part two of the ISRP assessment was published in 2021 and focused on nonpoint source control and characterization studies conducted by DWR (Branfireun *et al.* 2021).[158] DWR characterized methylmercury production in open water and tidal wetlands.

[157] The ISRP did not review the following control studies: *Characterization of Methylmercury Loads for Irrigated Agriculture in the Delta: Final Report* (Tetra Tech 2016); *Mercury on a Landscape Scale - Balancing Regional Export with Wildlife Health* (Marvin-DiPasquale *et al.* 2018); *Final Loads Determination Report: Mercury Control Studies for the Cache Creek Settling Basin, Yolo County, California* (Brown and Nosacka 2020); *Methylmercury Summary Report - Sacramento and Stockton Deep Water Ship Channels Operation and Maintenance Dredging* (USACE 2019).

[158] The ISRP review was separated into two parts to allow DWR to complete lengthy and complex control and characterization studies. Additionally, ISRP panelists included specific subject matter experts to evaluate and interpret DWR's modeling efforts.

Overall, the ISRP found the following:

- Workplans were generally followed, but urged caution when scaling up conclusions from pilot tests to regional implementation
- Impacts from and adaptations to changing climate, land use, and population were not robustly addressed and should be considered in future modeling efforts and the DMCP Review
- The relative methylmercury loading contributions by the studied point sources are minimal and cannot offset agricultural or tributary loads
- Methylmercury and inorganic mercury monitoring should be encouraged for updating WLAs rather than deeming these sources *de minimus*
- Not all methylmercury sources have equal or proportional impact as some sinks in the short-term may be sources in the medium- or long-term
- Changes from controls may not be quantifiable, as they may be masked or localized
- Tributary inputs are the largest relative source of methylmercury and inorganic mercury to the Delta
- Yolo Bypass seasonally flooded agriculture is the largest relative internal source of methylmercury in the Delta

The ISRP could not fully assess whether controls could be implemented to meet fish tissue objectives or whether source reductions could offset loads from other sources.

On 10 September 2020, Board staff virtually hosted the Delta Methylmercury Public Workshop for Control Study Entities. Control study entities were brought together to share key findings and recommendations, and to discuss the process and status of the DMCP Review. Control study authors provided a written summary, and most authors presented at the workshop. The meeting agenda and notes, presentation slides, control study summaries, and original control study documents were shared publicly via the Delta Mercury TMDL email list on 19 May 2021.

Feasible control methods evaluated in the control studies will be incorporated into the DMCP Review implementation plan. Applicable data from control studies were used in the methylmercury source analysis Section 6; final data used are listed in Appendix F.

Board staff reviewed the Phase 1 Methylmercury Characterization and Control Study Final Reports and provided summaries of each within this appendix. Noteworthy correspondence with the TAC, ISRP, or Board staff are addressed in the individual summaries.

E.1 Characterization of Methylmercury Loads for Irrigated Agriculture in the Delta

The DMCP identified agricultural fields as a potential nonpoint source of methylmercury. Agricultural and wetland managers are only responsible for the methylmercury added by their activity or land use, not methylmercury in source water. Tetra Tech, with support from USEPA Region 9 and Central Valley Water Board, performed a study to characterize total mercury and methylmercury loads in inflows, outflows, and drains of agricultural fields in the Delta. Study findings were provided in the *Characterization of Methylmercury Loads for Irrigated Agricultural in the Delta: Final Report* (Tetra Tech 2016).

This study was conducted at two areas near Dixon: one on Staten Island, and one on McCormick-Williamson Tract, near Walnut Grove and close to the Staten Island site. At each study area, four samples were collected in three locations: inflow, outflow (tail water), and drain (discharge channel). Sampling was performed mostly during the irrigation season (June to September) of 2014, with sampling in the wet season of 2015 limited by drought conditions. Sampling was focused on non-rice irrigated agriculture such as alfalfa, pasture, corn, and tomato. Measurements included unfiltered methylmercury and total mercury, as well as ancillary parameters dissolved organic carbon (DOC), DO, TSS, and EC. EC was used as a surrogate for dissolved solids and indicator of evapoconcentration. Net loads were calculated using assumed inflows and outflows. Several statistics were examined to determine if methylmercury was being produced on fields and if methylmercury production was related to ancillary parameters. Statistics included the relationships between ancillary parameters and changes in methylmercury and total mercury, ratios of parameters like methylmercury to total mercury, and ratios of outflow to inflow and drain to inflow concentrations.

Overall, the study showed that agricultural flood irrigation creates the conditions for methylation because concentrations are higher than would be predicted by evapoconcentration alone. Concentrations of total mercury and methylmercury were higher in drains and outflows compared to inflows. The outflow to inflow ratios of methylmercury and DOC were significantly correlated, and study authors suggest this relationship could be due to an increased methylation potential associated with DOC or methylmercury being transported on DOC. Alfalfa and pasture fields showed the highest potential for being a methylmercury source. Some fields were sinks of total mercury and methylmercury during summer irrigation due to outflow volumes being less than inflow volumes. Notably, the fields with the highest outflow methylmercury concentration had a negative load due to reduced outflow volume, whereas if outflow methylmercury concentrations remained the same during winter months, having higher outflow volumes, the fields may be a source of methylmercury.

The study did not propose any methylmercury control options, nor did it assess the ability to meet allocations. Load estimations were based on limited wet weather sampling and assumed flow volumes. More winter sampling and field hydrologic flow data is needed to accurately characterize the annual loading from farmed Delta islands.

E.2 Mercury on a Landscape Scale – Balancing Regional Export with Wildlife Health

The DMCP assigned wetland allocations to proponents of new wetland and wetland restoration and enhancement projects scheduled for construction after 20 October

2011. This includes but was not limited to projects developed, planned, funded, or approved by individuals, private businesses, non-profit organizations, and local, State, and federal agencies such as USACE, USWFS, NMFS, USBR, State Water Board, DWR, and CDFW. Two workgroups were formed to meet DMCP nonpoint source control study requirements that pertain to wetlands: the Tidal Wetlands Nonpoint Source Workgroup and the Nonpoint Source Workgroup. DWR and CDFW formed the Tidal Wetlands Nonpoint Source Workgroup and produced the *Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance Report* (Lee and Manning 2020), summarized in Appendix E.10. The Nonpoint Source Workgroup was specific for managed wetlands and included USBR and USGS. The United States Department of the Interior and USGS produced the *Mercury on a Landscape Scale – Balancing Regional Export with Wildlife Health Report in cooperation with USEPA, United States Bureau of Land Management, CDFW, the Central Valley Water Board, and the Cosumnes River Preserve* (Marvin-DiPasquale *et al.* 2018), summarized below.

The Cosumnes River watershed has been affected by historical mining which continues to supply total mercury and methylmercury loads to the Delta. The watershed contains vast floodplains, managed wetland habitats, and rice agriculture; all habitat types known to contribute to increases in methylmercury in the environment (Ackerman and Eagles-Smith 2010; Windham-Myers *et al.* 2014a). This watershed seasonally produces high concentrations of aqueous total mercury and methylmercury that subsequently discharge to the Delta (Wood *et al.* 2010; Eagles-Smith *et al.* 2014). The Cosumnes River is also listed on the CWA 303(d) List of Impaired Waters for elevated mercury fish tissue concentrations that can threaten the health of humans and wildlife, if consumed.

From 2014 to 2016, USGS performed a seasonal wetlands control study within the Cosumnes River Preserve. The Cosumnes River Preserve is subject to controlled flooding from mid-September through May in order to provide habitat for migratory waterfowl and mimic flow patterns of unmanaged wetlands. The study consisted of 4 treatment and 4 control wetlands. As most wetland topography is shallow (about 25 cm deep), USGS constructed deep pools or “cells” (greater than 75 cm deep) downgradient of the shallow treatment wetlands to test if altering wetland topography would reduce the methylmercury loads via processes like photodegradation, particle settling, and benthic microbial demethylation. USGS also maintained a continuous flow-through of water in treatment wetlands to compare to mercury exports from control wetlands with typical fill-and-maintain water management. To determine whether tested methods ultimately reduced mercury concentrations in fish, USGS measured bioaccumulation of methylmercury via caged fish studies.

The findings of this study demonstrate possible controls for methylmercury in seasonal wetlands. While not all wetlands are seasonal, managed, or able to undergo hydraulic manipulation, it is important to understand the mercury cycling mechanisms within these land cover types. Public agencies and non-profits responsible for wetland development can use lessons from this study to develop wetlands with an ecological benefit and minimize methylmercury production.

Key findings of the control study include the following:

- Deep cell wetlands were a net loss of methylmercury and total mercury
- Primary mechanisms by which methylmercury was removed in the deep cell test wetlands were benthos particle flux and photodegradation
- Flow-through treatment wetlands as a whole, includes the shallow and deep cells, exported more methylmercury than the fill-and-maintain managed control wetlands due to differences in hydrologic managements
- Shallow flow-through wetlands were a net source of methylmercury
- Methylmercury exports increased within the first three months after flooding the wetlands
- Concentrations of all aqueous mercury species were found to be higher at wetland outlets compared to wetland inlets, across all wetlands regardless of water residence time
- The presence of deep-water cells did not reduce total mercury bioaccumulation in caged fish at the outlet of the deep-water cell, neither relative to the outlet of the shallow wetland cell upstream of the deep-water cell nor relative to the outlet of the control wetlands
- The hydrologic flow-through management conditions tested in this study did not result in lower fish mercury concentrations in the shallow treatment cells upstream of the deep-water treatment cells, or relative to the control wetlands

Study authors suggest future studies that examine the effects of combining deep cells with fill-and-maintain or fill-and-trickle water management on mercury export and bioaccumulation. Future research should also align caged fish studies with the early- and mid-flooding periods, when aqueous methylmercury concentrations and loads are the highest.

E.3 Final Loads Determination Report: Mercury Control Studies for the Cache Creek Settling Basin, Yolo County, California

The 2010 TMDL Staff Report identified the CCSB as a tributary and a source of mercury and methylmercury to the Yolo Bypass - North subarea. The DMCP required the DWR, Central Valley Flood Protection Board, and USACE, in conjunction with any landowners and other interested stakeholders (hereafter "the agencies") to implement a mercury-contaminated sediment management plan. The DMCP established the Settling Basin Improvement Plan and Schedule consisting of compliance Items 1 through 5 as development milestones (see Section 4.5.4.3.5.7 of the Basin Plan).

Compliance items 1 through 4 were completed with submission of the Report of Findings: Mercury Control Studies for the Cache Creek Settling Basin (Report of Findings) dated 24 November 2015. Compliance items 1 through 4 required the agencies to initiate necessary steps to modify the CCSB, develop a strategy to reduce total mercury from the CCSB for the next 20 years, and evaluate the CCSB trapping efficiency including a 50% reduction of mercury loads to the Yolo Bypass.

DWR has continued to evaluate the trapping efficiency of the CCSB and submitted two updates, dated 30 November 2017 and 30 November 2019, to the Report of Findings. On 14 December 2020, DWR submitted the third and final update to the Report of Findings titled *Final Loads Determination Report: Mercury Control Studies for the Cache Creek Settling Basin, Yolo County, California* (Final Loads Report; Brown and Nosacka 2020), which evaluated feasibility of a 50% reduction in existing mercury loads. The 2010 TMDL Staff Report calculated the existing total mercury load from CCSB to be 118,000 g/yr based on annual load estimates from water years 1984 through 2003, a 20-year period with an even mix of wet and dry years. The Final Loads Report calculated the total mercury load from the CCSB is 32,600 g/yr, which is an approximately 72% reduction compared to the existing total mercury load calculated in the 2010 TMDL Staff Report. Additional key findings of the Final Loads Report include the following:

- CCSB is a net sink for the suspended fraction of methylmercury and total mercury
- CCSB is a net source for the dissolved fraction of methylmercury and total mercury
- WYs with higher methylmercury loads may be influenced by dryer conditions and report for potential controls in riparian and non-agricultural areas
- Proposed CCSB modifications include decreasing of riparian and non-agricultural areas to reduce areas with potentially higher methylation efficiency
- Proposed modifications are expected to increase the lifespan of the CCSB up to 60 years

Compliance item 5 of the 2010 BPA required the agencies to submit a detailed plan for improvements to decrease mercury loads from the CCSB. While this plan has not been submitted during development of the DMCP Review, the Final Loads Report outlines the following CCSB modifications most likely to be proposed: (1) raising the existing outlet weir, (2) notching the training levee, (3) expanding the Settling Basin by 300 acres with an additional outlet weir in the northeast corner, and (4) excavating and stockpiling 17,000 ac-ft of existing sediment within the CCSB. The Final Loads Report states that any modifications will require congressional authorization, coordination with other agencies, and can exceed 10 years to complete.

E.4 City of Stockton & County of San Joaquin - Methylmercury Control Study Final Report

In order to comply with Phase 1 of the DMCP, the City of Stockton and the County of San Joaquin developed, conducted, and reported on a methylmercury control study for urban runoff titled *City of Stockton and County of San Joaquin Methylmercury Control Study Final Report* (LWA 2018b). The City of Stockton and County of San Joaquin evaluated the total mercury and methylmercury removal efficiency and methylmercury production potential of a detention basin in an urban area, the Airport Business Center Basin. Influent and effluent monitoring was conducted from October 2013 to September 2016. For each study year, sampling was conducted during three wet weather events and one dry weather event. The City of Stockton and County of San Joaquin hypothesized that the Airport Business Center Basin would reduce total mercury and methylmercury loads, primarily by sedimentation and subsequent removal of mercury.

The results of the study showed that the Airport Business Center Basin's effluent total mercury and methylmercury concentrations were lower than the influent concentrations, but these differences were ultimately not statistically significant[159]. The City of Stockton and County of San Joaquin concluded that LID controls, such as detention basins, effectively reduce total mercury and methylmercury loads through settling and removal of sediment. The City of Stockton and County of San Joaquin further conclude that achieving their allocation during dry weather is feasible but likely not feasible during the wet season until further LID implementation. Achievement of the WLA was expected to extend beyond the 2030 compliance deadline set by Phase 1 of the DMCP, due to the nature of the urban development and redevelopment cycle. Implementation of detention basins and other LID controls were deemed by the City of Stockton and County of San Joaquin to be sufficient and preferred implementation actions to attain WLAs set by the DMCP.

The City of Stockton and County of San Joaquin provided several recommendations in two main categories. The first category described a long-term management strategy for mercury in the Delta, included suggestions to convene a facilitated stakeholder process, and supported the development of a mercury cycling model. The second category relates to the DMCP Phase 2 Implementation Plan for NPDES permitted urban runoff dischargers and included suggestions to consider aggregate WLAs, recognized LID controls as the primary method for reducing urban runoff methylmercury discharges, and included a finding that urban runoff dischargers are a *de minimis* source of total mercury and methylmercury.

The City of Stockton, County of San Joaquin, and ISRP all agree that the methylmercury contribution from stormwater is minimal compared to other sources. The City of Stockton and County of San Joaquin calculated that the methylmercury load from NPDES MS4s was 0.36% of all methylmercury sources to the Delta. The City of Stockton and County of San Joaquin state their methylmercury load is a fraction of 0.36% and, therefore, *de minimis*.

The ISRP had several critiques of the control study, including the following:

- The hypothesis regarding methylmercury formation did not account for mercury cycling
- The analysis did not include other collected data, such as SSCs, to fully test the hypothesis
- Grab sample concentrations would have been significantly affected by the timing of their collection

[159] The original Final Report claimed this difference was statistically significant. After conversations between Board staff and the City of Stockton and County of San Joaquin, this claim and the Final Report were revised.

- It is not possible to scale study findings to other LID implementations

The ISRP also pointed out an erroneous use of statistical methods leading to the incorrect conclusion that mercury concentrations significantly decreased in the effluent. Board staff agreed with this finding and in April 2020 requested the City of Stockton and County of San Joaquin to submit a control study addendum to correct the statistical analysis error and resulting conclusions. The control study addendum with revisions was submitted on 3 June 2020 and subsequently reviewed by Board staff (Stockton and SJC 2020). The City of Stockton and County of San Joaquin agreed that the dataset was small, with a high number of non-detects and low number of paired data, and therefore did not support a determination of statistical significance. The addendum resolved the statistical error and associated concerns.

E.5 City of Sacramento Combined Sewer System Methylmercury Control Study Final Report

The City of Sacramento conducted a control study titled *City of Sacramento Combined Sewer System Methylmercury Control Study Final Report* (LWA 2018a) regarding methylmercury discharges from their CSS to the Delta. The City of Sacramento also participated in the CVCWA's Methylmercury Special Project Group (SPG), the summary for which is in Appendix E.7. The City of Sacramento's workplan for the CSS control study was submitted in April 2013 and then revised based on comments from the TAC and Board staff. Revisions included adding composite sampling as needed and clarifying the experimental controls. The revised workplan was approved by the Central Valley Water Board in November 2013.

Consistent with the approved workplan, the CSS control study (1) evaluated the methylation potential in treatment and conveyance processes, and (2) assessed if continuing Combined Sewer System Improvement Plan (CSSIP) projects and implementing additional LID strategies would reduce methylmercury loads. Specifically, it was hypothesized that increased solids retention time would increase effluent methylmercury concentrations in the Pioneer Reservoir and Combined Sewer Treatment Plant. This hypothesis was tested by comparing solids removal processes and retention time at two different treatment sites and performing bench scale solids retention tests. The success of control measures was evaluated based on their expected effect on methylmercury concentrations in the influent and effluent.

According to the control study final report submitted on 19 October 2018, the treatment processes evaluated did not significantly affect methylmercury concentrations or loads. However, reducing flow was demonstrated to be the most effective method at reducing loads. There was no statistical difference in methylmercury concentration between time-adjusted influent and effluent, nor between collection system and treatment facility solids. The City of Sacramento stated conversion to LID controls would reduce loads over time, but not enough to meet their WLA in years with high flow.

The City of Sacramento estimated that implementing all projects in their Long-Term Control Plan, which includes 20% of prioritized CSSIP projects, would cost $67.2

million. If all CSSIP projects were implemented it would cost $403 million, and their WLA still would not be achieved during years of maximum discharge flows. It was estimated to cost $925 million to implement enough CSSIP projects and LID to meet the WLA in years of maximum discharge flow. Therefore, it was not feasible to meet the individual annual WLA by the 2030 compliance deadline. The City of Sacramento suggested using a five-year rolling average to determine compliance, as was done for MS4s because of climatic and stormwater volume variability. The City of Sacramento also proposed that their WLA would be met if considered part of a combined allocation for all SPG Facilities.

The CSS control study based allocation compliance on the assumption that the Central Valley Water Board will assess methylmercury annual loads on a five-year rolling average and found that seven of the nine years studied met the WLA. Therefore, descriptions of additional or alternate control methods, management plans, and implementation schedules were not included in the Final Report.

The ISRP detailed some concerns about the methods used and the interpretation of the data, but ultimately determined the work was adequately completed. Clarification on methods was needed and results were not deemed sufficient to conclude that solid holding time does not impact methylmercury concentrations. More studies and detailed sampling were suggested to support study findings. It was generally agreed that flow and load were related, specifically the number of high flow events in a year not just total flow. The ISRP also noted that there was a lack of investigation into impacts of climate change in this study.

E.6 Contra Costa Clean Water Program Methylmercury Control Study Final Report

The CCCWP serves 19 cities and towns in Contra Costa County, plus the Contra Costa County Flood Control and Water Conservation District (District) and unincorporated areas of Contra Costa County (County). CCCWP developed and implemented their control study on behalf of the jurisdictions located entirely or partly within the Region 5 Boundary, collectively known as the East County Permittees. The East County Permittees includes the District, the County, and the Cities of Brentwood, Oakley, and Antioch. The East County Permittees are divided across West Delta, Central Delta, and Marsh Creek Delta TMDL subareas. Of these subareas, the DMCP only required methylmercury reductions in the Marsh Creek subarea. As delineated in the 2010 TMDL Staff Report, Marsh Creek subarea primarily includes the City of Brentwood with smaller areas of the City of Antioch, the City of Oakley, and some areas of the unincorporated County.

CCCWP submitted the Control Study Final Report on 20 October 2018 (ADH and Wood 2018). In May 2020, Board staff met with CCCWP to discuss the data analysis and corresponding conclusions. CCCWP submitted a revised control study on 1 September 2020 (ADH and Wood 2020). The two primary goals of the control study were to determine if tributary flows from East Antioch Creek, West Antioch Creek, and Marsh Creek met the aqueous MeHg implementation goal established by the DMCP and whether LID, specifically bioretention cells, could reduce mercury concentrations in stormwater. For the first goal, a total of 18 dry weather and 37 wet weather samples were collected in Marsh Creek and Antioch Creek. For the second, influent and effluent stormwater samples were collected from bioretention cells in the City of Richmond and additional stormwater characterization samples were collected in the City of San Pablo, City of Richmond, and the County; for this goal, a total of 69 samples were collected.

A linear regression of methylmercury concentration versus SSC was performed to assess the relationship between SSC and methylmercury. Based on linear regression R^2 values, SSC was said to explain 30% of the variability in methylmercury concentrations across all subareas, and 42% of the variability in the Marsh Creek subarea. The remaining variability was attributed to the influence of higher methylation in areas with standing or slow-moving water. Some high methylmercury concentrations were outliers to the regression. CCCWP proposed these outliers may result from low DO conditions and algae blooms in ponded areas upstream, which would lead to high microbial activity and mercury methylation, followed by flushing from a late season storm. This hypothesis needs more information to be confirmed.

CCCWP determined that the East and West Antioch Creeks would be able to meet the assigned WLA for the West Delta subarea because the average methylmercury concentration was below 0.24 ng/L, the concentration used in the 2010 TMDL Staff Report to calculate the WLA, and assumed the same flow estimate calculated in the 2010 TMDL Staff Report. However, using similar methods, Marsh Creek did not meet the required allocation because the average methylmercury concentration exceeded 0.06 ng/L, the concentration used to calculate the Marsh Creek subarea WLA.

CCCWP stated that meeting the WLA for Marsh Creek by 2030 was infeasible because of background surface water methylmercury concentrations in SSC and the inability to implement sufficient control measures for stormwater. Using the linear regression of methylmercury concentration versus SSC, CCCWP determined that the median methylmercury to SSC ratio was 1.3 ng/g, which is within the range of background ratios, 1 nanogram per gram (ng/g) to 3 ng/g, found in a national survey of U.S. watersheds by Krabbenhoft *et. al.* (1999). Thus, to obtain a methylmercury concentration of 0.06 ng/L, Marsh Creek would need to have an SSC of 46 milligrams per liter (mg/L) or less, which CCCWP states is unreasonable and not feasible. The control study estimated that control measures, specifically retention and infiltration, would need to reduce SSC and urban stormwater runoff by 75% to achieve the Marsh Creek WLA.

The control study also found that bioretention cells subject to tidal inundation can enhance methylation and increase effluent concentrations of methylmercury. Thus, avoiding the use of a bioretention cell in areas where the base media may be inundated under tidal influence may be an effective methylmercury control measure. This finding is especially relevant in low-lying coastal cities like Oakley and Antioch.

The ISRP found the following:

- Meeting the Marsh Creek subarea allocation may be infeasible, however CCCWPs assessment of infeasibility from a model that pools data from different watersheds and flow regimes is inappropriate
- Suggest modeling separate regressions for each watershed and flow regime, monitoring to close data gaps and characterize high flow loading, exploring additional control measures, and addressing uncertainty in future reporting and load calculations
- The control study did not clearly address potential control measures such as improving drainage in detention basins
- The finding that bioretention cells enhance methylation may have been confounded by unanticipated effects of tidal inundation
- The assumption that a 75% reduction in SSC directly translates to a flow reduction of the same percent is inappropriate

Because CCCWP proposed additional studies to complete the control study, requirements to complete these studies were included in the Municipal Regional Stormwater Permit, which regulates the East County Permittees and was adopted by the San Francisco Bay Water Board as Order R2-2022-0018. The proposed studies were performing a Reasonable Assurance Analysis (RAA) to determine what methylmercury loads are achievable based on hydrologic models of future stormwater treatment scenarios, assess eutrophication in Marsh Creek as a potentially controllable methylmercury source, investigate specific control measures, and continue monitoring and outreach. In March 2022, CCCWP submitted the preliminary RAA results for Board staff review and the final RAA was submitted in November 2022. The RAA evaluated three modeling scenarios: (1) current conditions, (2) green stormwater infrastructure implementation plans for 2030 and 2040 and, (3) full green stormwater infrastructure retrofit being applied to all urban areas within the Marsh Creek subarea boundary. The RAA modeling results showed that CCCWP would meet the WLAs for the Central Delta and West Delta subareas in both scenario 1 and scenario 2, but not for the Marsh Creek subarea in either of the 3 scenarios. Scenario 3 is considered an economically unreasonable scenario and meeting the Marsh Creek WLA was considered infeasible.

As part of the RAA, CCCWP suggested updating the following during the DMCP Review:

- Delta TMDL subarea boundaries for Marsh Creek based on watershed drainage delineation
- The aqueous MeHg implementation goal
- Land use classifications

E.7 Central Valley Clean Water Association Methylmercury Special Project Group Methylmercury Control Study Final Report

The CVCWA formed a Methylmercury SPG that developed, conducted, and reported on a control study title *Methylmercury Control Study Final Report* (Gies *et al*. 2018) regarding methylmercury discharges from 20 NPDES POTWs wastewater dischargers, 14 of which discharge directly to the Delta. These 14 POTWs represent 99.5% of the total NPDES WWTF WLAs assigned by Phase 1 of the DMCP.

The control study examined whether (1) recently completed treatment process improvements, and those to be completed by 2030, provide effective control of methylmercury discharges from NPDES POTWs; (2) further treatment improvements or source control efforts would result in significant benefits; and (3) variability in influent and effluent methylmercury concentrations were correlated at different treatment levels.

Results of the study showed that the combined methylmercury load from all SPG facilities that are expected to occur in 2030 are significantly lower than 2004-2005 loads and the sum of all assigned WLAs. The study did not find a significant increase in removal efficiency beyond secondary nitrification and denitrification. Increasing the treatment beyond secondary treatment without nitrification or denitrification does not increase the effect of influent methylmercury concentration on effluent methylmercury concentrations. In other words, at higher levels of treatment, reducing influent concentrations (i.e., source control) is unlikely to provide additional reductions in effluent concentrations. The study also compared influent and effluent methylmercury concentrations across differing water year types (normal, dry, and wet). Only tertiary nitrification and denitrification showed statistically significant differences between wet and dry water years, with effluent concentrations being slightly higher (but still below WLAs) in the wet year.

CVCWA provided several recommendations in two main categories. The first category relates to a long-term management strategy for mercury in the Delta and includes suggestions to reconvene a representative stakeholder group and process, continue support of the Delta RMP, and consider a mercury offsets program. The second category relates to the DMCP Implementation Plan for NPDES permittees and includes suggestions to reduce routine monitoring requirements, create an aggregate WLA for NPDES WWTFs that discharge to the Delta, and include a finding that NPDES WWTFs are a *de minimus*, or insignificant, discharge of mercury. The ISRP agreed with CVCWA that additional treatment upgrades would require an exorbitant cost on a POTW that would not yield significant methylmercury concentration reductions. Regardless, the ISRP and Board staff support continued monitoring as necessary to protect the beneficial uses of the Delta and adapt to future environmental changes.

Overall, the ISRP found that the control study was sufficiently detailed and data-driven. Board staff agree the conclusions were supported based on the statistical analyses. On 24 March 2020, Board staff met with SPG representatives and requested clarification of their use of certain statistical terminology. CVCWA submitted a clarification memo on 27

April 2020, which was subsequently reviewed by Board staff. Together, the submitted information fulfilled the Phase 1 control study final reporting requirements.

E.8 Deuel Vocational Institution Methylmercury Control Study Final Report

The CDCR conducted a control study titled *Methylmercury Control Study Progress Report: California Department of Corrections and Rehabilitation Deuel Vocational Institution* (GHD 2018) regarding methylmercury discharges from the DVI WWTP to the Sacramento-San Joaquin Delta. The study evaluated the effectiveness of DVI's wastewater treatment process at removing methylmercury and total mercury. Existing tertiary wastewater treatment included, but was not limited to, biological nutrient removal, filtration, and ultraviolet disinfection. Influent and effluent samples were collected concurrently for methylmercury and total mercury from February to July 2013. While influent methylmercury and total mercury concentrations varied, effluent concentrations were consistently lower than the influent.

According to the Control Study Final Report submitted in October 2018, the treatment process described above effectively removed methylmercury and total mercury. On average, treatment was 93.13% and 97.60% efficient at removing methylmercury and total mercury, respectively. There was not enough information to determine the effects of increased flows from precipitation or wastewater on mercury effluent concentrations. It was determined that there is no obvious relationship between temperature and effluent mercury concentrations, but more information was needed to determine effects on influent concentrations. The Final Report determined that DVI was meeting their WLA, and additional source controls would not influence effluent methylmercury concentrations. Therefore, DVI did not explore source control as a study objective. The ISRP and Board staff agreed with this approach.

The ISRP described this study as straightforward and agreed with the conclusions drawn from monitoring results. Suggestions from the ISRP included monitoring in remaining months of the year to ensure the WLA is met year-round and concurrent monitoring of sediment concentrations in water.

In August 2021, DVI began a partial shutdown project. At the time of the DMCP Review, no inmates or staff are housed at DVI and no municipal wastewater is conveyed, treated, or discharged by the sewer system or WWTP. All supporting activities such as kitchen, laundry, and dining, have ceased. DVI is maintained by a staff of 20 or less with domestic waste being handled by portable facilities. The sewer system and WWTP components will be drained and cleaned of all municipal waste so that the sewer system only collects water from flushing the cold and hot water piping and other incidental flows that are conveyed to the WWTP. Incidental flows to the WWTP include basement drainage, groundwater inflow and infiltration, and rainwater runoff. The effluent flow is expected to be approximately 0.059 MGD. The CDCR requested that the DVI's NPDES permit (Central Valley Water Board Waste Discharge Requirements Order R5-2014-0014-01 (NPDES CA0078093)) be rescinded, and the surface water discharge will be enrolled under the Central Valley Water Board Order R5-2022-0006 Waste Discharge

Requirements for Limited Threat Discharges to Surface Waters General Order (NPDES CAG995002).

E.9 Mercury Open Water Final Report for Compliance with the Delta Mercury Control Program

The DMCP assigned open water load allocations jointly to the State Lands Commission, DWR, and the Central Valley Flood Protection Board. These three agencies along with the USEPA and USBR formed the Open Water Workgroup to meet DMCP control study requirements. DWR conducted the Mercury Open Water Final Report for Compliance with the Delta Mercury Control Program (DiGiorgio *et al.* 2020).

Due to political and regulatory limitations, DWR was unable to test or implement methylmercury controls in the Delta's open water regions. Therefore, the Central Valley Water Board approved a characterization approach that focused on modeling mercury cycling processes in the Delta and Yolo Bypass. The models were intended to quantify and reduce uncertainty related to mercury cycling in the Delta and Yolo Bypass. The Central Valley Water Board approved three extension requests for the Open Water Workgroup's Final Report. The first extension was approved 28 November 2016, the second 24 April 2019, and the third 16 June 2020. The requests were primarily to have additional time to develop, calibrate, and validate the models and synthesize field and lab results per the approved work plan.

For the Delta, the Open Water Workgroup used an existing one-dimensional open-source model, the DSM2 available for download on DWR's DSM2 website (https://data.cnra.ca.gov/dataset/dsm2). An extended version of DSM2, DSM2-Hg, was used to model the Delta and include simulations of mercury and methylmercury. The Delta model covered open water channels in the Delta between Sacramento, Vernalis, and Martinez. It used a 15-minute time step for simulations and was calibrated using data from 1999 to 2006.

Key findings of the DWR Open Water Report include the following:

- The Delta was a net sink for sediment and mercury
- Sacramento River was the largest source of water, sediment, and mercury to the Delta was and San Francisco was the largest loss
- During high flow, the Yolo Bypass was sometimes the largest source of methylmercury to the Delta
- Variability in sediment and mercury loading was strongly influenced by hydrology
- Sediment and mercury loads to San Francisco Bay were highest during winter months
- Concentrations of sediment and mercury in the Delta were higher when flow was higher
- During high flow, the periphery of the Delta had higher concentrations of sediment and inorganic mercury than the Central Delta

To model the Yolo Bypass, the existing proprietary model, Dynamic Mercury Cycling Model, also known as D-MCM, was used. The Model-Independent Parameter Estimation and Uncertainty Analysis software was used to fine-tune manual calibration and optimize parameter estimates. The Open Water Workgroup also conducted laboratory and mesocosm studies to provide data for model development and calibration. These studies also included developing a mass balance of methylmercury import to and export loads from the Yolo Bypass. The Yolo Bypass model used estimates of hydrology, land use, and methylmercury and total mercury surface sediment concentrations to simulate methylmercury flux from sediment to open waters and methylmercury load export from the Yolo Bypass, which was used as one of the inputs for DSM2-Hg, the Delta model. A model sensitivity analysis was performed to identify factors that affect the export of methylmercury from the Yolo Bypass. Due to resources and time constraints, a bioaccumulation model for the Yolo Bypass was not developed. Additionally, forecast scenarios as proposed in the workplan were not conducted.

Key findings of the laboratory and mesocosm studies and model development include the following:

- Model sensitivity analysis results showed the following:
    - Reducing the methylation rate constants by 50% also reduced the internal gross methylmercury load by 50%, resulting in 20% reduction of methylmercury exported from the Yolo Bypass to the Delta
    - Reducing methylmercury concentrations by 50% in either CCSB or Fremont Weir tributary flow reduced methylmercury export from the Yolo Bypass to the Delta by 5% to 10%
- Identified options to control methylmercury:
    - Limit inputs of inorganic mercury from inflows
    - Reduce organic matter (e.g., vegetation) availability
    - Optimize land use and hydrology to minimize methylation
- As tributary flows to the Yolo Bypass increase during a flood event, the delivery of total mercury and methylmercury increased as well
- Disking land to minimize the presence of decaying vegetation reduced methylmercury production compared to when vegetation was present

Overall, model results for the Delta and Yolo Bypass illustrated high variability in loads of suspended sediments, total mercury, and methylmercury being strongly influenced by hydrology. Reducing uncertainty and strengthening calibration of the models would likely require more sampling and field experiments in the Delta and Yolo Bypass. Sampling should include aqueous and fish tissue methylmercury and total mercury, TSS, as well as ancillary parameters such as DO, organic carbon, and selenium. Future model development could make it useful for evaluating management and source reduction alternatives.

The Open Water Workgroup evaluated the effects of climate change on mercury cycling in the Delta. They predicted that with climate change, the Yolo Bypass will remain a significant net export of methylmercury to the Delta and methylation potential may increase across the watershed. They also predicted the larger size, frequency, and severity of fires in California will increase mercury loading to the Delta. In addition, sea level rise may lead to inundation of lands previously not flooded, causing a spike in methylmercury production. All impacts were described with a high level of uncertainty and were dependent on other factors, such as vegetation senescence and salinity intrusion.

The ISRP recognized the effort to model complex mercury dynamics in the Delta and Yolo Bypass. However, the models were deemed not useful for making predictions due to challenges in validation, input data quality, and definition of boundary conditions. The ISRP supported the conclusion that upstream inputs of mercury and farmed Delta islands are the largest external and internal sources of methylmercury, respectively, and need to be reduced in order to achieve meaningful reductions and TMDL targets in the Delta. The ISRP did not support the finding that the Delta is a net sink for methylmercury due to error and uncertainty in the model inputs and calibration. The ISRP suggested that models be further refined and integrate impacts of bioaccumulation, biomagnification, water conveyance, and climate change. Both within-Delta and upstream controls will likely be necessary to achieve load allocations. The ISRP described the climate change section of the report as very general and suggested the Delta mercury model incorporate a down-scaled climate model. Board staff agree with these ISRP findings and encourage further modeling and field study efforts to explore effective methylmercury controls in Delta open waters and the Yolo Bypass.

On 20 December 2021, Board staff met with DWR to ask questions about model properties and study findings. Answers that were unavailable during the meeting were provided later via email to Board staff. DWR staff worked with the study's consultant, Reed Harris, to answer more detailed questions about inputs, outputs, and methods. These questions and others about the Yolo Bypass model and studies were answered via email on 28 July 2022.

E.10 Mercury Imports & Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, & Suisun Marsh for Delta Mercury Control Program Compliance

The DMCP assigned wetland allocations to proponents of new wetland and wetland restoration and enhancement projects scheduled for construction after 20 October 2011. This includes but was not limited to projects developed, planned, funded, or approved by individuals, private businesses, non-profit organizations, and local, State, and federal agencies such as USACE, USFWS, NMFS, USBR, State Water Board, DWR, and CDFW. Two workgroups were formed to meet DMCP nonpoint source control study requirements that pertain to wetlands: the Nonpoint Source Workgroup and the Tidal Wetlands Nonpoint Source Workgroup. The Nonpoint Source Workgroup was specific for managed wetlands, was comprised of USBR and USGS, and produced the Mercury on a Landscape Scale – Balancing Regional Export with Wildlife Health

Report (Marvin-DiPasquale *et al.* 2018), for more information see Appendix E.2. DWR and CDFW formed the Tidal Wetlands Nonpoint Source Workgroup: DWR provided funding for lab analyses, field staff, and office staff; CDFW provided funding for methylmercury sample design expertise and access to tidal wetlands. DWR staff produced the *Mercury Imports and Exports of Four Tidal Wetlands in the Sacramento-San Joaquin Delta, Yolo Bypass, and Suisun Marsh for Delta Mercury Control Program Compliance Report* (Lee and Manning 2020), summarized below.

The Central Valley Water Board approved the Tidal Wetlands Nonpoint Source Workgroup's control study work plan to monitor several tidal wetlands in and near the Delta to characterize methylmercury loads. The workgroup anticipated that future projects in the Delta would result in the restoration of tens of thousands of acres of tidal wetlands, were concerned that the DMCP allocations for wetlands were determined using data that was not representative of freshwater and brackish water tidal wetlands, and wanted to provide robust study findings to the Central Valley Water Board for use in the DMCP Review. Due to little information available on tidal wetland effects on methylmercury production in the Delta, the plan did not include the development and implementation of mercury control measures and management practices.

The final study characterized four tidal wetlands in or near the Delta to determine if the wetlands were a source or sink of methylmercury, and by what mechanisms. Correlated ancillary parameters of mercury, organic carbon, and TSS were characterized as well. The four tidal wetlands studied were the Yolo Wildlife Area Tidal Wetland, North Lindsey Slough Tidal Wetland, Westervelt Cosumnes River Tidal Wetland, and the Blacklock Tidal Wetland. The Yolo Wildlife Area and North Lindsey Slough Tidal Wetlands are located in the Yolo Bypass - South subarea, the Westervelt Cosumnes River Tidal Wetland is located in the Mokelumne/Cosumnes Rivers subarea, and the Blacklock Tidal Wetland is located in Suisun Marsh, which is outside the Delta MeHg TMDL Boundary and Central Valley Water Board jurisdiction. Analyte and flow data were collected from approximately monthly tidal events to calculate seasonal, monthly, and 25-hour tidal loads. Challenges with equipment failures, flooding, and site access issues created a smaller dataset than anticipated, but the data obtained was enough to perform the proposed evaluations of the wetlands. Study data are available on DWR's Water Data Library website (https://wdl.water.ca.gov/waterdatalibrary/WaterQualityDataLib.aspx).

Key findings of the DWR Tidal Wetlands Report include the following:

- None of the tidal wetlands appeared to be a significant annual source of methylmercury since exports are not significantly higher than imports, however flow and concentration data were missing for some months
- Tidal wetland source water is generally higher than the DMCP's aqueous implementation goal of 0.06 ng/L
- Methylmercury test conclusions varied by study site:
    - Only the Yolo tidal wetland was a significant sink in a 25-hour tidal cycle period

    - Both Yolo and Blacklock tidal wetlands were significant monthly sinks
    - Concentrations were significantly different in ebb and floods only at North Lindsey, with significantly less total methylmercury exported
- Total mercury test conclusions varied by study site:
    - In a 25-hour tidal cycle period, Yolo was a significant sink of filtered total mercury, Blacklock was a significant sink of unfiltered total mercury, and Westervelt was a significant source of unfiltered total mercury
    - In monthly estimates, Yolo was a significant sink of filtered total mercury, Blacklock was a significant sink of unfiltered total mercury, and North Lindsey was a significant source of particulate total mercury
    - In comparing ebb and flood flows, Blacklock was a significant sink of unfiltered total mercury in ebb flows, and both North Lindsey and Westervelt were significant sources of unfiltered total mercury in flood flows
- Seasonal pattern test conclusions varied by analyte:
    - For methylmercury, Blacklock showed a potential seasonal pattern of higher export concentrations in warmer months and Yolo had increased concentrations after a flood event
    - For total mercury, only Yolo had a slight seasonal pattern of increased particulate total mercury during drier months (April-August)
- Methylmercury relationship with organic carbon varied by study site:
    - Only the Yolo and North Lindsey wetlands had a significant correlation of filtered methylmercury with DOC, and total methylmercury with total organic carbon
    - Only the Blacklock and North Lindsey tidal wetlands had a significant correlation of particulate methylmercury and particulate organic carbon

Due to issues faced during the study, DWR recommends future studies include more frequent monitoring over a longer period of time at more tidal wetlands to better determine effects on parameters. Additionally, DWR acknowledges that though this study did not include an assessment of mercury toxicity in localized biota, it would be beneficial information to gather in future studies. Because the study focused on monitoring tidal wetlands and summarizing data gathered, DWR did not include potential effects of climate change on parameter characterization within tidal wetland habitats.

The ISRP recognized the study's scientific objectives were well developed, the scope of work was executed similarly to the workplan, and the usefulness of findings. Additionally, the ISRP commended the DWR Tidal Wetlands Report's methylmercury analysis, total mercury analysis, and quality assurance/quality control measures. However, the report was critiqued for lacking rigorous data analysis, key data components, and link to the Open Water Workgroup's models and report. Specifically, the ISRP pointed out possible errors in flow calculations, a lack of uncertainty analysis, and the relatively dry period when the study took place as potentially contributions to inaccurate flow and mercury load findings in the DWR Tidal Wetlands Report.

Board staff noticed the following two discrepancies regarding ISRP's comments. First, the ISRP stated that the study was focused on freshwater tidal wetland habitats and would not be useful for brackish or saline water tidal wetlands. However, the Tidal Wetlands Report described Blacklock as a brackish water tidal wetland. Second, the ISRP said they were unable to fully support the finding that "tidal wetlands do not contribute methylmercury to the Delta." However, while the report found that some wetlands act as a significant net sink of methylmercury, it also states that tidal wetlands do export methylmercury to adjacent waterbodies.

In April 2022, DWR provided comments in response to the ISRP's report stating that DWR stands by their report's data and findings. Due to ISRP's concern of possible flow calculation errors, DWR verified flow measurements and reviewed regression models used in the report. This resulted in using a different equation to estimate the last six months of flow data at the Blacklock South location but did not result in different findings from the DWR Tidal Wetlands Report. Additional responses to ISRP's comments include:

- Explained data limitations due to workplan restrictions, staff availability and safety, cost restrictions, and limited observable wetland locations in other subareas
- Identified that the report used medians whereas the ISRP used means
- Provided clarification on why tidal wetland data was not incorporated in the Open Water Workgroup's Delta and Yolo Bypass models
- Answered specific questions asked by the ISRP
- Reviewed and provided summaries on recommended reference studies provided by the ISRP

The Central Valley Water Board approved two extension requests for the Tidal Wetlands Nonpoint Source Workgroup's report. The first extension was approved on 28 November 2016 due to site and equipment trouble, delays in work plan approval, and additional time required to study a fourth wetland. The second extension was approved on 27 November 2019 due to unexpected weather delays and equipment failures that limited the time for data analysis and final report preparation.

DWR provided clarifications and answers to Board staff questions via email on 23 November 2021 and during a meeting on 29 November 2021. Board staff determined the control study and supplemental information fulfilled reporting requirements.

E.11 Port of Stockton Methylmercury Control Study Final Report

The DMCP allocated methylmercury loads for the Port of Stockton's urban runoff, named the Port of Stockton in the list of known entities that may dredge Delta waterways, and required the Port to participate in a control study for dredging activities.

DMCP requirements were incorporated in the Port of Stockton's 2011 NPDES permit. To fulfill these requirements, the Port of Stockton conducted the *Port of Stockton Methylmercury Control Study Final Report* to evaluate the effects of storm drain catch basin maintenance on the accumulation and production of methylmercury and mercury in water and sediment (RBI 2018). The Port of Stockton hypothesized that storm drain catch basins may encourage mercury methylation due to the build-up of moist sediment and organic carbon.

The Port of Stockton planned to sample mercury in sediment and water three times per year for two years at two sets of storm drains. Each set of drains consisted of two drains: one upstream "treatment" drain, and another downstream "control" drain. Upstream drains received annual maintenance that consisted of removing water and sediment from catch basins, while downstream drains received no maintenance. Notably, in Summer 2016, a communication error caused one of the upstream drains to be cleaned before crucial pre-maintenance samples could be taken, reducing summer sampling events for that year by half. In addition, aqueous methylmercury samples processed in January 2017 were not held at the correct temperature and may have been biased low, but these data were still used in the evaluation. Other existing maintenance practices were described including street sweeping, erosion and sediment control best management practices, and filtration materials in or around catch basins. It was estimated that street sweeping removes 20 times more material than catch basin cleaning and both control measures together remove about 0.11 grams per year of methylmercury from the MS4.

The Port of Stockton, Board staff, and ISRP all found the results of this Control Study to be inconclusive. No relationship was found between sediment or aqueous methylmercury concentrations in upstream and downstream catch basins. The Port of Stockton suggests its other maintenance practices reduce the amount of accumulated sediment in catch basins, which could have contributed to the inconclusive results. The ISRP found the conclusions were based on limited sampling and recommended the Port of Stockton continue sampling to confirm initial findings. Regardless of the inconclusive study results, the Port of Stockton suggested existing maintenance practices were still beneficial because removing sediment prevented methylmercury contained in the sediment from washing into receiving waters. Therefore, the Port of Stockton planned to continue with existing maintenance practices, which are technically and economically feasible.

The feasibility of attaining allocations was also assessed as part of this control study. The Port of Stockton discharges to both the Central Delta and San Joaquin River Delta TMDL subareas and therefore is assigned two WLAs in the DMCP. The Port of Stockton's assessment included newer land use classification and changes to the Delta TMDL subarea delineations, resulting in different WLAs for both subareas than what were adopted by the DMCP. The Final Report stated that the Port of Stockton would be in compliance with these WLAs and therefore did not include descriptions of additional or alternative control methods, management plans, and implementation schedules.

In February 2020, Board staff requested that the Port of Stockton submit a technical memorandum clarifying the Port of Stockton's recommendation to modify their WLA for the Central Delta and San Joaquin River subareas. The technical memorandum was submitted on 14 April 2020 (RBI 2020). Based on several follow-up conversations between Board staff and the Port of Stockton, land cover classifications were further updated and modified for the DMCP Review (Appendix D). Board staff did not alter subarea boundaries as part of the DMCP Review. Altogether, the submitted information fulfilled the Phase 1 Control Study final reporting requirements.

E.12 Sacramento Stormwater Quality Partnership TMDL Phase 1 Implementation: Final Methylmercury Feasibility Report

The SSQP is comprised of the County of Sacramento and six of the incorporated cities within the County that are co-Permittees of an MS4 NPDES stormwater permit. The cities included are Citrus Heights, Elk Grove, Folsom, Galt, Rancho Cordova, and Sacramento. SSQP's methylmercury WLA set by the DMCP applies only to the jurisdictional runoff area within the Delta MeHg TMDL Boundary (JRAD), a subset area of the total MS4 permitted urban area.

SSQP developed the *Sacramento Stormwater Quality Partnership TMDL Phase 1 Implementation: Final Methylmercury Feasibility Report* (SSQP 2018) to evaluate the effectiveness and feasibility of LID to reduce methylmercury discharges in urban runoff and to meet their methylmercury WLA. The control study workplan was submitted to the Central Valley Water Board in April 2013. The TAC requested the workplan to focus on one technical study instead of a wide range of control and modeling studies. SSQP revised the workplan and identified LID as the methylmercury control measure that could be most widely implemented in areas of new development and redevelopment to potentially provide methylmercury load reductions. SSQP hypothesized that on a load-per-area basis, LID features reduce methylmercury discharge compared to non-LID urban areas. The revised workplan was approved by the Central Valley Water Board on 7 November 2013. SSQP submitted a progress report in October 2015 to the Central Valley Water Board, which was reviewed by the TAC and Board staff.

The control study compared different periods of urban development: 1) pre-1996, before stormwater quality design standards were in place (referred to as "old development"); 2) 1996-2018, implementation of updated stormwater quality design standards (referred to as "new development"); and 3) after July 2018, implementation of LID standards for new development and redevelopment projects (referred to as "LID standards"). The effects of methylmercury pre- and post-LID construction were compared at two sites: Citrus Heights Police Station and Sylvan Community Center. Monitoring and sampling occurred during 2014 and 2015 for a total of nine large rainfall sampling events. Samples were collected for methylmercury, total mercury, and other parameters. Continuous sensors were installed to evaluate water quality parameters and runoff volumes. The estimated methylmercury load post-LID standards was 0.027 ng/L, which is considerably lower than before LID standards (0.14 ng/L), a new development site (0.14 ng/L), and two old development sites (0.24 ng/L and 0.49 ng/L). LID standards resulted in an 85% reduction for methylmercury, 57% reduction for total mercury, and

52% reduction for suspended sediment compared to pre-LID standards. These results confirmed the study hypothesis that LID features reduce methylmercury load and runoff coefficients and do not create conditions that enhance mercury methylation. However, the sample size of the study was small, and the error associated with the small sample size means these results should be used with caution, especially when scaling up to larger or more diverse areas.

SSQP also performed a compliance evaluation for the WLA of 1 g/yr using the Basin Plan specified 5-year rolling average for MS4s. This evaluation was based on methylmercury concentrations sampled in urban runoff from 2002 through 2017, observed runoff conditions, and statistical tools and models. Conditions, as of 2016, were modeled using a statistical multi-variate regression continuous simulation model over a 46-year period of climatic record. This evaluation indicated that SSQP was in compliance with the five-year average WLA, but there may have been some instances in which the WLA was exceeded, as suggested by the 36% average model error. Land use conversion was also compared between the three urban development periods. A factor analysis determined that development standards, measured as development age, were a significant factor in reducing methylmercury urban runoff discharge and showed new development standards implemented since 1996 were effective in reducing methylmercury loads.

SSQP estimated it would cost $728 million to reduce the methylmercury load by 0.65 grams a year, which equates to $1.12 billion per one gram reduced annually. This was calculated from the maximum theoretical reduction if there was complete conversion of the JRAD to LID and an 85% reduction of methylmercury attributable to LID standards. Due to the high cost, low overall reduction, and technical inability to convert the entire JRAD to LID standards, it was determined to be infeasible to reduce the load beyond meeting the WLA. As there are limited opportunities for implementing LID in the JRAD, it is more effective to use resources to implement LID in conducive locations, for example upstream of the JRAD, instead of extra resources to design LID that would be successful in the JRAD. SSQP anticipated the implementation of the 2018 Stormwater Quality Design Manual for new development and redevelopment would result in future load reductions.

SSQP recommended the Central Valley Water Board make changes to WLAs and the determination of compliance based on the demonstration of effective controls, long timescales, lack of local agencies' control to redevelop private urban areas, limited public areas for redevelopment relative to the overall jurisdictional runoff area, small relative contribution from MS4s, and coordination with other SSQP programs and mercury requirements in other parts of the JRAD. SSQP also recommended that the Central Valley Water Board recalculate the DMCP linkage analysis with new available data, develop a process to perform a Use Attainability Analysis for DMCP WLAs, develop a methylmercury offsets program, and coordinate with other methylmercury regulatory programs of Delta tributaries to coordinate consistent implementation and compliance approaches.

The ISRP had several concerns about sampling and evaluation issues, error and scaling-up, and data gaps. The lack of sampling at the Sylvan Community Center site was specifically called out, which SSQP attributed to a lack of stormwater flow during planned sampling years. Reevaluations by the ISRP of some report analyses showed differing results than what was presented by SSQP, and without additional data the ISRP was not able to confirm the findings of such analyses. The conclusion that development age is the primary factor affecting methylmercury discharge was not supported and likely confounded by whether samples were taken below a detention pond or in the channel. The ISRP questioned the ability to scale the methylmercury reduction seen in the Police Station study, which had limited data and high error estimates, to larger areas or different hydrological conditions. Such estimates of error were not evaluated nor carried into modeling of future loading after LID implementation. It was recommended that gaps in data and high error estimates should be considered when interpreting or extrapolating this study's findings. Despite potential problems with the data and evaluation presented, the ISRP generally agreed SSQP was in compliance with their WLA based on a five-year rolling average. Future reductions from LID implementation will likely not have measurable effects because of the overall small proportion of methylmercury loads to the Delta. The ISRP suggested improved monitoring of stormwater and river loading to ensure compliance and effectively characterize the effects of LID implementation.

As previously stated, compliance was not able to be demonstrated at a high level of confidence in this study due to model error. Due to the reasonable chance that the WLA may occasionally be exceeded, the implementation strategy for SSQP to achieve constant compliance with the current WLA is to continue LID land use conversion according to the July 2018 Stormwater Quality Design Manual at a reasonable rate throughout the entire jurisdictional area of the MS4, annually track redevelopment projects, and continue to characterize methylmercury in urban runoff. Potential environmental effects are conditions in the LID that could be conducive to methylmercury production (such as tidal zone infiltration), maintenance of LID may increase greenhouse gases, flow reduction could have a long term impact on concentrating constituents downstream, and maintenance failures or construction defects can lead to flooding, odor, vector habitat, and reduced DO.

SSQP submitted a response to the ISRP Review on 21 February 2020. In this, they clarify study findings, recommend best management practices-based compliance modeled after the Statewide Mercury Provisions, disagree with the need to reduce model uncertainty, and agree with the need for improved monitoring and load characterization. For example, it was clarified that study sampling was purposefully conducted at points of compliance to demonstrate the effect of post-1996 improvements such as detention ponds. In addition, SSQP clarified that scaling of control study findings were used as a theoretical maximum reduction, not to determine compliance with the WLA.

On 5 March 2020, Board staff and SSQP met to discuss questions regarding the control study. SSQP submitted the *Delta Mercury Control Program Control Study Summary* dated 21 May 2020 to clarify Board staff questions discussed during the meeting (SSQP

2020). Board staff reviewed the summary and determined that the control study and submitted supporting information fulfilled the Phase 1 Control Study final reporting requirements.

E.13 Methylmercury Summary Report - Sacramento & Stockton Deep Water Ship Channels Operation & Maintenance Dredging

The USACE was labeled a responsible agency for activities subject to the open water methylmercury allocations in the Delta and Yolo Bypass in the DMCP, alongside DWR, State Lands Commission, Central Valley Flood Protection Board, USBR, and the State Water Board. The DMCP listed dredging and dredge material disposal and reuse as activities subject to the open water methylmercury allocations, which were also listed as a potential methylmercury source to the Delta in the 2010 TMDL Staff Report. As such, USACE performed several studies and developed the *Methylmercury Summary Report – Sacramento and Stockton Deep Water Ship Channels Operation and Maintenance Dredging* (USACE 2019) to fulfil the DMCP control study requirements.

USACE performed total mercury and methylmercury studies during dredging activities in the Sacramento and Stockton DWSCs in 2009 through 2011 and 2014 through 2017; studies were not conducted in 2012 and 2013 due to contract issues. These studies were designed to gather data on total mercury and methylmercury levels in ambient channel water and in DMPSs with and without vegetation. The goals of the studies were to determine the following: whether dredging activities resuspend mercury-bound sediment in the water column; whether DMPS discharges impact receiving water total mercury or methylmercury concentrations at or downstream of outflows; what the optimal holding time for DMPS water is for turbidity/TSS, total mercury, and methylmercury; and whether performing vegetation clearing on a DMPS prior to dredged slurry placement reduces methylmercury production.

Studies were conducted in several locations in the Delta, including at Sour Pond, McCormack Pit, Roberts Island I, Roberts Island II, Bradford Island, Twitchell Island, S-31, and MO1 (Rough and Ready Island) DMPSs. Ambient concentration sample locations in Delta waterways were subject to tidal influences and were conducted in accordance with USEPA and Surface Water Ambient Monitoring Program (SWAMP) guidelines.

Overall findings of the USACE Methylmercury Summary Report include the following:

- At many, but not all study site locations, methylmercury concentrations within the DMPS ponds increased above inflow levels rapidly within the first two weeks after dredged material placement
- Removing vegetation appeared to be an effective best management practice strategy to reduce methylmercury production within the DMPS
- Releasing discharge waters 1 to 3 days after slurry placement appeared to be ideal with regards to minimizing methylmercury production

- Total and methylmercury concentrations in discharges from DMPS are typically higher than receiving water concentrations, and in the case of methylmercury, above the DMCP Phase 1 safe concentration target of 0.06 ng/L
- More information is needed to determine whether there is a relationship between elevated discharge methylmercury and total mercury concentrations with elevated concentrations downstream of discharge location
- Study results at the same sites across years were not consistent, possibly due to test sensitivity, small sample sizes, variation in weather or climate, changes in DMPS conditions, and other factors
- Calculations based on pre-dredge sediment, methylmercury concentrations, and total mercury concentrations demonstrate a large net removal of methylmercury and total mercury from the rivers

An estimate of total mercury and methylmercury removed annually by dredging activities in 2008 through 2017 was included in the USACE's Operation and Maintenance Dredging in the Sacramento and Stockton DWSCs, Methylmercury Summary Report (USACE 2019). This analysis pulled information from the 2010 TMDL Staff Report and individual annual monitoring reports for calculations. Assumptions used to determine these estimates were noted in USACE Methylmercury Summary Report footnotes. The analysis concluded that dredging activities in the Sacramento and Stockton DWSCs removed 161.3 grams per year (g/yr) and 178.4 g/yr of MeHg, and 26,886 g/yr and 29,723 g/yr of total mercury, respectively. These losses included the estimated amounts of methylmercury and total mercury that are released back into the Delta during DMPS discharge. Thus, the USACE Methylmercury Summary Report concluded that though DMPS discharges may have high concentrations of total mercury and methylmercury, dredging projects in the DWSCs result in an overall net loss of total mercury and methylmercury.

USACE DMPS discharges primarily occur in the West and Central Delta subareas but may also occur in the Sacramento River and Yolo Bypass - North subareas. Ambient aqueous methylmercury concentrations for each subarea are listed in Table 8.2 of the 2010 TMDL Staff Report. The West and Central Delta subarea aqueous methylmercury concentrations were 0.083 ng/L and 0.06 ng/L, respectively. Both subareas were assigned a 0% reduction to meet the aqueous methylmercury implementation goal of 0.06 ng/L. The Sacramento River subarea methylmercury concentration was 0.108 ng/L, requiring a 44% reduction to meet the 0.06 ng/L goal. And the Yolo Bypass - North subarea methylmercury concentration was 0.273 ng/L, requiring a 78% reduction. As mentioned above, the Methylmercury Summary Report included calculations estimating dredging activities result in a large net loss of both methylmercury and total mercury from the Delta. However, the average methylmercury discharge concentration from samples from the 2014-2017 studies used in that calculation was 0.55 ng/L,[160] which is higher than each subarea's ambient aqueous methylmercury concentration, listed above.

[160] Table 9 Note 6 of USACE Methylmercury Summary Report (USACE 2019).

In reviewing the USACE Methylmercury Summary Report, Board staff noted that graphs of data, photos of sampling, and statistical comparisons were not included, which would have provided visual representation of trends, evidence for conclusions, and a better overall understanding. Loading from the DMPS only analyzed aqueous methylmercury and did not include an analysis of mercury-bound sediment in the turbid effluent discharges, which may underestimate methylmercury loading from DMPS. Board staff agree that more information is needed to clarify and determine relationships between discharge water and downstream receiving waters. Further, Board staff recommend additional and newer information should be used to confirm the conclusions of the USACE Methylmercury Summary Report.

Information from the individual methylmercury studies, the Methylmercury Summary Report, and from email correspondence from USACE were instrumental in updating the dredging loss estimate for the DMCP Review. Board staff were able to better understand and estimate the amount of methylmercury removed from water and sediment from Delta waterways and amount of water and sediment methylmercury loads discharged from DMPS. Management techniques studied by USACE have informed Board staff on appropriate control measure requirements in dredging related activity project permits in waterways impaired by mercury or methylmercury.

E.14 References

References listed below were relied upon in the text of Appendix E. For more information on references, see the “Appendix E – List of References.xlsx” Microsoft Excel workbook.

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APPENDIX F – OPTIONS CONSIDERED FOR MISSING DATA IN STREAM GAGES

Board staff used available streamflow gage data from WYs 2000-2019 to estimate annual flow volumes for tributary inflows (Section 6.2.1.2) and the CCSB (Section 6.3.7.2). Streamflow gages for Cache Creek, CCSB Outflow, CCSB Overflow Weir, Fremont Weir, Ridge Cut Slough (Knights Landing), and Sacramento Weir were incomplete. Board staff contacted DWR staff via email correspondence to determine reasons for missing data at the Fremont Weir gage and were told reasons could be no flow, low flow, or the gage was turned off (Mulligan 2023).

Board staff considered several calculation methods to account for missing data and to determine representative annual flows for Cache Creek, CCSB Outflow, CCSB Overflow, and Fremont Weir (Table F.1). Board staff decided that substituting missing data with zeros and using the monthly mean (see Table F.1, Option Considered "Substitute Missing Data with Zeros" and Calculation Method "Mean") was the most representative calculation method for representing annual flows since periods of missing data mostly corresponded with dry months and dry years when there is likely little to no flow.

Table F.1: Calculation Options Considered for Incomplete Streamflow Gage Datasets of Cache Creek, CCSB Outflow, CCSB Overflow Weir, and Fremont Weir

Option Considered	Calculation Method	Cache Creek (cf/yr)	CCSB Outflow (cf/yr)	CCSB Weir (cf/yr)	Fremont Weir (cf/yr)
Reported Gage Values	Median	2,889,729,216	1,518,754,320	361,932,192	178,365,190,841
Reported Gage Values	Modified Median[161]	3,029,312,546	1,519,920,720	1,624,170,857	178,365,190,841
Reported Gage Values	Mean	8,880,132,036	2,091,764,407	8,464,879,664	252,630,891,030
Substitute Missing Data with Zeros	Median	2,213,082,518	1,129,999,680	191,305,152	0
Substitute Missing Data with Zeros	Modified Median	2,311,341,807	1,253,774,400	903,078,249	75,022,035,989
Substitute Missing Data with Zeros	Mean	8,130,817,808	1,687,382,097	6,686,369,725	75,022,035,989
Remove Reported Zeros	Median	3,625,558,704	1,733,434,560	8,643,534,624	178,365,190,841
Remove Reported Zeros	Mean	10,318,381,578	2,232,771,727	14,074,855,899	252,630,891,030
WY Cumulative of Reported Gage Values	Median	4,454,762,400	1,240,475,429	2,154,824,640	6,999,696,000
WY Cumulative of Reported Gage Values	Mean	8,237,664,585	1,742,290,897	6,646,495,752	76,544,263,228
Substitute Missing Data with Monthly Mean	Median	3,596,592,494	1,986,147,333	3,098,774,345	252,630,891,030
Substitute Missing Data with Monthly Mean	Mean	8,880,132,036	2,091,764,407	8,464,879,664	252,630,891,030
Multiple Imputation using R (50th percentile)	Median	5,011,653,427	1,833,062,400	3,017,777,904	210,985,824,414
Multiple Imputation using R (50th percentile)	Mean	8,792,434,522	2,085,820,911	8,343,935,028	251,923,145,760
Multiple Imputation using R (95th percentile)	Median	5,298,149,218	2,265,891,840	5,612,249,376	290,261,522,706
Multiple Imputation using R (95th percentile)	Mean	9,724,151,111	2,305,812,334	10,213,215,808	292,023,411,482

[161] When the monthly median equaled zero, the monthly mean was used instead.

Option Considered	Calculation Method	Cache Creek (cf/yr)	CCSB Outflow (cf/yr)	CCSB Weir (cf/yr)	Fremont Weir (cf/yr)
Multiple Imputation using R (50th percentile; Substitute Missing Data with Zeros for Dry & Critical Years)	Median	4,541,513,184	1,123,135,526	2,199,204,000	44,564,990,400
Multiple Imputation using R (50th percentile; Substitute Missing Data with Zeros for Dry & Critical Years)	Mean	8,269,065,101	1,702,467,433	6,704,533,944	106,897,598,789
Multiple Imputation using R (95th percentile; Substitute Missing Data with Zeros for Dry & Critical Years)	Median	4,645,331,798	1,384,836,480	2,291,211,360	93,076,574,301
Multiple Imputation using R (95th percentile; Substitute Missing Data with Zeros for Dry & Critical Years)	Mean	8,628,166,164	1,797,258,444	6,979,238,568	131,045,481,534
Bootstrap using R (50th percentile)	NA	6,766,465,939	2,013,701,040	7,326,660,384	227,609,404,138
Bootstrap using R (95th percentile)	NA	22,311,690,209	3,796,355,520	22,922,602,560	500,326,588,800
Bootstrap using R (50th percentile; Substitute Missing Data with Zeros for Dry & Critical Years)	NA	6,039,287,424	1,632,752,640	3,408,264,000	85,771,094,400
Bootstrap using R (95th percentile; Substitute Missing Data with Zeros for Dry & Critical Years)	NA	21,331,086,666	3,430,977,316	20,086,531,200	314,626,982,400
WY Daily Statistic Output from USGS	Median	1,374,897,888	928,488,096	43,219,872	NA
WY Daily Statistic Output from USGS	Mean	9,218,171,520	2,022,927,264	8,374,466,880	NA

Option Considered	Calculation Method	Cache Creek (cf/yr)	CCSB Outflow (cf/yr)	CCSB Weir (cf/yr)	Fremont Weir (cf/yr)
Raw Daily Mean, Mean of Day Per Month, Summed Per Month	Mean	9,219,432,387	2,023,238,146	8,374,495,012	53,032,570,028
2010 TMDL Staff Report's Fremont and Cache method	Median	2,884,754,304	1,411,779,024	531,015,264	180,306,259,200
2010 TMDL Staff Report's Fremont and Cache method	Mean	8,158,236,403	1,743,830,781	7,012,027,564	75,262,404,960