Contra Costa Clean Water Program

Methylmercury Control Study

Final Report

October 2018

Submitted to

CONTRA COSTA CLEAN WATER PROGRAM

Contra Costa Clean Water Program
255 Glacier Drive
Martinez, California 94553

Submitted by

ADH Environmental

ADH Environmental
3065 Porter Street, Suite 101
Soquel, California 95073

and

wood.

Wood Environment & Infrastructure Solutions, Inc.
180 Grand Avenue, Suite 1100
Oakland, California 94612

This page intentionally blank

Contra Costa Clean Water Program

Methylmercury Control Study

Final Report

October 2018

Submitted to

Contra Costa Clean Water Program
255 Glacier Drive
Martinez, California 94553

Submitted by

ADH Environmental
3065 Porter Street, Suite 101
Soquel, California 95073

and

Wood Environment & Infrastructure Solutions, Inc.
180 Grand Avenue, Suite 1100
Oakland, California 94612

This page intentionally blank

TABLE OF CONTENTS

Table of Contents i
List of Tables ii
List of Figures ii
Acronyms and Abbreviations iv
Executive Summary 1
1. Introduction and Background 10
1.1 Problem Statement 10
1.2 Environmental and Regulatory Setting 12
1.3 TMDL Framework for Stormwater Management of Mercury in the Delta 15
1.4 Conceptual Model for Managing Methylmercury in Urban Runoff in the TMDL Framework 19
1.5 Other Delta Municipal Stormwater Program's Methylmercury Control Approaches 23
1.6 Features of Marsh Creek Relevant to Methylmercury Monitoring and Management 24
2. Study Approach 29
2.1 Field Methods 29
2.2 Laboratory Methods 30
2.3 Quality Assurance / Quality Control 30
3. Study Results 37
3.1 Phase 1: Watershed Characterization 37
3.2 Phase 2: BMP Effectiveness Evaluation 44
4. Study Conclusions 49
4.1 Infeasibility of Achieving Methylmercury Load Allocations for Marsh Creek or Wasteload Allocations for Stormwater Discharges in the Marsh Creek Sub-area 49
4.2 Data Gaps and the Approach to Refining Present Day Load Estimates and Potential Future Load Reductions 53
4.3 Lessons Learned that Inform Actions, Monitoring, and Adaptive Management 57
5. Methylmercury Control Plan 61
5.1 Total Mercury Source Control 61
5.2 Runoff Volume and Methylmercury Load Reduction via Green Infrastructure 62
5.3 Additional Investigation of Ponded Areas Upstream of the Brentwood WTP 65
5.4 Monitoring and Adaptive Management 66
5.5 Mercury Risk Reduction Program 69
5.6 Preliminary Assessment of Costs, Effectiveness, Environmental Effects, and Overall Feasibility 70
5.6.1 Analysis of Costs and Summary of Uncertainties Related to Costs 72
5.6.2 Control Measure Effectiveness 73
5.6.3 Potential Environmental Effects 73
5.6.4 Overall Feasibility 74

6. Schedule 77
7. References 81
Appendix A: Current Requirements to Implement a Methylmercury Control Study ..... A
Appendix B: Results from Watershed Characterization and BMP Effectiveness Evaluation ..... B
Appendix C: Marsh Creek Storm Sampling Hydrographs and GRAB Sample Timing C
Appendix D: Anticipated Future Requirements to Develop a Green Infrastructure Plan ..... D

List of Tables

Table ES-1. Schedule for Methylmercury Control Plan Implementation 9
Table 1. TMDL Allocations Assigned to Urban Runoff in Eastern Contra Costa County 19
Table 2. Analytical Tests, Methods, Reporting Limits and Holding Times 30
Table 3. Quality Control Issues with Methylmercury Samples at Locations Around Marsh Creek, Lake Alhambra, and Various Locations around Richmond, Including Cutting Boulevard – 2014-2018 35
Table 4. Average Methylmercury Concentrations in Creeks and Urban Stormwater 38
Table 5. Comparison of Percent Methylated, Total Mercury Ratios to SSC, and Methylmercury Ratios to SSC in Marsh Creek when Marsh Creek Reservoir (MAC) is Flowing vs. Not Flowing 42
Table 6. Comparison of Percent Methylated, Total Mercury Ratios to SSC, and Methylmercury Ratios to SSC for the 04/04/13 Storm Event vs. All Other Storms Monitored 43
Table 7. Comparison of Methylmercury in Water and Percent Methylated Between Upstream vs. Downstream Locations at Lake Alhambra 44
Table 8. Comparison of Bioretention Influent vs. Effluent Resulting from Two Unusual Designs 45
Table 9. Schedule for Methylmercury Control Plan Implementation 77

List of Figures

Figure ES-1. Sub-areas of the Delta Receiving Urban Runoff from East County Permittees 3
Figure 1. Jurisdictions of SFRWQCB (red) and CVRWQCB (blue) in Contra Costa County (yellow border) 14
Figure 2. Delta Sub-regions Defined in the TMDL 18
Figure 3. Conceptual Model for Managing Methylmercury in Urban Runoff in the TMDL Framework 20
Figure 4. Overview Map of Marsh Creek Watershed, Showing Key Features Affecting Water Quality and Locations of Monitoring Stations for the Marsh Creek SSID Study Currently Under Way 26
Figure 5. Sample Locations for Watershed Characterizations in Marsh Creek 31
Figure 6. Sample Locations for Watershed Characterizations in East and West Antioch Creek 32

Figure 7. Sample Locations for BMP Effectiveness Evaluations and Additional Urban Runoff Characterization 33
Figure 8. Design Drawing and Photographs of Treatment Bioswale at So. 1st Street and W. Cutting Boulevard, Richmond 34
Figure 9. Summary of Methylmercury Results for All Phase 1 Watersheds Assessed 38
Figure 10. Summary of Methylmercury / Total Mercury Ratios (Percent Methylated) for Phase 1 39
Figure 11. Relationship Between Methylmercury in Water and Suspended Sediment Concentration 40
Figure 12. Total Mercury vs. SSC as a Tool for Estimating Total Mercury in Suspended Sediment Concentrations 41
Figure 13. Comparison of Methylmercury – SSC Relationships in Marsh Creek During Storm of 04/04/13 to all Other Stormwater Samples Analyzed in This Study 43
Figure 14. Effects of Treatment Via Bioretention on Methylmercury in Water in an Unusual Design 45
Figure 15. Time Variability of Methylmercury Concentrations in Bioretention Effluent 47
Figure 16. Time Variability of Methylmercury / Total Mercury Ratios in Bioretention Effluent 48
Figure 17. (Zoomed) Relationship Between Methylmercury in Water and Suspended Sediment Concentration 50
Figure 18. (Zoomed) Effects of Treatment Via Bioretention on Methylmercury in Water in an Unusual Design 52
Figure 19. Superposition of Marsh Creek Sub-Area Outline on Jurisdictional Map of the East County Permittees 56
Figure 20. Excerpts from Delta Household Hazardous Waste Collection Brochures in English and Spanish 62
Figure 21. Examples of Bioretention Facilities from the CCCWP C.3 Guidebook 64
Figure 22. Examples of Porous Pavement and Self-Retaining Areas from the CCCWP C.3 Guidebook 64
Figure 23. Visible Unattached Algae in Marsh Creek as Seen from the Ground and Above 65
Figure 24. Wetland Habitat Created as Part of the Upper Sand Creek Basin Restoration Project 66
Figure 25. CCCWP's Robust Monitoring Program Includes Continuous Monitoring of Water Quality in Marsh Creek 67
Figure 26. Risk Communication Guidance in Multiple Languages is Distributed by CCCWP to Marinas, Piers and Bait Shops 71
Figure 27. Examples of Porous Pavement and Self-Retaining Areas from the CCCWP C.3 Guidebook 74

Acronyms and Abbreviations

BASMAA	Bay Area Stormwater Management Agencies Association
Bay	San Francisco Bay
Bay Area	San Francisco Bay Area
BMP	best management practices
CCCWP	Contra Costa Clean Water Program
CDFW	California Department of Fish and Wildlife
CVRWQCB	Central Valley Regional Water Quality Control Board
Delta	Sacramento-San Joaquin River Delta
EPA	United States Environmental Protection Agency
g/yr	grams per year
kg	kilogram
LCS	low concentration standard
MDL	method detection limit
µg/g	micrograms per gram
mgd	million gallons per day
mg/g	micrograms per gram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MRL	method reporting limit
MRP	SF Bay Municipal Regional Stormwater Permit
MS/MSD	matrix spike/matrix spike duplicate
MS4	municipal separate storm sewer system
ng/g	nanograms per gram
ng/L	nanograms per liter
NPDES	National Pollutant Discharge Elimination System
PCBs	polychlorinated biphenyl congeners
POC	pollutants of concern
QA/QC	quality assurance/quality control
RAA	Reasonable Assurance Analysis
RL	reporting limit
RMC	Regional Monitoring Coalition
RMP	regional monitoring program
ROWD	Report of Waste Discharge
RPD	replicate percent difference
SFRWQCB	San Francisco Bay Regional Water Quality Control Board
SSC	suspended sediment concentration
SSID	stressor/source identification
TMDL	total maximum daily load
WTP	wastewater treatment plant

EXECUTIVE SUMMARY

The Contra Costa Clean Water Program (CCCWP) developed and implemented this methylmercury control study (study) on behalf of the Cities of Brentwood, Oakley, and Antioch; unincorporated Contra Costa County; and the Contra Costa County Flood Control and Water Conservation District (collectively known as the East County Permittees). This final report on the study findings and recommendations includes a plan describing preferred methylmercury controls and proposed methylmercury management actions, including an implementation schedule for achieving methylmercury allocations. This fulfills a requirement for the East County Permittees established through Provision C.11.l of Regional Board Order No. R5-2010-0102 regulating the discharge of urban runoff (the East County Permit).

Methylmercury is a mercury atom bonded to a carbon atom. It is the chemical form of mercury of greatest concern because the "methyl", the carbon atom, makes mercury very strongly bind to proteins, causing it to accumulate in organisms (bioaccumulate) and increase in concentration at successively higher levels of the food web (biomagnify). This leads to the pervasive post-industrial environmental problem of too much mercury in fish. Across the nation and around the planet, assessments of mercury levels in fish show concentrations that exceed acceptable risk guidelines for unlimited consumption by humans and wildlife who depend on fish for food.

The Central Valley Regional Water Quality Control Board (CVRWQCB) established water quality objectives for acceptable levels of mercury in fish and translated those water quality objectives to the numeric "implementation goal" of 0.06 nanograms per liter (ng/L) methylmercury in water. The CVRWQCB adopted a total maximum daily load (TMDL) for methylmercury in the Sacramento-San Joaquin River Delta (Delta Methylmercury TMDL) based on the 0.06 ng/L implementation goal as an annual average in receiving waters of the Delta. The TMDL developed by the CVRWQCB assigns responsibility for dischargers to the Delta, including East County Permittees, for achieving annual mass limits of methylmercury calculated based on achieving 0.06 ng/L as an annual average in their discharges. The water concentration implementation goal of 0.06 ng/L is multiplied by annual average urban runoff volumes to arrive at the methylmercury wasteload allocations for urban runoff.

Key Points

- *There is too much mercury in fish found in the Delta.*
- *The CVRWQCB required this study and control plan of East County Permittees, as well as other regulated dischargers to the Delta, to address mercury in fish.*
- *The study is aimed at understanding whether urban runoff from East County can achieve the TMDL goal of 0.06 ng/L methylmercury in water and, if not, what methylmercury reductions are achievable.*

The conceptual model for methylmercury management in stormwater starts with the knowledge that methylmercury is formed from total mercury, and that both forms of mercury tend to adhere to sediments. The affinity for sediments means that control measures that reduce suspended sediments tend to reduce total mercury and methylmercury. Another approach is controlling the factors that promote formation of methylmercury. The naturally occurring bacteria that make methylmercury tend

to thrive under low oxygen conditions. Slow moving, ponded, or stagnant waters can promote methylmercury formation.

Focusing questions for this study were based on guidance from the CVRWQCB (2012):

- How does urban runoff from the municipal separate storm sewer system (MS4) of East County Permittees compare to the 0.06 ng/L implementation goal?
- If the implementation goal of 0.06 ng/L is exceeded in discharges, what causes that exceedance and what can be done about it?
- If the implementation goal of 0.06 ng/L cannot be achieved as an annual average, can the annual mass limit calculated from the implementation goal be achieved by reducing runoff volume using infiltration best management practices?
- If the mass-based implementation goal cannot be achieved, what methylmercury load reductions are achievable?
- What is the approach, schedule, and cost for implementing controls which reduce methylmercury loads to the maximum extent practicable?

This study was completely successful in answering the first two questions above, and advanced progress toward addressing the latter three. This study established that receiving waters downstream of the East County MS4 consistently exceed the implementation goal of 0.06 ng/L. The study also established that variability of suspended sediment concentration (SSC) accounts for about a third of the variability in methylmercury concentrations. The results show that natural background concentrations of suspended sediment in water with background, typical methylmercury concentrations that could be found anywhere in waters of the United States will tend to cause surface waters and stormwater to exceed the 0.06 ng/L methylmercury implementation goal. These findings of infeasibility for the implementation goal are supported by data from this study, assessments of San Francisco Bay Area (Bay Area) stormwater by the San Francisco Estuary Institute, assessments of stormwater treatment effectiveness by the Bay Area Stormwater Management Agencies Association (BASMAA), and a national study of methylmercury in United States waters by Dr. David Krabbenhoft of the U.S. Geological Survey, an expert peer reviewer panelist for the Delta Methylmercury TMDL.

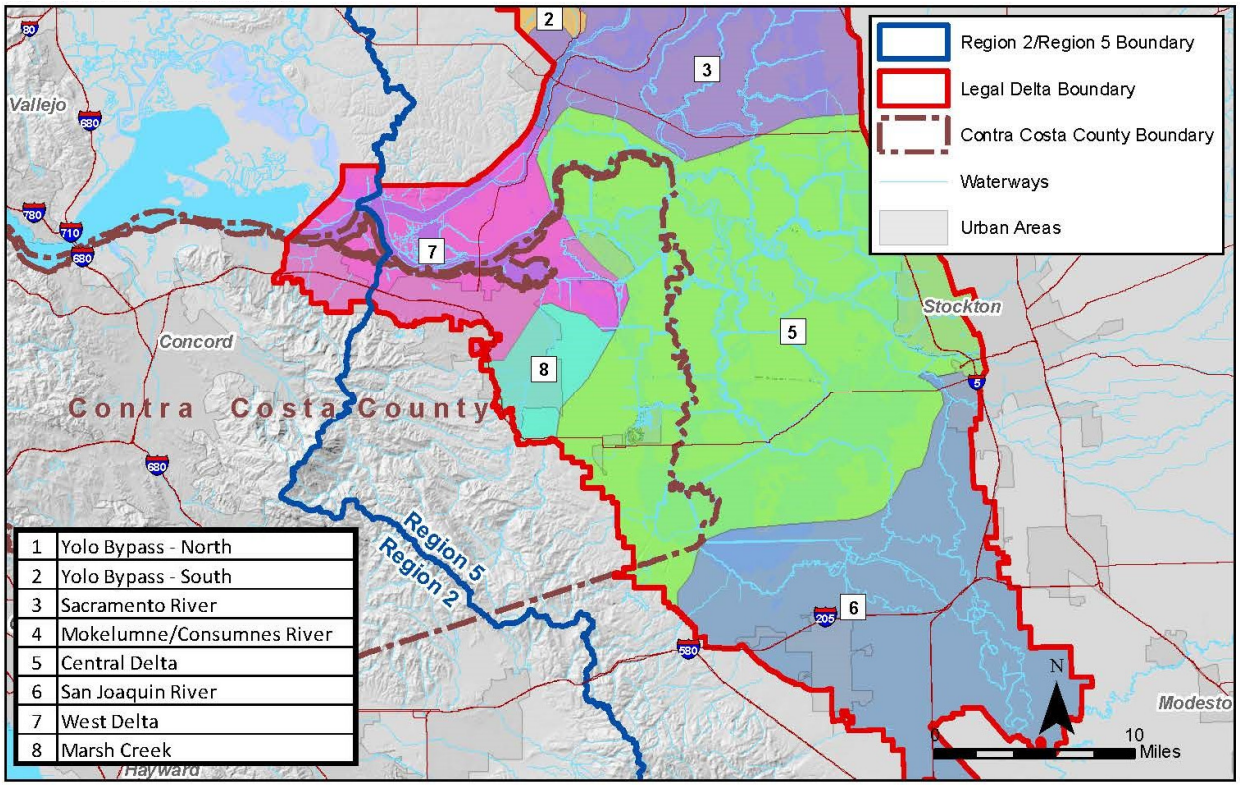
Key Points

- *The study approach aimed to answer five basic questions about controlling methylmercury in urban runoff.*
- *Data from this study, supported by regional and national studies, demonstrate that reliably achieving a concentration of 0.06 ng/L in stormwater or surface waters is infeasible.*
- *Mass limits based on the 0.06 ng/L implementation goal are only imposed in those sub-areas of the Delta exceeding 0.06 ng/L as an annual average.*

Mass limits based on the 0.06 ng/L implementation goal are only imposed on discharges to sub-areas of the Delta, such as Marsh Creek, where receiving waters exceed the implementation goal. The TMDL

divides the Delta into sub-areas (Figure ES-1). The West Delta, Central Delta, and Marsh Creek sub-areas receive urban runoff discharges from East County Permittees.

Figure ES-1. Sub-areas of the Delta Receiving Urban Runoff from East County Permittees



Receiving waters of the West and Central Delta sub-areas meet (or are close to) the 0.06 ng/L implementation goal and are therefore not subject to methylmercury load reduction requirements for regulated discharges. Rather, tributary discharges, including urban creeks, are expected to maintain loads at or below current levels. For the West Delta, which receives discharges from the City of Antioch, this means showing that the annual average methylmercury concentration in flows reaching the Delta is maintained at 0.24 ng/L or less, which is the present day annual average concentration for tributary and urban runoff flows to that sub-area. In the Delta Methylmercury TMDL framework, annual average methylmercury concentration goals are multiplied by annual average flow volumes to express allocations in terms of annual mass (e.g., grams of methylmercury per year reaching the Delta from the source or watershed subject to a wasteload or load allocation).

Discharges from urban creeks in the City of Antioch to the West Delta were evaluated as part of this study, and evaluation results verified that the current allocated load for urban runoff discharges to the West Delta appears to be attained. The creeks exceed 0.06 ng/L but are below the assumed 0.24 ng/L threshold used to allocate methylmercury loads to the West Delta from urban runoff. Receiving waters of the Marsh Creek sub-area, in contrast, exceed the 0.06 ng/L implementation goal as an annual

average and so wasteload allocations[1] based on the 0.06 ng/L implementation goal are assigned to East County Permittee discharges within the Marsh Creek sub-area.

The definition in the Delta Methylmercury TMDL of the Marsh Creek sub-area is "the portion of the Marsh Creek watershed within the legal Delta boundary that is upstream of tidal effects." This definition excludes the Marsh Creek watershed above the Marsh Creek Reservoir. It also means most of the urban areas served by an MS4 in the defined sub-area are located within the City of Brentwood. Much of the City of Antioch is outside the Marsh Creek watershed. A small portion of Antioch with developed land in the Sand Creek watershed, tributary to Marsh Creek, is subject to the wasteload allocations based on the implementation goal. The City of Oakley, above the zone of tidal influence, is subject to the wasteload allocations. Some developed lands of unincorporated Contra Costa County (e.g., Knightsen) appear to lie within the delineation identified by the CVRWQCB in Figure ES-1; however, Knightsen is outside the Marsh Creek watershed. The disparity may be due to the CVRWQCB's use of 1990 land use layers; development and flood control projects may have realigned the watershed boundary since then.

Key Points

- *Of the sub-areas touching Eastern Contra Costa County, only the Marsh Creek sub-area exceeds the 0.06 ng/L implementation goal.*
- *This study verified that urban runoff discharges to West Delta sub-area, which touches the Antioch and Oakley shorelines, meet the methylmercury load allocations set in the TMDL.*
- *The definition of the Marsh Creek sub-area means the largest amount of developed lands subject to methylmercury load reduction requirements are in Brentwood, with smaller areas located in Antioch and Oakley. There may be little to developed areas of Unincorporated Contra Costa County within the Marsh Creek sub-area, depending on the exact delineation of the sub-area.*
- *Achieving mass limits based on 0.06 ng/L would require capture and infiltration of 75 percent of urban runoff, which is infeasible by the 2030 final compliance date in the TMDL.*

Permittees subject to the wasteload allocation will have a difficult time reliably achieving methylmercury concentrations as low as 0.06 ng/L in stormwater. Even treatment with bioretention using an underdrain will discharge some amount of residual SSC leached from the root zones that would cause exceedance of the goal because of methylmercury adsorbed to the SSC. The only reasonable and foreseeable means to achieve the mass limits based on 0.06 ng/L is to infiltrate stormwater to reduce runoff volumes. Based on the wasteload allocations, this would correspond to as much as a 75 percent reduction in the volume of urban stormwater discharged from the MS4 from the time the TMDL was adopted in 2011.

Development that occurred since the advent of C.3 requirements[2] in the early 2000s and any new development are already infiltrating stormwater in compliance with C.3 standards and therefore should

[1] In TMDL regulations, "load allocations" are assigned to sources not regulated by a National Pollutant Discharge Elimination System (NPDES) permit, such as streams and runoff from open spaces, whereas wasteload allocations are assigned to sources such as urban runoff which are regulated by an NPDES permit.

[2] Provision C.3 of the East County Permit, the MRP, and predecessor permits require post construction stormwater treatment controls on new development and redevelopment projects exceeding a certain size.

not be subject to new controls. Older areas not developed under C.3 would require treatment retrofits if they were to increase the amount of stormwater infiltrated. That would be a massive planning and capital investment far exceeding the resources available to the cities subject to the wasteload allocations.

Feasibility is a matter of schedule, site-specific engineering feasibility, and available funding. Public parcels and rights-of-ways, private commercial parcels, and multifamily residential areas within the Marsh Creek watershed will all eventually be redeveloped under C.3 and will eventually receive some level of stormwater treatment. Single family residential areas, in contrast, may not ever be redeveloped in a manner that triggers C.3 requirements. Retrofitting 75 percent of developed lands by the final TMDL compliance date of 2030 is clearly not a reasonable or foreseeable outcome.

The CVRWQCB direction in the permit is: if a discharger makes a finding of infeasibility for achieving wasteload allocations in their final reports on the methylmercury control study, they are to state what methylmercury load reductions are achievable, by when, and at what cost. To answer that question, East County Permittees will need to develop green infrastructure plans[3] to map out what level of green infrastructure implementation is achievable over time, and where the best opportunities exist for early actions. Green infrastructure plans will provide the schedule and cost of compliance. The information on how much methylmercury load reduction can be achieved will come from a Reasonable Assurance Analysis (RAA). An RAA is an assessment, using hydrologic models, demonstrating what loads are achievable based on future stormwater treatment scenarios. An RAA is required by the U.S. Environmental Protection Agency (EPA) and the state to justify alternative compliance with TMDLs through integrated watershed management, like the proposed green infrastructure plan approach.

Key Points

- *The recommended approach to compliance with the TMDL is green infrastructure.*
- *A Reasonable Assurance Analysis will answer the question of what loads are achievable, and by when.*
- *This study identified a potential source of methylmercury within Marsh Creek that may be related to low dissolved oxygen in ponded, stagnant waters.*
- *Further investigation of that potential methylmercury source will be integrated with an ongoing study of the causes of fish kills in Marsh Creek.*

The study revealed a potential methylmercury source in Marsh Creek that contributes to increasing concentrations substantially above the baseline established by natural variability in SSC. A late season

[3] According to the SFRWQCB MRP, Green Infrastructure plans are "intended to describe how the Permittees will shift their impervious surfaces and storm drain infrastructure from gray, or traditional storm drain infrastructure where runoff flows directly into the storm drain and then the receiving water, to green—that is, to a more-resilient, sustainable system that slows runoff by dispersing it to vegetated areas, harvests and uses runoff, promotes infiltration and evapotranspiration, and uses bioretention and other green infrastructure practices to clean stormwater runoff.

The CCCWP Stormwater C3 Guidebook (https://www.cccleanwater.org), uses "Low Impact Development" (LID) instead of "green infrastructure" The C3 Guidebook defines LID as: "A stormwater management strategy aimed at maintaining or restoring the natural hydrologic functions of a site. LID design detains, treats, and infiltrates runoff by minimizing impervious area, using pervious pavements and green roofs, dispersing runoff to landscaped areas, and routing runoff to rain gardens, cisterns, swales, and other small-scale facilities distributed throughout a site." Regardless of the terminology used, LID / green infrastructure is the preferred method of treatment in Contra Costa County (CCCWP, 2017).

April storm in 2013 showed methylmercury and SSC ratios were nearly four-fold greater than background conditions. This may have been due to flushing of ponded, stagnant water that is often present in Marsh Creek upstream of the Brentwood Wastewater Treatment Plant (WTP). Algae tends to bloom in that reach of the creek beginning in April. It is possible that increased biological activity and/or low dissolved oxygen led to increased methylmercury in particles subsequently flushed downstream by the late season storm.

CCCWP is currently conducting a stressor source identification (SSID) study of dissolved oxygen, dry weather flows, and algal blooms in relation to recurrent fish kills in Marsh Creek. The study scope will be expanded to include methylmercury monitoring. This will provide additional data to confirm if the occurrence of elevated methylmercury in the late season April storm of 2013 is a repeatable phenomenon, and if any linkage can be established between elevated methylmercury concentrations and the annual cycle of algal blooms and low dissolved oxygen. If there is a need to address this process with a control measure, the action would be part of a broader strategy to address eutrophication and low dissolved oxygen in Marsh Creek upstream of the WTP. Next steps in planning potential corrective measures would need to come after the SSID study is complete, anticipated to be no later than March 2021.

An important lesson learned from a bioretention effectiveness assessment is to avoid bioretention with an underdrain in areas subject to tidal influence. Tidal inundation of bioretention media appears to risk increasing methylmercury in treated water. This is significant to low-lying coastal cities like Oakley and Antioch.

Another important lesson learned is that the Mount Diablo Mercury Mine, which is upstream of the Marsh Creek Reservoir, does not appear to increase the total mercury or methylmercury concentrations in suspended sediments of Marsh Creek above background. This is an important finding, because it addresses a data gap identified during study development. The Marsh Creek Reservoir flows into lower Marsh Creek infrequently – two or three times during wet years, but not at all during dry years such as water years 2014 and 2015. Sampling flows from the upper watershed requires waiting until the reservoir has filled to capacity, the ground is saturated, and a large storm occurs. The Marsh Creek Reservoir and the numerous other detention basins in the watershed function as sediment traps, as evidenced by the need for desilting.

Key Points

- *Avoid bioretention with underdrains near sea level – tidal flooding of the media can increase mercury methylation.*
- *Flows from the upper watershed, which includes the Mount Diablo Mercury Mine, do not appear to bring sediments with elevated mercury or methylmercury into the lower watershed.*
- *Stormwater discharges from East County Permittees will soon be regulated by the SFRWQCB through the MRP.*
- *The MRP requires development and implementation of green infrastructure plans.*

East County Permittees will soon be obtaining coverage under the Municipal Regional Stormwater Permit (MRP) issued by the San Francisco Bay Regional Water Quality Control Board (SFRWQCB). This is an administrative convenience beneficial to CVRWQCB and CCCWP and has been agreed upon by all parties involved. The MRP requires Permittees to develop and implement green infrastructure plans, so the new permit framework is well aligned with the implementation needs of this TMDL. CCCWP is currently developing a countywide RAA addressing mercury and polychlorinated biphenyl congeners (PCB) TMDLs for San Francisco Bay. The geographic scope of the modeling analysis for the RAA includes East County. An RAA for methylmercury in East County will build on lessons learned from the countywide mercury and PCBs RAA.

The methylmercury control plan of this report (Section 5) presents an orderly approach to commence green infrastructure planning, continue ongoing Permittee activities to control total mercury loads, perform an RAA of green infrastructure plans, and assess the possibility that regions of eutrophication in Marsh Creek constitute a controllable methylmercury source. The plan and schedule also include commitments to mercury monitoring and multilingual public outreach, making information available about safe consumption habits to sport and subsistence fishers.

Submittals to the SFRWQCB of Permittee annual reports, pollutants of concern (POC) reports, CCCWP's annual urban creeks monitoring reports, CCCWP's five-year integrated monitoring reports, and CCCWP's report of waste discharge for permit re-issuance will all be copied to the CVRWQCB. This communication plan assures CVRWQCB will be kept up to date with progress on Delta Methylmercury TMDL implementation by East County Permittees at least three times a year and included in the dialogue to develop permit provisions addressing TMDLs affecting East County Permittees when the MRP is re-issued every five years. Rather than requiring any new, separate reports or updates to this plan, CCCWP recommends the above submittals include a progress report on methylmercury control plan implementation, as appropriate.

The iterative, adaptive process for methylmercury control plan implementation described above is consistent with the adaptive management framework described in the resolution adopting the TMDL (CVRWQCB, 2010b):

> *"The Regional Board will review the feasibility of meeting wasteload allocations based on reliable data and information regarding variability in methylmercury concentrations and treatment efficiencies and time needed to comply with the wasteload allocations. The Phase 1 Control Studies are designed to provide this information. As needed, the Regional Board shall incorporate the Phase 1 Control Studies into compliance schedules. When Phase 1 studies are complete, the Regional Board will review the need for additional time during Phase 2 for NPDES permittees to comply with the final wasteload allocations."*

The detailed schedule for this methylmercury control plan is shown in Table ES-1.

Section 1 of this report presents an introduction and background. The problem statement, environmental setting, and regulatory framework are intended to help the reader understand the

drivers for this project. The TMDL framework is explained in more detail, along with a conceptual model for managing methylmercury in urban runoff. A review of how other Central Valley municipal stormwater programs are approaching their control plans shows that East County Permittees are aligned with their peers. The introduction concludes with an overview of the Marsh Creek watershed features that affect mercury and methylmercury.

Section 2 presents the study approach, and Section 3 the study results. Study conclusions, including the finding of infeasibility, are detailed in Section 4. The methylmercury control plan is presented in Section 5. The schedule of activities appears in Section 6.

Key Points

- *The schedule proposed includes three submittals per year to the SFRWQCB that will be copied to the CVRWQCB:*
  - *Annual Report*
  - *Pollutants of Concern Report*
  - *Urban Creek Monitoring Report*
- *Once every five years an Integrated Monitoring Report is produced that informs the Report of Waste Discharge for the permit re-issuance.*
- *Those five-year reports will also be copied to CVRWQCB on submittal to the SFRWQCB.*
- *The annual and once per five-year reports will include sections describing progress on the Delta Methylmercury TMDL.*
- *There is no need for any additional report submittals to the CVRWQCB related to the Delta Methylmercury TMDL because of the well-defined, regular reporting process in the plan.*

Table ES-1. Schedule for Methylmercury Control Plan Implementation

Date	Activity	By Whom
10/15/18	POC Report to CVRWQCB and SFRWQCB (submitted)	CCCWP
10/20/18	Submit Final Methylmercury Control Study Final Report	CCCWP
01/21/19	Amend MRP 2.0 to include East County Permittees	SFRWQCB
01/31/19	Complete Stormwater Resources Plan	CCCWP
03/31/19	Submit Urban Creeks Monitoring Report with Marsh Creek SSID Study Status Report	CCCWP
09/15/19*	Submit Annual Report to CVRWQCB and SFRWQCB	CCCWP
10/15/19*	Submit POC Report to CVRWQCB and SFRWQCB	CCCWP
12/31/19	Complete Green Infrastructure Work Plans	East County Permittees
03/31/20	Submit Integrated Monitoring Report including Delta Methylmercury updates	CCCWP
05/22/20	Submit Report of Waste Discharge, including Delta Methylmercury TMDL updates	CCCWP
07/22/20	Provide input to SFRWQCB on MRP provisions for East County Permittees	CVRWQCB
9/31/20	Submit Annual Report to CVRWQCB and SFRWQCB	CCCWP
10/15/20	Submit POC Report to CVRWQCB and SFRWQCB	CCCWP
11/19/20	Re-issue MRP	SFRWQCB
2020	Review of Numeric Targets and Associated Load and Wasteload Allocations for TMDL	CVRWQB
12/31/20	Complete Green Infrastructure Plans	East County Permittees
01/01/21	Commence Green Infrastructure Plan Implementation	East County Permittees
03/15/21	Complete RAA of Green Infrastructure Plans	East County Permittees
03/31/21*	Submit Urban Creeks Monitoring Report including Delta Methylmercury updates	CCCWP
09/31/21	Submit Annual Report to CVRWQCB and SFRWQCB	CCCWP
10/15/21	Submit POC Report to CVRWQCB and SFRWQCB	CCCWP
03/31/25	Submit Integrated Monitoring Report including Delta Methylmercury updates	CCCWP
05/22/25	Submit Report of Waste Discharge, including Delta Methylmercury updates	CCCWP
07/22/25	Provide input to SFRWQCB on MRP provisions for East Count Permittees	CVRWQCB
11/20/25	Re-issue MRP	SFRWQCB

*Indicates activities that will recur annually in the same month

Shaded rows indicate the recurring steps in the five-year permit re-issuance process

1. INTRODUCTION AND BACKGROUND

The Contra Costa Clean Water Program (CCCWP) implements applied water quality monitoring and assessment studies to identify potential solutions to water quality problems. Completion of these studies fulfills Clean Water Act permit requirements established for all Permittees of CCCWP named in National Discharge Elimination System (NPDES) stormwater permits. This report summarizes the findings and recommendations of one such required study, a methylmercury control study for urban stormwater discharges from Eastern Contra Costa County Permittees (Antioch, Oakley, Brentwood, and portions of the Contra Costa County Flood Control and Water Conservation District and unincorporated Contra Costa County).

CCCWP began implementation of a methylmercury control study in 2012 to fulfill the requirements of Provision C.11.l of the Central Valley Permit (East County Permit, Order No. R5-2010-0102). A methylmercury control study work plan (Amec, 2013) was prepared in response to Provision C.11 and was designed to 1) evaluate the effectiveness of existing best management practices (BMPs) for the control of methylmercury; 2) evaluate additional or enhanced BMPs, as needed, to reduce mercury and methylmercury discharges to the Delta; and 3) determine the feasibility of meeting methylmercury wasteload allocations. An interim progress report was submitted to the Central Valley Regional Water Quality Control Board (CVRWQB) in October 2015. This final report completes the requirements of C.11.l in Order No. R5-2010-0102.

This introduction and background provide a summary of the problem statement, the environmental and regulatory setting, and the total maximum daily load (TMDL) framework for managing methylmercury. The discussion of the TMDL framework includes a brief review of how other municipal stormwater programs are addressing this same requirement to develop and implement a methylmercury control plan. Because the TMDL focuses Contra Costa County implementation mainly on the Marsh Creek watershed, a section on the landscape features and water quality monitoring programs in that watershed is relevant to this study and included. This section concludes with a summary of the conceptual model for managing methylmercury as it relates to municipal stormwater management.

Section 2 of this report presents the study approach. Section 3 presents the study results and data analysis. Section 4 presents the study conclusions, including the finding of infeasibility. Section 4 describes the plan for controlling methylmercury in urban runoff discharges. Section 5 is a summary of the data quality assurance and quality control (QA/QC) procedures, and the schedule of activities appears in Section 6. Section 7 contains the references cited.

1.1 Problem Statement

The motivation for this study was the determination by CVRWQCB that mercury concentrations in fish species found in the Sacramento-San Joaquin River Delta (the Delta) exceed acceptable levels for protection of human health and wildlife that depend on fish for food (CVRWQCB, 2010a). The root cause of this is numerous legacy mining and old industrial mercury sources, and global atmospheric mercury sources, in addition to smaller contributions from urban stormwater and publicly owned treatment

works. Methylmercury is a form of mercury of heightened environmental concern because it binds to proteins and, therefore, bioaccumulates in organisms and biomagnifies at successively higher levels of the food chain.

Thousands of scientific publications over the past several decades provide detailed insights into the complex environmental factors affecting how mercury is converted to methylmercury (i.e., methylated) and how methylmercury is converted back to inorganic mercury (i.e., demethylated). The key points about mercury methylation and demethylation most relevant to stormwater management include:

- Mercury methylation is a microbially mediated process in which bacteria take up inorganic mercury and add carbon to make methylmercury.
- The bacteria that methylate mercury thrive under low oxygen (suboxic) or no oxygen (anoxic) conditions, therefore slow moving or stagnant water is a risk factor for increased mercury methylation.
- Cyclical wetting and drying, such as in tidal systems or small streams with intermittent discharge, is also a risk factor for increased mercury methylation
- Methylation and demethylation constantly occur in natural waters. Methylmercury concentration reflects the balance between the forward (methylation) and reverse (demethylation) reactions at any given time and location.
- Methylmercury tends to adhere to sediment particles. Thus, suspended sediment concentrations (SSC) in water directly affect methylmercury concentrations in water. Higher SSC result in higher methylmercury concentrations.

Mercury in fish is an issue of statewide and global significance. It is recognized by state and federal regulatory agencies as a complex problem with a long-term trajectory toward recovery. Under such circumstances, where best attainable technological controls have been implemented at regulated point sources and receiving waters still fail to attain water quality standards, the Clean Water Act requires development of a TMDL. A TMDL is a water quality planning analysis allocating responsibility for control measures to all known sources of pollutants of concern to a receiving waterbody. Requirements to implement control measures are typically specified through applicable permits. This study of methylmercury control measures in urban runoff is responsive to implementation requirements of the Sacramento-San Joaquin River Delta Estuary TMDL for Methylmercury (Delta Methylmercury TMDL).

Key Points

- *The CVRWQCB established a TMDL for methylmercury in the Delta to address the problem of mercury levels in fish exceeding risk guidelines protective of people and wildlife that eat fish from the Delta.*
- *Methylmercury, which is mercury bound to a carbon atom, is the form of concern that increases to higher levels at higher levels in the food chain.*
- *There are a lot of things affecting how mercury converts to methylmercury, but at least one factor relevant in this study is that low-oxygen, stagnant waters can promote the formation of methylmercury.*
- *The TMDL allocates responsibility to Delta dischargers, including East County Permittees, for reducing the annual mass of methylmercury released to the Delta from their discharges.*

1.2 Environmental and Regulatory Setting

Contra Costa County is situated at the gateway between San Francisco Bay and the Delta. The northern and western shorelines provide ample opportunities for sport and subsistence fishing, supported by a network of marinas and fishing supply stores. In 2016, the nearly 68,000 fishing licenses sold in the County place it in the top ten of California's 58 counties by number of licenses sold (CDFW, 2018). Shoreline recreational trails, habitat restoration projects, and the ready availability of boats for hire to explore Delta wildlife habitats support birdwatchers and other wildlife enthusiasts. These details serve as evidence that the issue of elevated mercury in fish is clearly important to the values and economy of Contra Costa County residents.

Representing a cosmopolitan Bay Area community spanning the jurisdictions of two Regional Water Quality Control Boards (RWQCB), CCCWP implements policies of both CVRWQCB and SFRWQCB in the management of water quality (Figure 1). Greater than 80 percent of the County's 1.1 million residents live within the SFRWQCB jurisdiction, whereas a little over 200,000 people reside in the CVRWQCB jurisdiction (East County). Historically, Permittees within the SFRWQCB jurisdiction are enrolled in the NPDES stormwater permit issued by the SFRWQCB (MRP), whereas East County Permittees are enrolled in a separate permit issued by CVRWQCB (East County Permit). The East County Permit would typically be issued one year after the SFRWQCB permit and would be closely aligned with the permit language developed by the SFRWQCB.

During 2018, East County Permittees applied to SFRWQCB for coverage under the SF Bay MRP that applies to all other Bay Area Phase I (large municipality) stormwater permittees. This administrative change has the concurrence of the CVRWQCB. The intention is to simplify permit administration for both regulatory agencies as well as CCCWP. The CVRWQCB retains permit and enforcement authority for all other aspects of Clean Water Act and State Water Code implementation in East County. The CVRWQCB would retain authority to require information of East County Permittees through Water Code Section 13267 letters and issue notices of violation directly if Permittees are found to be in violation of CVRWQCB policies. TMDLs issued by the CVRWQCB still apply to East County Permittees, whereas TMDLs issued by the SFRWQCB would continue to only apply within the boundaries of the SFRWQCB.

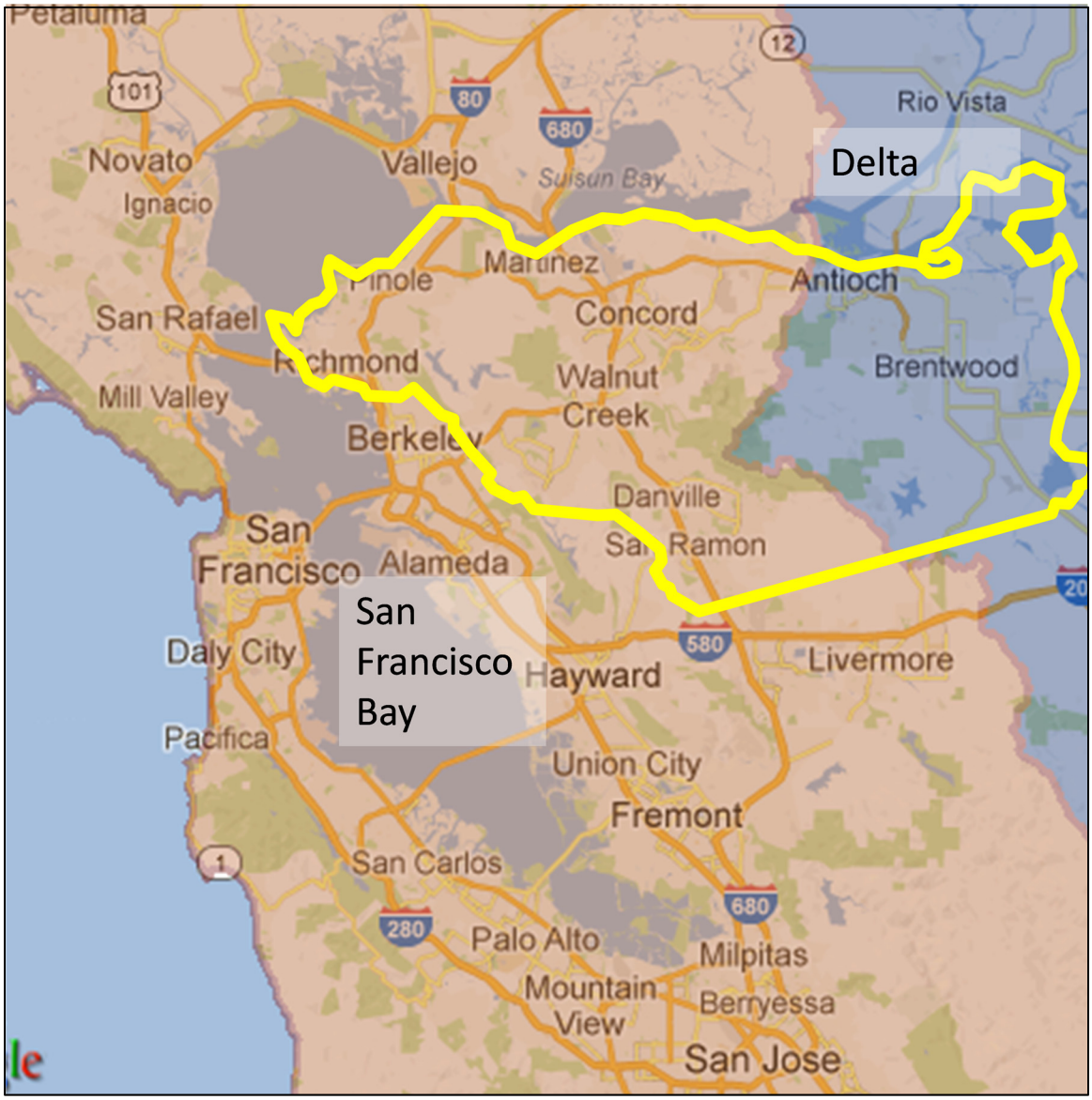
Thus, even though East County Permittees are moving to coverage under the MRP, they are still bound by the existing CVRWQCB permit requirement to submit this final report on the methylmercury control study, including a plan and schedule for implementation of control measures. This report is a pilot test of the new paradigm for overseeing compliance with CVRWQCB TMDLs by East County Permittees with coverage under a permit issued by the SFRWQCB. Proposed mechanisms for CCCWP to support CVRWQCB oversite of TMDL implementation by East County Permittees include:

- Providing copies of annual stormwater reports from East County Permittees to the CVRWQCB along with submittals to the SFRWQCB;
- Providing copies of annual Urban Creeks Monitoring Reports to the CVRWQCB along with submittals to the SFRWQCB, and highlighting studies or findings from East County of significance to the CVRWQCB;
- Providing copies of the work plan for the Marsh Creek SSID study and subsequent reports to CVRWQCB staff, along with any other special studies which occur in or touch on East County;
- Developing green infrastructure[4] plans to treat urban stormwater, in compliance with the MRP, and sharing those plans with CVRWQCB staff;
- Including CVRWQCB in the Report of Waste Discharge prepared for each five-year cycle of permit reissuance; and
- Responding to comments from CVRWQCB on reports provided and working with both the CVRWQCB and SFRWQCB staffs to develop language for future iterations of the MRP which directs implementation of CVRWQCB TMDL requirements.

[4] According to the SFRWQCB MRP, Green Infrastructure plans are "intended to describe how the Permittees will shift their impervious surfaces and storm drain infrastructure from gray, or traditional storm drain infrastructure where runoff flows directly into the storm drain and then the receiving water, to green—that is, to a more-resilient, sustainable system that slows runoff by dispersing it to vegetated areas, harvests and uses runoff, promotes infiltration and evapotranspiration, and uses bioretention and other green infrastructure practices to clean stormwater runoff.

The CCCWP Stormwater C3 Guidebook (https://www.cccleanwater.org), uses "Low Impact Development" (LID) instead of "green infrastructure" The C3 Guidebook defines LID as: "A stormwater management strategy aimed at maintaining or restoring the natural hydrologic functions of a site. LID design detains, treats, and infiltrates runoff by minimizing impervious area, using pervious pavements and green roofs, dispersing runoff to landscaped areas, and routing runoff to rain gardens, cisterns, swales, and other small-scale facilities distributed throughout a site." Regardless of the terminology used, LID / green infrastructure is the preferred method of treatment in Contra Costa County (CCCWP, 2017).

Figure 1. Jurisdictions of SFRWQCB (red) and CVRWQCB (blue) in Contra Costa County (yellow border)



Key Points

- *Contra Costa County's position at the gateway to the Delta means the eastern portion of the County is in the CVRWQCB jurisdiction, whereas the western portion is in the SFRWQCB jurisdiction.*
- *This study was required of East County Permittees through the permit issued by the CVRWQCB in 2010 (No. R5-2010-0102).*
- *East County Permittees will soon be covered under the MRP administered by the SFRWQCB.*
- *This Methylmercury Control Plan proposes a process to implement the plan through compliance with the MRP, while keeping the CVRWQCB up to date on progress and involving them in permit reissuance of the MRP.*

1.3 TMDL Framework for Stormwater Management of Mercury in the Delta

The TMDL process translates the desired water quality objective into numeric targets that are measurable parameters related to the pollutant of concern. Numeric targets are then transformed to quantitative estimates of the maximum pollutant load that can be assimilated by the receiving water while still attaining numeric targets.

The Delta methylmercury TMDL established water quality objectives for acceptable concentrations of methylmercury in fish to be protective of human and wildlife consumers:

- 0.24 mg/kg (Trophic Level 4)[5]
- 0.08 mg/kg (Trophic Level 3)
- 0.03 mg/kg (< 50 mm length)

These fish tissue targets were translated to a water column implementation goal of 0.06 ng/L methylmercury in unfiltered water. As an implementation goal, 0.06 ng/L is not by itself enforceable as a numeric water quality objective. Rather, it is a planning goal used to translate the desired receiving water outcomes to stormwater planning goals, translated to a maximum mass per year of methylmercury discharged from urban runoff to the Delta by multiplying 0.06 ng/L times the annual average flow volume of urban runoff.

The linkage analysis translating fish tissue water quality objectives to the implementation goal of 0.06 ng/L methylmercury was a controversial topic during TMDL development, engendering numerous technical comments and critiques from stakeholders. The linkage analysis relied upon correlations between measurements of mercury in fish tissue and methylmercury in water, food web models, and lessons learned published in peer-reviewed scientific articles. The CVRWQCB and their scientific peer reviewers acknowledged there were uncertainties in the linkage analysis but were nonetheless obligated by Clean Water Act regulations to adopt fish tissue water quality objectives for methylmercury and to translate those objectives into numeric targets for completion of the TMDL analysis. Recognizing the inherent uncertainty in the linkage analysis, the TMDL implementation plan also calls for a review of numeric targets and associated load and wasteload allocations[6] in the years 2020 and 2030. The monitoring design for the Delta Regional Monitoring Program (Delta RMP) includes management questions related to the link between mercury sources and methylmercury concentrations in fish (Aquatic Science Center, 2018).

Questioning or discussing the TMDL linkage analysis is outside the scope of the permit requirements driving this study. Introducing evidence for attainment of wasteload allocations based on 0.06 ng/L is within the scope of Provision C.11.l.iii(2) (see Appendix A for the full permit provision):

[5] Trophic level refers to how high an organism is on the food chain. Trophic level 4 refers to upper level predators (e.g., large-mouth bass). Trophic level 3 refers to fish lower on the food chain, such as trout, bluegill, and crappie. Because of the tendency of methylmercury to biomagnify to higher concentrations at higher levels in the food chain, fish tissue objectives typically are established with reference to trophic status and/or size.

[6] In the TMDL regulations, a wasteload allocation is a load allocation assigned to a source with an NPDES permit. Load allocation are assigned to sources not typically associated with an NPDES permit, such as airborne deposition.

> *If the Control Study results indicate that achieving a given methylmercury allocation is infeasible, then the Permittees shall provide detailed information in the Final Report on why full compliance is not achievable, what methylmercury load reduction is achievable, and an implementation plan and schedule to achieve partial compliance.*

CCCWP presented evidence for the infeasibility of achieving 0.06 ng/L methylmercury in stormwater to CVRWQCB in the work plan for this study (CCCWP, 2013), as well as in the 2015 status report (CCCWP, 2015). This evidence will be discussed in detail in the results section (Section 3) of this study.

The Delta Methylmercury TMDL parses out the problem definition and associated responsibility for actions into geographic sub-areas of the Delta (Figure 2). Only the West Delta, Central Delta, and Marsh Creek sub-areas touch Contra Costa County and need to be assessed for compliance with the East County Permit. Attainment of fish tissue targets and associated water column implementation goals is also evaluated by sub-areas. Currently, fish caught from the Central Delta meet water quality objectives, and the implementation goal of 0.06 ng/L in water is attained in the Central Delta. Waters of the West Delta are also very close to attainment of the 0.06 ng/L implementation goal. Consequently, the wasteload allocations for urban runoff from CCCWP Permittees into the West and Central Delta sub-areas are set at existing loads (i.e., no actions are required of the Permittees to reduce methylmercury loads from urban runoff into those specific sub-areas).

Waters of the Marsh Creek sub-area, on the other hand, are well above the implementation goal. CVRWQCB reported the average methylmercury concentration for water flowing from Marsh Creek was 0.224 ng/L (CVRWQCB, 2010a) based on data collected in the 2003-2004 time frame. The TMDL assumption is that load reductions needed are proportional to the concentration reduction needed to attain 0.06 ng/L. Load reductions proportional to concentration reductions means that if achieving 0.06 ng/L is infeasible, volume reduction can be implemented to achieve load reductions required in the TMDL. For example, the Marsh Creek sub-area needs methylmercury loads to be reduced to 28 percent of the presumed present-day load (0.224 ng/L x 0.28 = 0.06 ng/L). If the annual average concentration will always be 0.224 ng/L, then runoff volumes would have to be reduced to 28 percent of present-day runoff volumes. Table 1 shows how this is translated into current and future compulsory methylmercury loads discharged from Contra Costa County urban stormwater to the Delta.

Key Points

- *The CVRWQCB adopted water quality objectives specifying acceptable concentrations of mercury in fish tissue.*
- *The fish tissue objectives are translated in the TMDL to a water column implementation goal of 0.06 ng/L methylmercury.*
- *The requirement to produce this study included the option to make a case for infeasibility of achieving goals established by the TMDL.*
- *CCCWP previously presented evidence in the work plan and status report on the infeasibility of achieving 0.06 ng/L methylmercury in stormwater.*
- *The TMDL divides the Delta into sub-areas, three of which touch Contra Costa County: the West Delta, the Central Delta, and Marsh Creek.*
- *Of the three sub-areas, only Marsh Creek exceeds the implementation goal of 0.06 ng/L, and therefore the methylmercury control measures required of East County Permittees are in the Marsh Creek watershed.*

Figure 2. Delta Sub-regions Defined in the TMDL

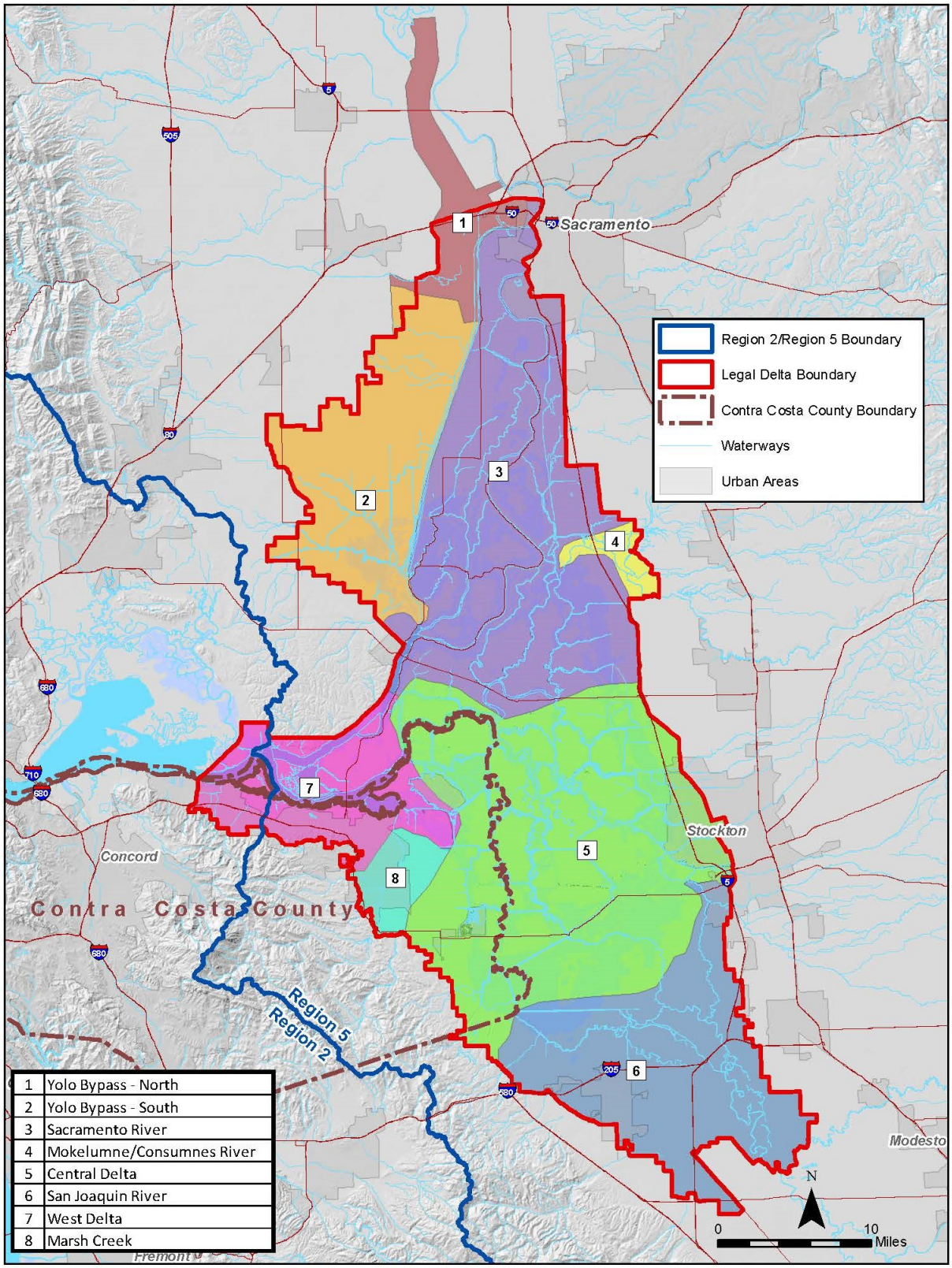


Table 1. TMDL Allocations Assigned to Urban Runoff in Eastern Contra Costa County

	West Delta	Central Delta	Marsh Creek
Existing Average Methylmercury Concentration in Urban Runoff (ng/L)[1]	0.24	0.24	0.24
Existing Average Methylmercury Load (g/year)[1]	3.2	0.75	1.2
Average Methylmercury Concentration used to Calculate Allocation (ng/L)[1]	0.24	0.24	0.06
Methylmercury Wasteload Allocation (g/year)[1]	3.2	0.75	0.3
Percent Load Reduction Required[2]	None	None	75%
Presumed Total Annual Average Urban Runoff Volume Used in TMDL[3] (acre-feet)	10,813	2,534	4,055
Urban Acres Assumed in TMDL[4]	9,518	2,181	3,427
Average Annual Urban Dry Weather Urban Runoff Flows Assumed in TMDL (acre-feet)[5]	2,263	519	815
Average Annual Urban Wet Weather Urban Runoff Flows Assumed in TMDL (acre-feet)[6]	8,550	2,016	3,240
Presumed Runoff Coefficient Used in TMDL[7]	0.62	0.65	0.66

1 From Tables 8.4a, 8.4b, and 8.4f of Delta Methylmercury TMDL Report (CVRWQCB, 2010)

2 Calculated as (Existing Average Methylmercury Load) (g/year) / (Methylmercury Wasteload Allocation) x 100%

3 Calculated as (Existing Average Methylmercury Load) (g/year) / Existing Average Methylmercury Concentration (ng/L) x (109 ng/g) x (8.11 x 10-7 acre-feet/liter)

4 From Table 6.10 of CVRWQCB (2010)

5 Calculated as urban acreage x (254 gallons/acre/day) x (305 dry days/year) per Appendix E.2.3 of CVRWQVB (2010)

6 Calculated as Total Annual Average Urban Runoff Volume – Average Annual Dry Weather Urban Runoff Volume

7 Calculated based on Section E.2.3 of CVRWQCB (2010) using Qe = Rf x A x RC, where:

Qe = estimated annual runoff volume (acre-feet/year)

Rf = annual precipitation amount in watershed (feet/year) = 1.43 feet/year based on Stockton Fire Station 4 (STK) from Table E.3 of (CVRWQCBN, 2010)

A = urban acreage

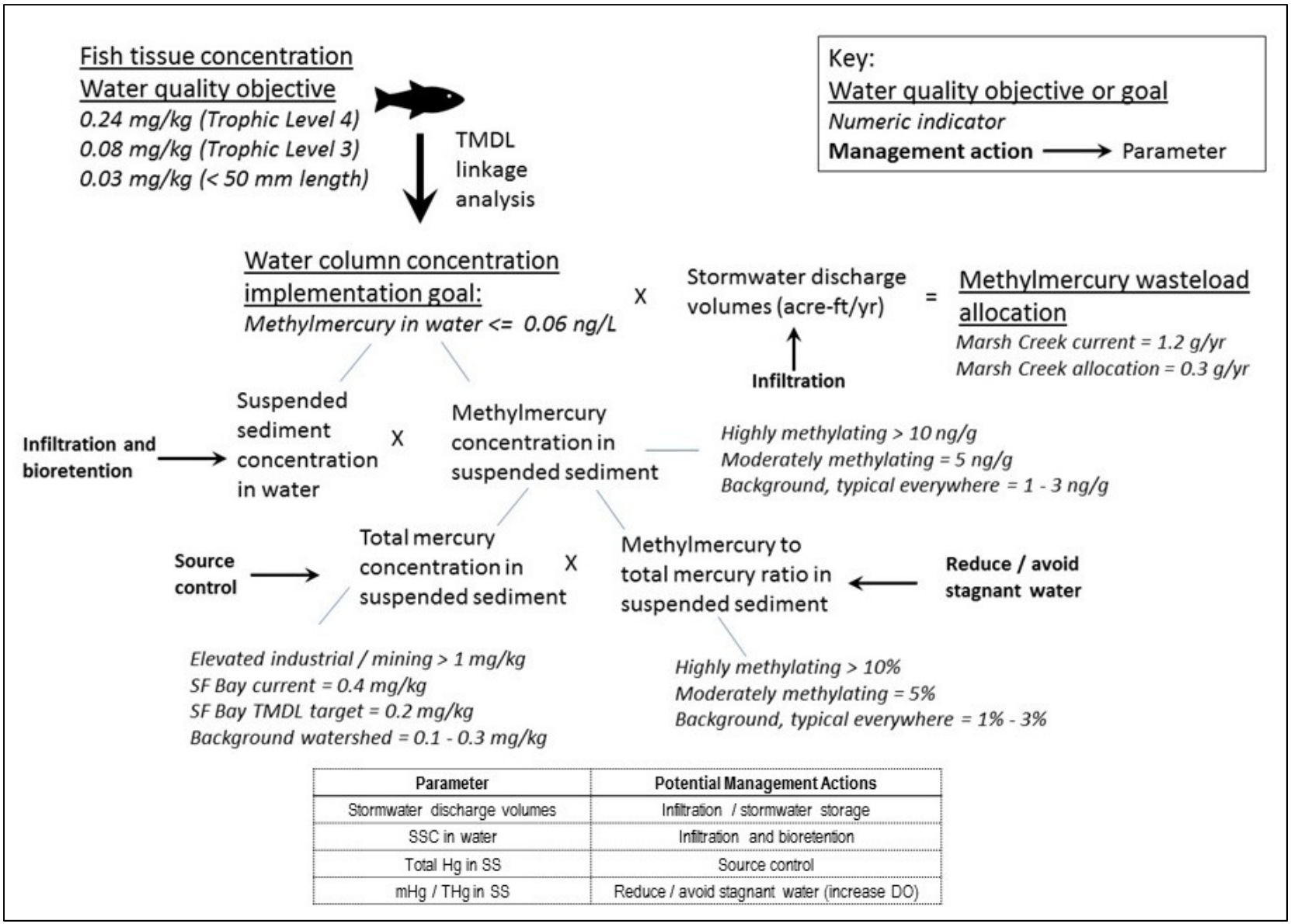
RC = runoff coefficient

1.4 Conceptual Model for Managing Methylmercury in Urban Runoff in the TMDL Framework

A conceptual model helps non-specialized managers connect measurements to goals and resulting actions. Figure 3 takes the TMDL policy goals described above and breaks them down into practical, quantifiable parameters addressed through this study. In the top row of Figure 3, the fish tissue objectives and associated TMDL implementation goal are restated for clarity. In the second row, the water concentration implementation goal of 0.06 ng/L is multiplied by annual average urban runoff volumes to arrive at the methylmercury wasteload allocation (0.3 g/yr) for the Marsh Creek sub-area. This leads to infiltration to reduce runoff volumes as a potential control measure.

The third row illustrates how methylmercury concentrations in water are a product of suspended sediment concentrations in water and the methylmercury concentrations of suspended sediments. A national survey of methylmercury in U.S. watersheds (Krabbenhoft, 1998) shows that 1 to 3 ng /g methylmercury in sediments is a typical background concentration that could be found in almost any watershed.

Figure 3. Conceptual Model for Managing Methylmercury in Urban Runoff in the TMDL Framework



Parameter	Potential Management Actions
Stormwater discharge volumes	Infiltration / stormwater storage
SSC in water	Infiltration and bioretention
Total Hg in SS	Source control
mHg / THg in SS	Reduce / avoid stagnant water (increase DO)

The pervasive baseline level of methylmercury in wetted sediments is key to understanding this study's conclusions that reliably attaining the implementation goal of 0.06 ng/L in stormwater or natural surface waters is infeasible. If under normal, common watershed circumstances, suspended sediment in contact with water can reasonably be expected to have 1 to 3 nanograms per gram (ng/g) methylmercury because of atmospheric deposition and natural background methylation alone, then increasing amounts of suspended sediment will consistently lead to increasing methylmercury above those levels. As will be shown using the monitoring data, this is indeed the case in the Marsh Creek sub-area where existing, natural SSC establishes a methylmercury floor that is well above the 0.06 ng/L implementation goal.

It is important to separate the concept of "infeasible" as the implementation goal is applied to surface waters versus stormwater discharges. Achieving 0.06 ng/L is infeasible in surface waters because naturally occurring mercury concentrations and the resulting natural background of methylmercury in suspended sediments will cause the goal to be exceeded at natural surface water SSC. In stormwater discharges, the same is generally true, except certain kinds of stormwater treatment can bring SSC down to concentrations low enough that the 0.06 ng/L implementation goal is achieved. In the case of stormwater discharges, the infeasibility justification shifts from physical factors to the time and capital investment necessary to treat enough stormwater runoff volume to achieve the TMDL mass limits that are based on 0.06 ng/L.

In the fourth row of Figure 3, methylmercury concentrations in suspended sediments are further broken down into two contributing factors: the total mercury concentrations in sediments, and the fraction of mercury that is methylated (the percent methylated, or the methyl-total ratio). The percent methylated is an indicator for methylation efficiency, or net methylation rates. Again, referring to Krabbenhoft (1998), almost any uncontaminated soil-water system could be expected to have 1 to 3 percent methyl-total ratios. Moderately high methylation efficiency is indicated by methyl-total ratios of around 5 percent. Waters with methyl-total ratios exceeding 10 percent are considered to have high methylation efficiencies (i.e., are highly methylating).

Similarly, the San Francisco Bay mercury TMDL (SFRWQCB, 2006) and references cited therein help contextualize total mercury concentrations in suspended sediments reported in this study. Bay Area watersheds with open spaces, no mining sources, and no industrial sources, as well as newer urban developments, tend to have mercury concentrations in bedded and suspended sediments around 0.1 to 0.3 milligrams per kilogram (mg/kg) (100 to 300 ng/g; see also McKee et al., 2016). The implementation goal for the San Francisco Bay TMDL is 0.2 mg/kg (200 ng/g), as compared to the contemporary average of around 0.4 mg/kg (400 ng/g) in fine-grained Bay sediments. Downstream of historic mercury mines, such as New Almaden, total mercury concentrations in bedded and suspended sediments frequently exceed 1 mg/kg (1000 ng/g). In old industrial areas of the Bay, where historic activities, such as auto dismantling, released mercury from old electrical switches, mercury concentrations in sediments around 1 mg/kg (1000 ng/g) are also encountered. Data from this study confirm the finding for an old industrial area in the City of Richmond.

The four management actions listed in the table within Figure 3 are examples of how stormwater programs can affect the parameters of interest and make progress toward a TMDL implementation goal.

To obtain methylmercury concentrations in water below 0.06 ng/L, SSC would have to be reduced. Specific threshold levels of SSC that would equate to attaining the implementation goal are discussed in Section 3 (Study Results and Conclusions). From a management perspective, Figure 3 presents the main tools available for reducing SSC: settling (e.g., detention basins), infiltration and filtration (e.g., bioretention). Detention basins are already widely used in the Marsh Creek watershed for flood control purposes. Infiltration refers to stormwater treatment accomplished by detaining stormwater and completely infiltrating it into the subsurface, achieving essentially 100 percent removal of suspended sediment from stormwater that is infiltrated.

In most settings of the Bay Area, the proportion of runoff that can be infiltrated is limited due to soil type. Bioretention, however, can be implemented in any setting. Bioretention captures runoff in a surface pond and then filters the captured runoff through an engineered soil mix comprising sand and compost. Plant roots and organic processes maintain soil permeability and enhance pollutant removal. In unlined bioretention cells, filtered runoff accumulates in a subsurface reservoir (gravel layer) and then infiltrates into the subsurface soils, at a rate dependent on the permeability of those soils. When the rate of inflow exceeds the rate of infiltration for a prolonged period, the subsurface reservoir fills, and an underdrain located at the top of the subsurface reservoir drains excess treated runoff to the storm drain system. In lined bioretention cells, only treatment by filtration is achieved, with no infiltration.

Based on lessons learned by the California Department of Transportation (Caltrans), bioretention is extremely effective at reducing SSC when incoming concentrations exceed 100 milligrams per liter (mg/L) (California Department of Transportation, 2014). At lower SSC, the residual SSC leached from root zones tends to diminish the apparent SSC reduction benefit. Lessons learned from the Caltrans study and from BASMAA (2017) indicate the maximum extent practicable for reducing SSC by known stormwater treatment technologies of the types approved in Contra Costa County's green infrastructure design guidance is around 30 to 50 mg/L. For comparison, the International Stormwater BMP Database shows a median SSC concentration of 10 mg/L and a 75th percentile of 18.5 mg/L for bioretention effluent (Clary et al., 2017).

In addition to reducing SSC to reduce methylmercury concentrations, another option is to focus on reducing methylmercury concentrations adhered to suspended sediments. This can be achieved using source control actions to either 1) reduce total mercury concentrations in sediments, which reduces the amount of mercury supply that could be methylated, or 2) reducing stagnant (suboxic to anoxic) water that favors the microbially mediated methylation of total mercury. This study shows examples of where source control appears to be working in the Marsh Creek watershed, but also where legacy (and possibly contemporary) industrial sources continue to cause total mercury concentrations in storm-borne sediments to reach 1 mg/kg (1000 ng/g) or more in another watershed in western Contra Costa County. The study also identifies:

- A first flush event that may indicate elevated methylmercury in sediments because of stagnant waters, where application of source control to reduce water stagnation may reduce methylmercury concentrations; and

- A bioretention BMP that increased the percent of methylated mercury in sediments already elevated in total mercury, presumably due to either suboxic or anoxic conditions or increased microbial activity as a result of tidal inundation, resulting in substantial increases in methylmercury.

In summary, the conceptual model helps break down the TMDL goals into measurable parameters. Three of the key parameters in Figure 3 are measured directly in this study: SSC, total mercury, and methylmercury. Methylmercury concentrations in suspended sediment are estimated from the ratios of methylmercury in water to SSC; similarly, for total mercury in suspended sediments. Methylation efficiency is estimated by the ratio of methylmercury to total mercury in unfiltered water samples. All five of those parameters are associated with a management action. The four management actions available are infiltration, bioretention, total mercury source control, and avoiding or reducing stagnant water.

Key Points

- *Methylmercury loads in stormwater (i.e., the mass of methylmercury discharged per year) are equal to the concentration of methylmercury in the runoff multiplied by the volume of runoff.*
- *If achieving the implementation goal of 0.06 ng/L is infeasible, the only alternative to meet the mass limits set in the TMDL is through volume reduction of runoff.*
- *The conceptual model breaks down the TMDL implementation goal into component parts that can be monitored and managed.*
- *The component parts of interest are suspended sediment concentrations, total mercury in suspended sediments, methylmercury in suspended sediments, and the ratio of methylmercury to total mercury.*

1.5 Other Delta Municipal Stormwater Program's Methylmercury Control Approaches

A review of the approaches explored by other programs facing the same TMDL requirements uses the same types of source control shown in the conceptual model in Figure 3. The Sacramento Stormwater Quality Partnership evaluated infiltration BMPs featured in grant-funded green infrastructure pilot projects (Larry Walker Associates, 2015a). Their research approach is complementary to this study. Both studies evaluated the performance of green infrastructure treatment in reducing methylmercury concentrations after infiltration capacity is exceeded and treated water flows to the MS4 system. Both studies include the limitations of local and regional infiltration capacity, among other factors, in the overall assessment of feasibility.

Other programs also focused on either reduction of SSC or abatement of methylating conditions in suboxic or anoxic waters. The City of Stockton and County of San Joaquin are evaluating the effectiveness of detention basins, which provide particle removal by sedimentation (Larry Walker Associates, 2015b). Lessons learned from that study can improve CCCWP's understanding of the potential load reduction benefits provided by detention basins in the Marsh Creek watershed. The Port of Stockton is evaluating how the frequency and timing of sediment catch basin cleanouts may abate methylating conditions (RBI, 2015). The City of Sacramento's Department of Utilities is evaluating ways

to evaluate and potentially abate methylating conditions in their combined sewer conveyance system and treatment processes (Larry Walker Associates, 2015c).

In summary, the five methylmercury control studies representing essentially all the major Phase I NPDES municipal stormwater Permittees subject to the Delta Methylmercury TMDLs focus on one or more of the management actions shown in Figure 3. There are no management actions under study by other programs not represented in Figure 3. Thus, the review of the TMDL, the conceptual model, and the review of other municipal stormwater programs demonstrates that CCCWP's approach is consistent with the approach of other Central Valley municipal stormwater peers.

Key Points

- *There are five methylmercury control studies by Permittees subject to the Delta Methylmercury TMDL.*
- *All these studies center on one of the four management actions: infiltration, bioretention, source control, reduction or avoidance of stagnant water.*

1.6 Features of Marsh Creek Relevant to Methylmercury Monitoring and Management

A brief overview of the Marsh Creek watershed (Figure 4) is essential to understanding the data and the proposed implementation approach in the Marsh Creek sub-area. The key Permittees in the watershed, with respect to management actions in the Marsh Creek sub-area, are the City of Brentwood and the City of Oakley, which lie entirely within the Marsh Creek watershed. The City of Antioch will have less involvement, as small portions of its jurisdiction lie within the Sand Creek watershed, tributary to Marsh Creek. The Contra Costa Flood Control and Water Conservation District may have a role in investigating the causes and potential remedies, should Marsh Creek itself require source control for enhanced mercury methylation. Unincorporated Contra Costa County would likely have very little direct activity in relation to implementing this control plan, as they have very little developed urban jurisdiction within the Marsh Creek watershed.

According to the Contra Costa County Watershed Atlas (Contra Costa County Community Development Department, 2003), Marsh Creek watershed is the second largest watershed in Contra Costa County, totaling over 60,000 acres of urban (12,000 acres), agricultural (26,000 acres), and open space (20,000 acres) land uses[7]. The creek flows 34.6 miles from its headwaters in the Mount Diablo foothills to the San Joaquin River Delta at Big Break (see Figure 4). Tributaries entering the middle portion of the main stem near and within the City of Brentwood include Dry Creek (5.8 miles), Sand Creek (18.7 miles), and Deer Creek (9 miles). The Marsh Creek Reservoir (Reservoir) interrupts the flow from the upper watershed at 24.4 miles downstream of the headwaters. Flows only occasionally overtop the Reservoir's primary spillway to reach the lower watershed, typically late in the wet season after a series of storms. In addition to the Reservoir, numerous other stormwater detention basins in the watershed are owned

[7] The approximately 2,000 aces not captured by the three broad categories include water (201 acres) and public/semi-public lands (1,837 acres).

and maintained by the Contra Costa Flood Control and Water Conservation District for managing stormwater flows.

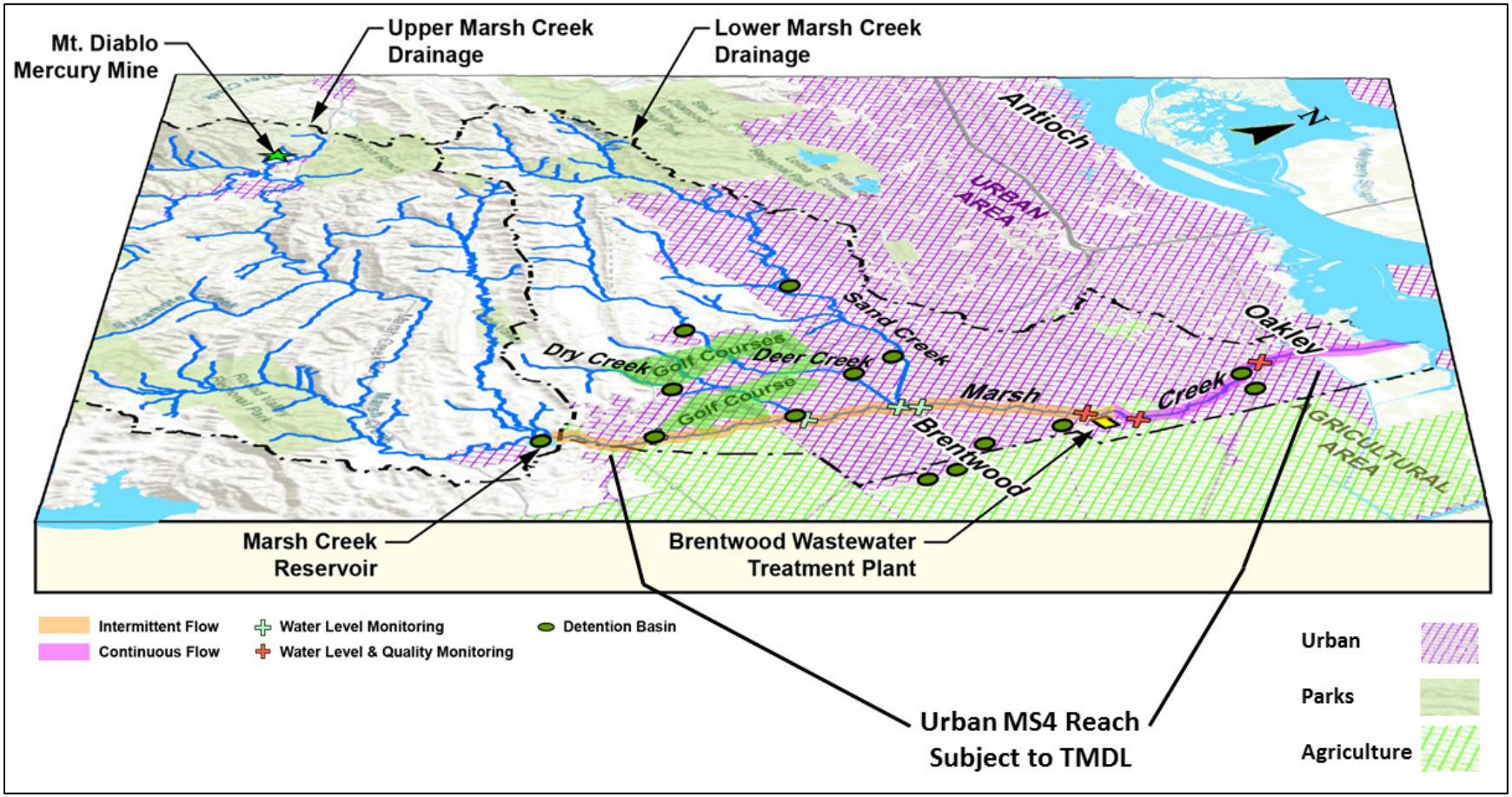
Marsh Creek reservoir itself is listed by the State Water Resources Control Board as impaired due to mercury. The reservoir is currently closed to fishing and secured from public access with fencing. Addressing mercury impairment of Marsh Creek Reservoir is outside the scope of this study. Mercury in reservoirs may in the future be subject to a Statewide Mercury Control Program for Reservoirs (State Water Resources Control Board, 2016).

In addition to reducing flood risk, the Reservoir and detention basins tend to trap sediment. The sediment trapping effect also starves the stream reach below the Reservoir. In the past, downcutting of the Marsh Creek channel bottom and undermining of the channel side resulting from this sediment deficit necessitated the installation of check dams approximately every 300 feet along the channel bottom between the toe of the Reservoir and the mouth of Marsh Creek at Big Break.

These check dams, in turn, have potentially interesting effects that may be relevant to mercury methylation. During the development of an SSID study for Marsh Creek in 2018, CCCWP scientists became aware that Marsh Creek at low flow acts as a series of interconnected ponds. Upstream of the City of Brentwood Wastewater Treatment Plant (Brentwood WTP), these ponds experience intermittent dry weather flows. There are a multitude of farms, businesses, and storm drains which may discharge stormwater and non-stormwater runoff into Marsh Creek. Agricultural and golf course irrigation, hydrant flushing, and residential irrigation are all potential sources of non-stormwater flow into Marsh Creek. These sources of dry weather runoff tend to refill the ponds between check dams from time to time in the dry season.

Algae blooms begin in the early spring, causing daily swings in pH and dissolved oxygen concentrations in the pooled water along the creek channel. CCCWP is currently investigating whether this process causes lethally low dissolved oxygen levels that account for recurrent fish kills in Marsh Creek (CCCWP, 2018). Low dissolved oxygen is also associated with increased mercury methylation, and so the low-flow configuration of Marsh Creek may also explain the observation of elevated methylmercury in suspended sediments during an April 2013 storm event, as discussed in Section 3. The locations of water level monitoring sites and continuous water quality monitoring sondes (temperature, pH, dissolved oxygen, conductivity, and turbidity) that are part of the fish kills investigation are indicated in Figure 4. There may be synergies between the investigation of eutrophication and low dissolved oxygen in the context of the fish kills study and potential future exploration of how conditions in Marsh Creek affect mercury methylation. This is discussed in more detail in Section 5.

Figure 4. Overview Map of Marsh Creek Watershed, Showing Key Features Affecting Water Quality and Locations of Monitoring Stations for the Marsh Creek SSID Study Currently Under Way



The Brentwood WTP, located approximately 3.6 miles southwest of the Delta at Big Break, treats sanitary wastewater from nearby residential areas and discharges its effluent into Marsh Creek, as authorized by a NPDES permit. The treatment plant has a design capacity of 5 million gallons per day (mgd). Present actual flows are more typically in the range of 2 to 3 mgd, depending in part on recycled water consumption by irrigators. The Brentwood WTP's effluent methylmercury concentrations average around 0.02 ng/L, well below the TMDL implementation goal of 0.06 ng/L. Under normal dry weather conditions, whenever water is flowing from the Brentwood WTP the effluent-dominated reach of Marsh Creek downstream of the Brentwood WTP would therefor also be expected to meet the TMDL implementation goal.

In the region downstream of the Brentwood WTP, Marsh Creek flows, following urban rhythms, show daily cycles. Flow rates tend to peak mid-day, following peaks in early morning residential usage, and are at minimum in the pre-dawn hours, sometimes reaching zero for a few hours a day in the spring through early fall seasons. Thus, because of the check dams along the creek channel, during the dry season, Marsh Creek below the Brentwood WTP alternates between a flowing stream most of the day to a series of interconnected ponds by night and becoming isolated ponds for a few pre-dawn hours each day during the driest times of the year (May through September).

The bifurcation of the watershed by the Reservoir into upper and lower segments has interesting implications for this study. Referring to Figure 2, the legal boundary of the Delta ends at the Reservoir. The upper Marsh Creek watershed, which includes the Mount Diablo Mercury Mine, is technically not in the geographic scope of the Delta Methylmercury TMDL. The mine site, located on privately owned lands, contains historic mining buildings, piles of exposed waste rock with mercury-containing calcines (processed mercury ore), and residual acidic drainage (CCCWP, 2013). The EPA is currently conducting a remedial investigation in coordination with U.S. Army Corps of Engineers (USACE) under Water Resources Development Act authorization (USACE, 2012) and the Remediation of Abandoned Mines program.

Even though the mine site itself lies outside the TMDL boundary, it is important to understand whether the mine site occasionally affects methylmercury loads in lower Marsh Creek when there is flow from the upper watershed. For this reason, this study purposefully targeted late season large storms, in addition to the more frequent and more easily sampled smaller storms. Six stormwater samples were successfully collected during two events when water from the upper watershed reached the monitoring station in lower Marsh Creek, as discussed in the Section 3.

Key Points

- *The Marsh Creek Reservoir and stormwater detention basins trap sediment resulting in the installation of check dams between the reservoir and the mouth of Marsh Creek. Potential benefits of methylmercury load reduction through desilting at the reservoir and check dams has not been quantified.*
- *During periods of low flow, Marsh Creek becomes a series of interconnected ponds at these check dams, with algae blooms with associated daily pH and dissolved oxygen swings.*
- *The Brentwood WTP discharges approximately 2 to 3 mgd into Marsh Creek with an average methylmercury concentration of 0.02 ng/g.*
- *The Mount Diablo Mercury Mine is outside the geographic scope of the Delta Methylmercury TMDL, but this study was designed to examine if the mine site affects loads to Marsh Creek.*

2. STUDY APPROACH

CCCWP's monitoring contractor, ADH Environmental, implemented the control study sampling under the direction of CCCWP. The following two subsections describe field and laboratory methods used in the implementation of the Work Plan (CCCWP, 2013).

2.1 Field Methods

Phase 1 water sampling was performed at eight stream locations in eastern Contra Costa County following clean-hands/dirty-hands grab sampling protocols (EPA Method 1669) for low-level mercury analysis (EPA Method 1631E). Phase 1 sampling was performed during dry and wet weather periods in Marsh Creek (Figure 5) and Antioch Creek (Figure 6). Wet weather samples were collected during elevated stream stages near storm peak discharge. A total of 18 dry weather samples and 37 wet weather samples were collected in Phase 1.

Phase 2 stormwater samples were collected at the influent and effluent points of each of two BMP bioretention cells in the City of Richmond (locations designated LAU3 and LAU4 in Figure 7). Additional stormwater characterization samples were collected in the Cities of Richmond and San Pablo and in unincorporated Contra Costa County (Figure 7). A total of 69 BMP effectiveness evaluation samples were collected in Phase 2.

Influent samples from the bioretention cells (Figure 8) were pumped from the curb and gutter conveyance on the north side of Cutting Boulevard, and effluent samples were pumped from the terminus of each biofiltration cell underdrain outfall within the City's municipal storm sewer system. Samples were drawn with non-contaminating peristaltic pumps fitted with solid fluorinated ethylene propylene (Teflon®) semi-rigid tubing and styrene ethylene butylene (C-Flex®) pump-roller tubing. All wetted surfaces of the tubing were cleaned with non-ionic detergent and hydrochloric acid prior to use. Clean sets of tubing were used at each sampling point and for every sampling event. Additionally, all tubing was thoroughly rinsed by pumping site water through each tubing assembly before each round of sample collection. Clean-hands/dirty-hands protocols were used for the collection of all mercury and methylmercury samples.

Key Points

- *Sampling followed EPA Methods 1669 and 1631E.*
- *Phase 1 sampled dry and wet weather grab samples from eight locations in eastern Contra Costa County.*
- *Phase 2 sampled influent and effluent at two BMP biofiltration cells in the City of Richmond.*

2.2 Laboratory Methods

Caltest Analytical Laboratory of Napa, California, performed all analytical testing. Table 2 presents the study's analytical test types, methods, reporting limits and holding times.

Table 2. Analytical Tests, Methods, Reporting Limits and Holding Times

Analytical Test	Method	Reporting Limit	Holding Time
Total (Unfiltered) Mercury	EPA 1631E	0.5 ng/L	90 days
Total (Unfiltered) Methylmercury	EPA 1631E	0.05 ng/L	90 days
Suspended Sediment Concentration	ASTM D3977-97B	3 mg/L	7 days

Key Points

- *Total mercury and total methylmercury analyzed using EPA Method 1631E.*
- *SSC analyzed using ASTM D3977-97B.*

2.3 Quality Assurance / Quality Control

This study analyzed data from samples collected in Contra Costa County during dry and wet weather events during the water years 2014 through 2018, as well as wet weather samples collected in water years 2012 and 2013. The latter data set was found to be acceptable under the measurement quality objectives of the Quality Assurance Project Plan, Regional Monitoring Coalition Pollutants of Concern Loads Monitoring Program (RMC, 2011). The quality assurance/quality control (QA/QC) acceptance of these data was detailed in the RMC POC loads monitoring reports for water years 2012 and 2013 (SFEI, 2012 and SFEI, 2013).

The samples analyzed during water years 2014 through 2018 followed the measurement quality objectives of the CCCWP Methylmercury Control Study Work Plan (Amec, 2013). These samples all met quality objectives except for those flagged samples shown in Table 3. Given that all the quality control issues described in Table 3 show that all issues were of minor consequence, the data from these samples are of acceptable quality and have been included in the data set analyzed in this progress report.

Key Points

- *Data are of acceptable quality.*

Figure 5. Sample Locations for Watershed Characterizations in Marsh Creek

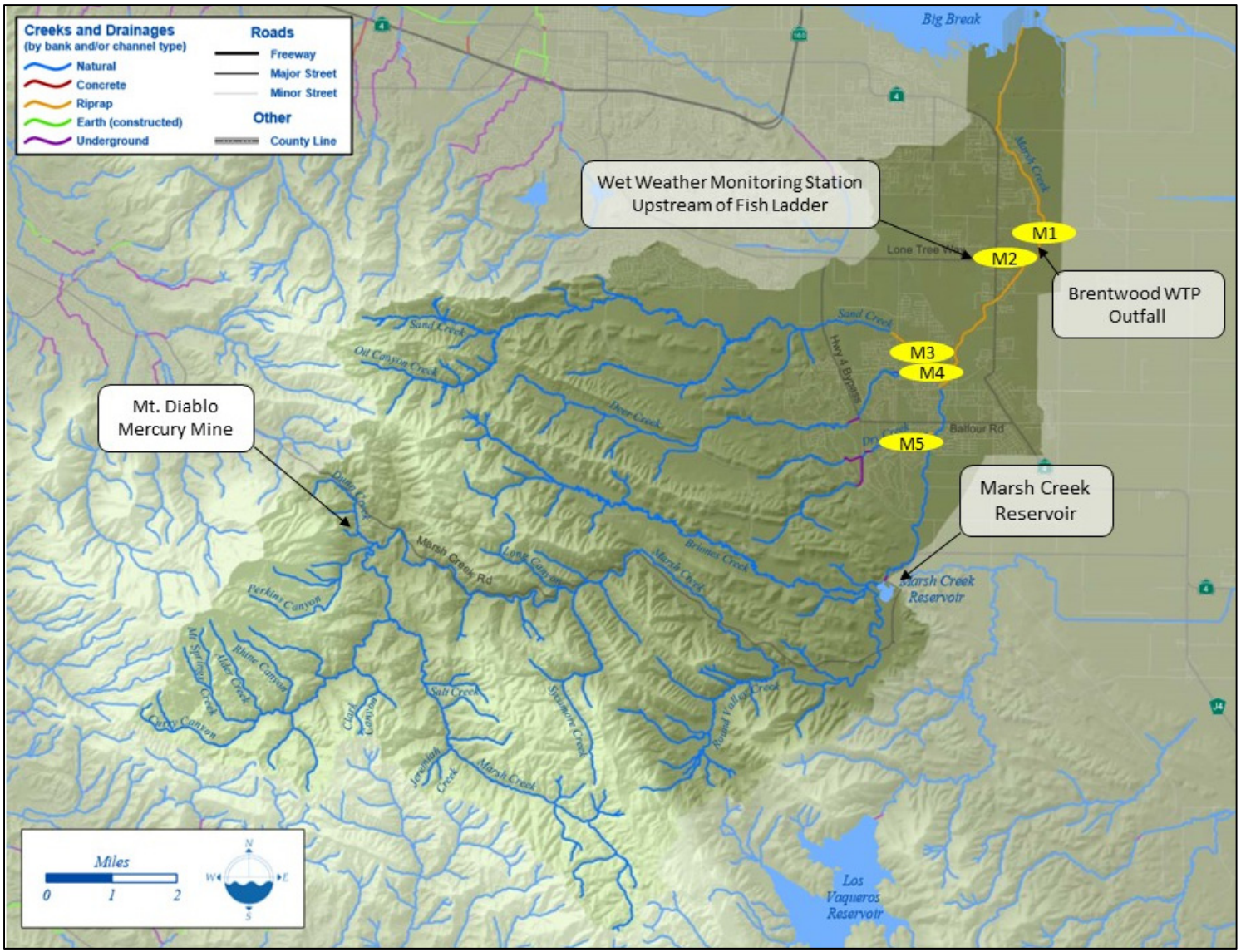


Figure 6. Sample Locations for Watershed Characterizations in East and West Antioch Creek

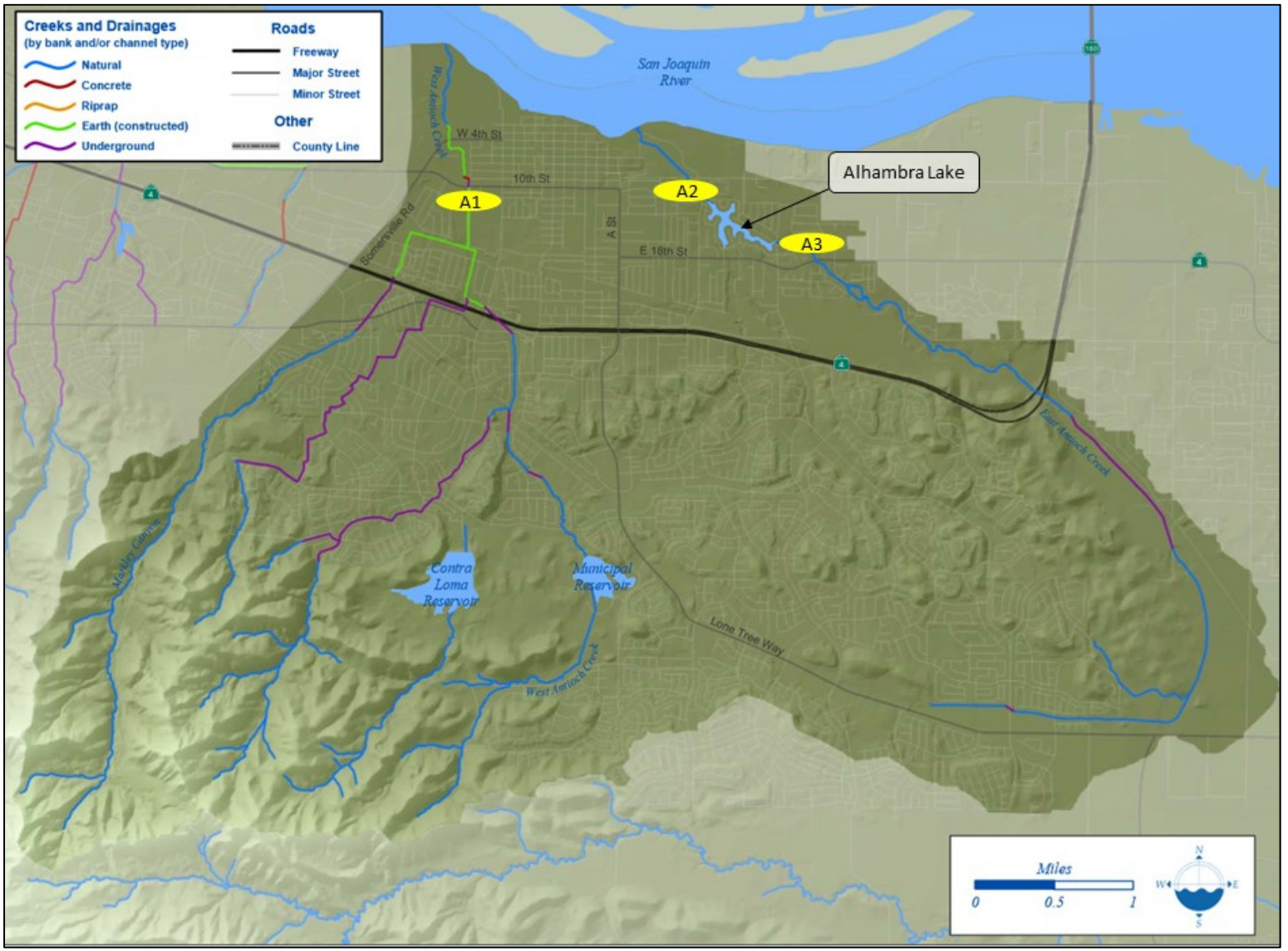


Figure 7. Sample Locations for BMP Effectiveness Evaluations and Additional Urban Runoff Characterization

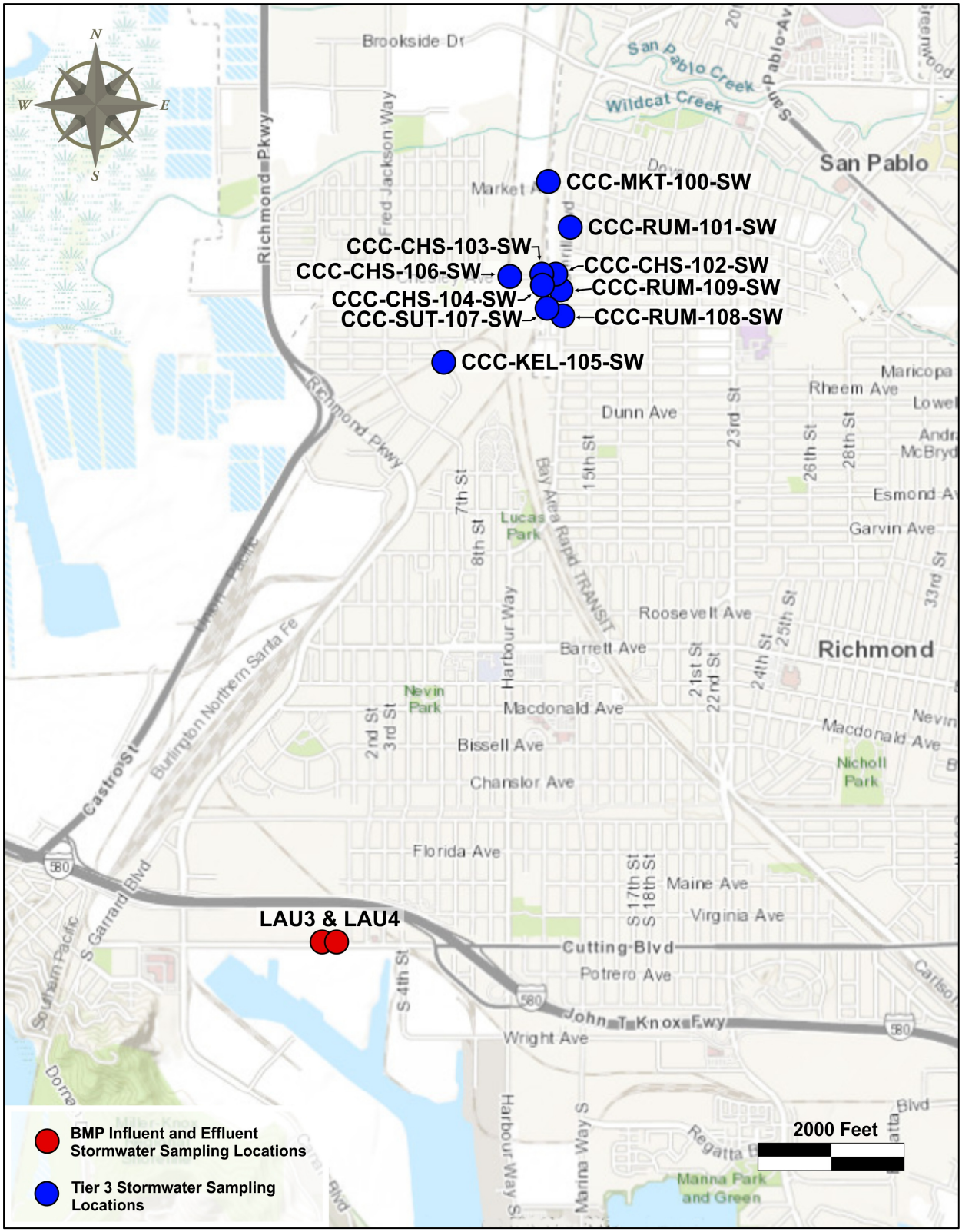


Figure 8. Design Drawing and Photographs of Treatment Bioswale at So. 1st Street and W. Cutting Boulevard, Richmond

BMP Type Bioretention

Location S. 1st St. and W. Cutting Blvd., Richmond, CA

Drainage Area 1.66 acres

Construction Completed September 2014

Total Design and Construction Cost $466,305

Description Bioretention with curb cuts

Number of Cells 4 unlined cells
Cells 1 & 2 - no underdrain
Cells 3 & 4 - underdrain

Media Type & Depth 18-inch media depth
Cells 1-3 = 60% sand, 40 % compost
Cell 4 = 75% soil mix, 25% biochar

Sizing Cells 3 & 4 =4% of impervious area
Cells 1 & 2 = less than 4% due to utility constraints

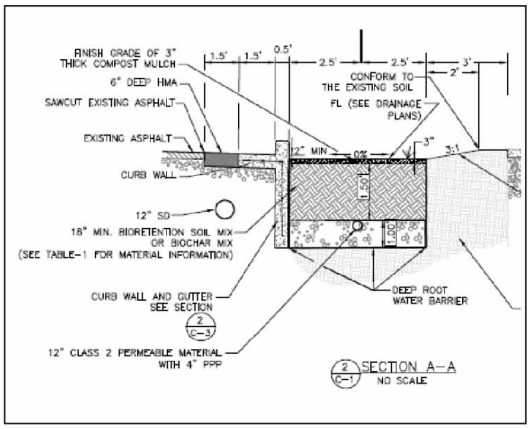
Ponding Depth 6 inches (based on design drawings)

Monitoring Locations Cell 1: influent only
Cell 2: visual observations only
Cells 3 & 4: influent and effluent

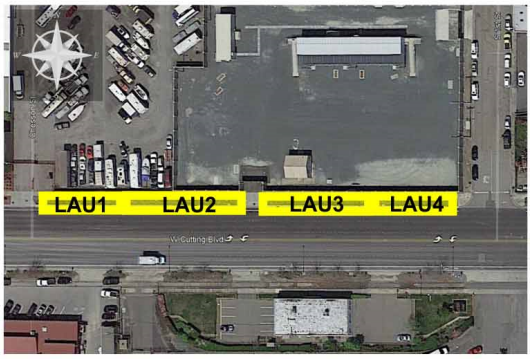
Monitored Dates 11/22/14, 12/02/14, 12/15/15, 02/06/15, 04/07/15, 04/25/15, 01/05/16, 01/13/16, 01/17/16

Influent Sampling Curb immediately upstream of cell

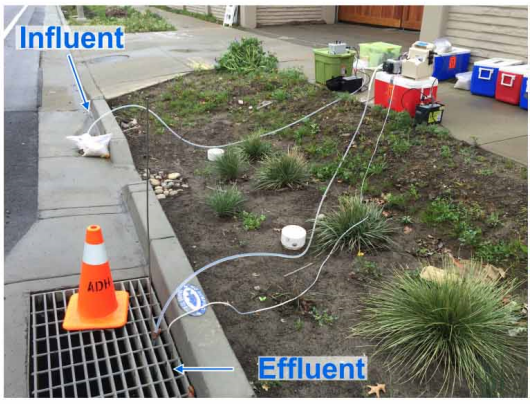
Effluent Sampling PVC pipes discharge flow from cell's underdrains into drop inlets



Design elevation view of bioretention cell with underdrain (LAU3 or LAU4)



Bioretention cells LAU1 through LAU4 on Cutting Boulevard in Richmond



Typical monitoring configuration for influent and effluent sampling of bioretention cell with underdrain (LAU3 or LAU4)

Table 3. Quality Control Issues with Methylmercury Samples at Locations Around Marsh Creek, Lake Alhambra, and Various Locations around Richmond, Including Cutting Boulevard – 2014-2018

Field/Lab Sample ID	Sampling Period	Issue Analysis
A33-201501141219-D1	Phase 1, Dry 1 (01/14/15)	RPDs for all analytes for field duplicate outside of acceptable limits.
		This is not an unexpected result for 1) field duplicates sampled sequentially, and 2) low concentrations in parent sample.
626078	Phase 1, Storm 1 (02/08/15)	SSC detected in laboratory blank at 3.2 mg/L.
		All field sample results in same analytical batch had levels of SSC over 10 times the blank result. The field results are acceptable.
M6-201502261250-D2	Phase 1, Dry 2 (02/26/15)	RPD for SSC for field duplicate for site M4 outside of acceptable limit.
		This is not an unexpected result for 1) field duplicates sampled sequentially, and 2) low concentration in parent sample.
637559	Phase 1, Storm 3 (04/25/15)	Percent recovery of this matrix spike sample was not calculated due to the high native concentration in the sample selected for MS/MSD vs. lab spike concentration.
		An LCS sample and another MS/MSD pair in the same analytical batch had acceptable levels of percent recovery, indicating the entire batch was in control. This result is acceptable.
615175	Phase 2, Storm 1 (11/22/14)	SSC detected in laboratory blank at 2.9 mg/L. (less than RL of 3.0).
		Field samples LAU3-I-SSC-02, LAU3-I-SSC-03, LAU3-E-SSC-01, LAU3-E-SSC-02, LAU3-E-SSC-03 results all less than 10 times the blank level detection. Results flagged as estimates.
S010587001/ LMC-201701080920-01 S010587002/ LMC-201701081220-02 S010587003/ LMC-201701081445-03	Phase 1, Storm 5 (01/08/17)	SSC analyzed out of holding time.
		In the three samples, SSC was analyzed from 1 to 5 hours over the holding time of 7 days. All results were more than 10 times the RL and, as such, were acceptable given the slight nature of the holding time overage.
K1700258-002/ CCC-CHS-154-SW	Phase 1, Storm 5 (01/08/17)	RPD for SSC for field duplicate for site CHS104 outside of acceptable limit.
		This is not an unexpected result for field duplicates sampled sequentially.
T030078002/LAU3-I-20180301-0840-000 T030078001/LAU3-E-20180301-0845-000 T030078004/LAU4-I-20180301-0820-000 T030078003/LAU4-E-20180301-0825-000	Phase 2, Storm 8 (03/01/18)	SSC analyzed out of holding time.
		In the four samples, SSC was analyzed from 1 to 5 hours over the holding time of 7 days. All results were more than 3 to 20 times the RL and, as such, were acceptable given the slight nature of the holding time overage.

LCS = low concentration standard
MS = matrix spike
MSD = matrix spike duplicate
RL = reporting limit
MRL = method reporting limit
RPD = replicate percent difference

This page intentionally blank

3. STUDY RESULTS

The results summarized in Appendix B show that the study objectives have been fulfilled, in that CCCWP developed sufficient monitoring data to resolve the key hypotheses of this study:

- H_0 (null hypothesis) – The variability of methylmercury concentrations in discharges from the Contra Costa County MS4 system is explained entirely by variability of SSC.
- H_A (alternate hypothesis) – The variability of methylmercury concentrations in discharges from the Contra Costa County MS4 system is explained by both variability of SSC and enhanced methylation efficiency found within areas with standing or slow-moving water.

The data supports the alternate hypothesis. Although SSC explains a substantial part (about 30 percent) of the variability in methylmercury concentrations, unique areas of enhanced methylation also play a role. Section 3.1 provides detailed analysis from Phase 1 of this study, the watershed characterization. Section 3.2 provides details of the results of the BMP effectiveness evaluation. Section 3.3 provides a quantitative analysis of the feasibility of achieving the 0.06 ng/L implementation goal for methylmercury in stormwater. Section 3.4 brings the study findings together to draw overall conclusions that inform the methylmercury control plan presented in Section 4.

3.1 Phase 1: Watershed Characterization

The watersheds monitored generally attained the 0.06 ng/L implementation goal during the dry season, and generally exceeded it during the wet season (Figure 9). By watershed, East Antioch Creek had an average dry weather methylmercury concentration of 0.10 ng/L, compared to the dry weather average of 0.03 ng/L in Marsh Creek (Table 4). East Antioch Creek had an average of 0.16 ng/L methylmercury in wet weather, compared to 0.30 ng/L in Marsh Creek and 0.19 ng/L in the western county urban watersheds of Richmond and San Pablo. As discussed in Section 1, Marsh Creek is the only one of those areas with a wasteload allocation based on the 0.06 ng/L TMDL implementation goal.

Based on the study conceptual model (Figure 3), this leads naturally to the question of whether the difference between dry and wet weather conditions is due to differences in SSC, differences in methylation efficiencies, or both. Figure 10 shows that methylation efficiency is somewhat higher during dry season monitoring (around 2.5 percent average methylmercury to total mercury ratio) compared to wet season (around 1 percent average methylmercury to total mercury ratio). Following the metrics of the conceptual model (Figure 3), both wet and dry season methylmercury total mercury ratios do not indicate unusually high methylation efficiencies.

Figure 9. Summary of Methylmercury Results for All Phase 1 Watersheds Assessed

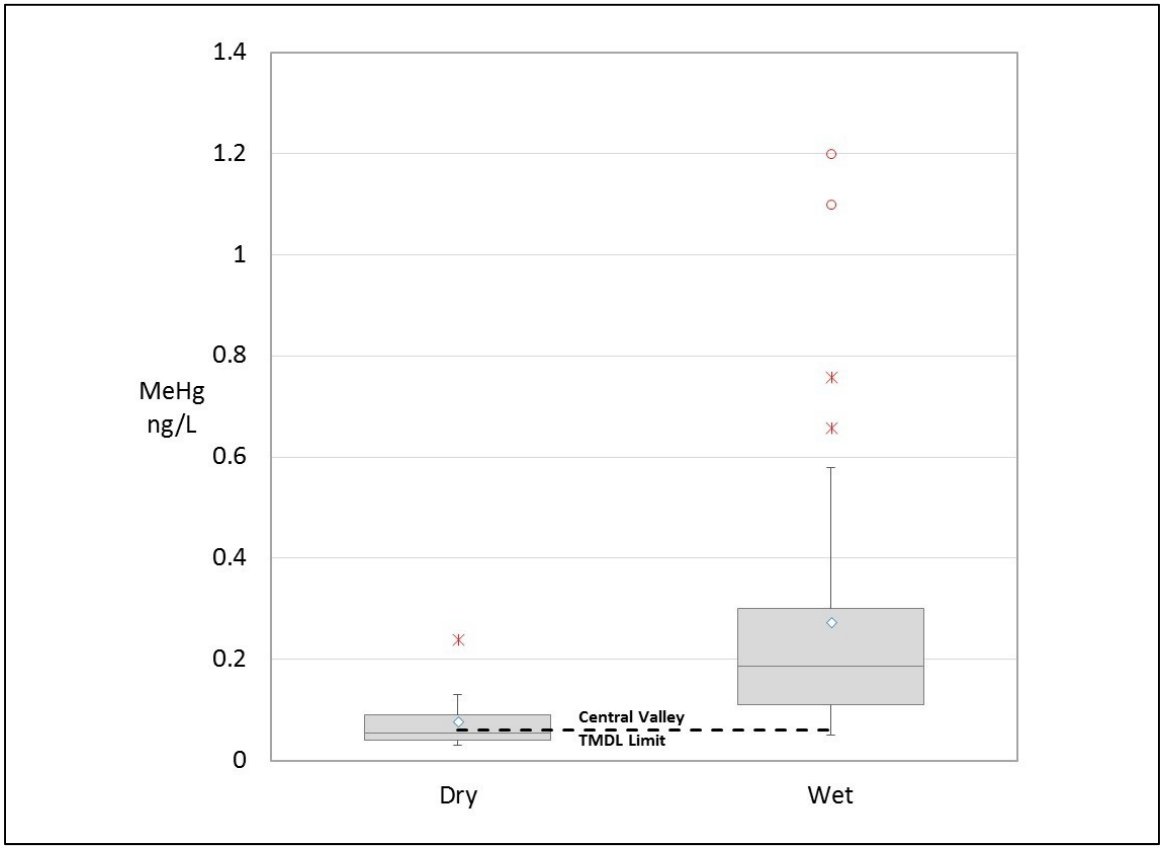
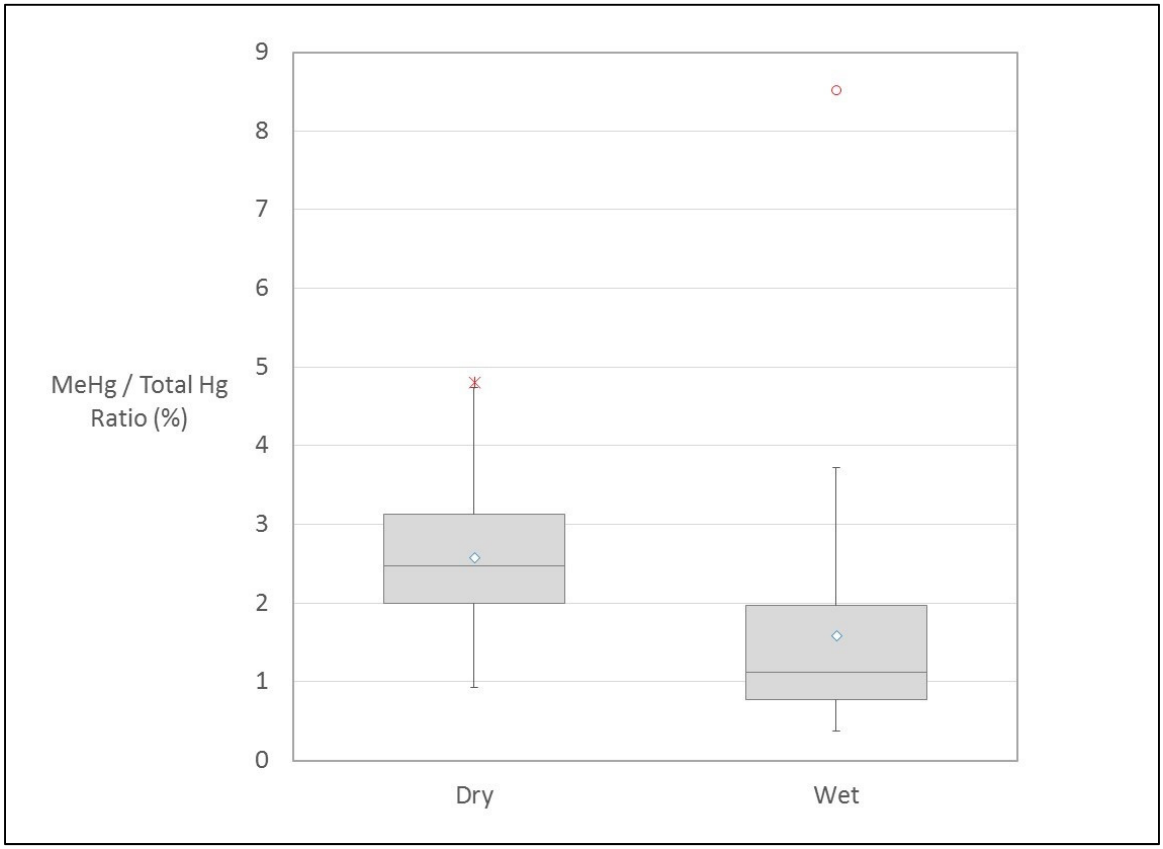


Table 4. Average Methylmercury Concentrations in Creeks and Urban Stormwater

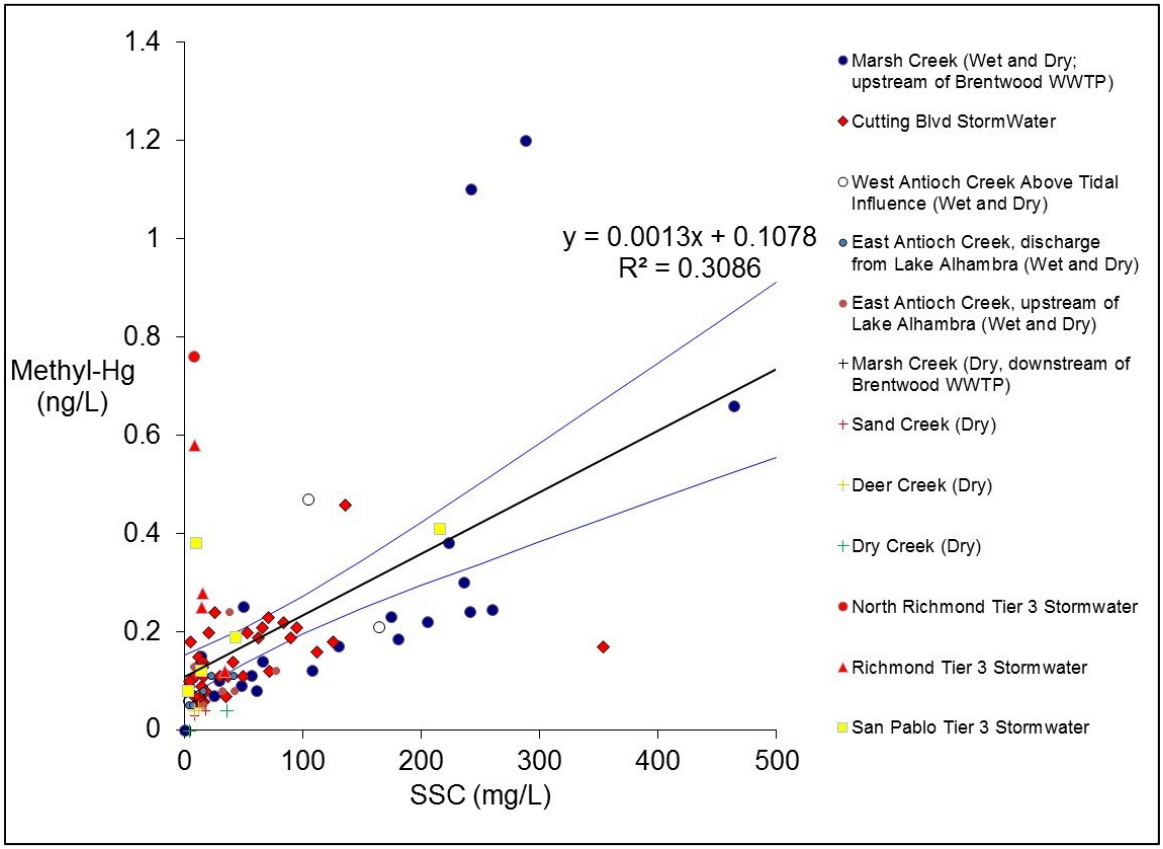
Location	Average Total MeHg (ng/L)	
	Wet	Dry
East and West Antioch Creeks	0.16	0.10
Marsh Creek	0.30	0.03
Richmond and San Pablo	0.19	NA

Figure 10. Summary of Methylmercury / Total Mercury Ratios (Percent Methylated) for Phase 1



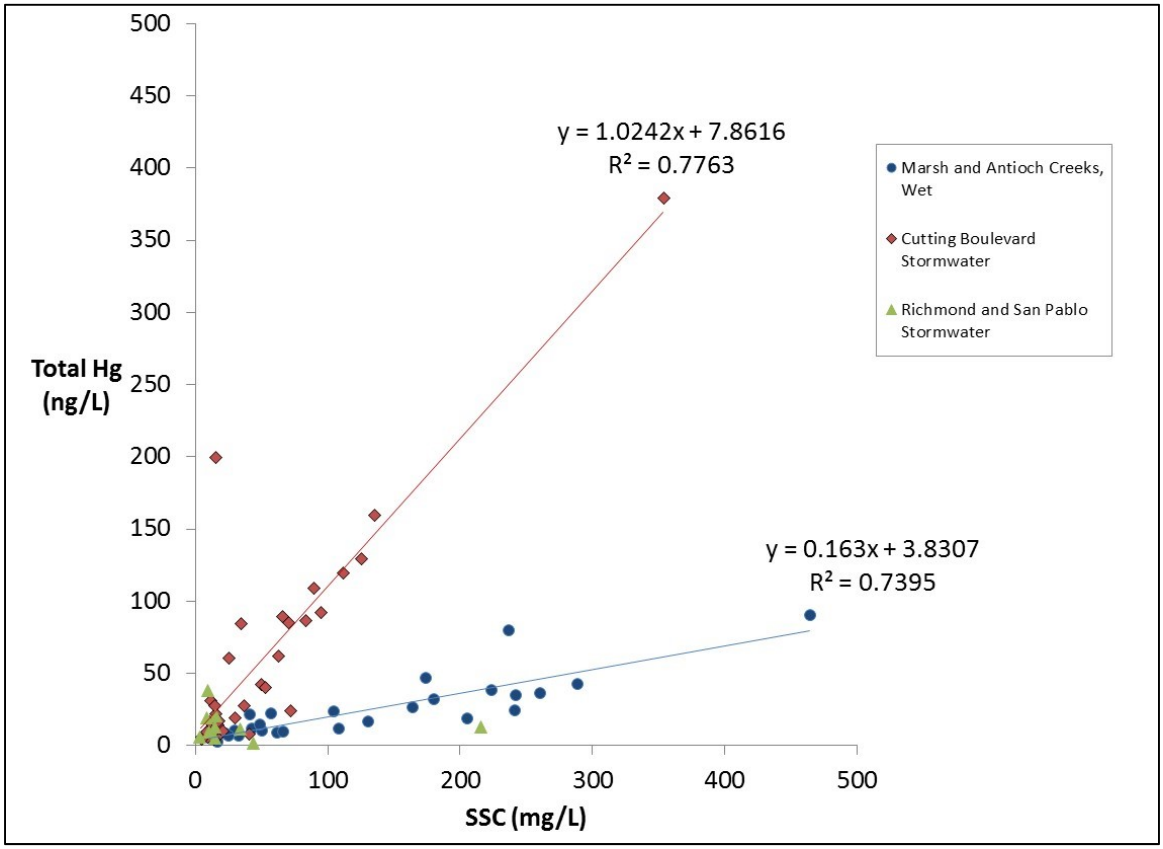
A scatter plot of methylmercury versus SSC from paired grab samples for both wet and dry season helps better understand what factors control methylmercury concentrations in urban stormwater and stream flows (Figure 11). Dry season samples have generally low SSC concentrations compared to wet season (Note: dry season data is clustered in lower left-hand corner of scatter plot in Figure 11). The data tend to fall about a regression line with a slope of 0.0013 ng methylmercury per mg SSC, which equates to about 1.3 ng/g. Again, following the metrics of the conceptual model (see Figure 3), 1.3 ng/g methylmercury in suspended sediments indicates a methylation efficiency that could be expected in any typical natural waters. There are, however, substantial outliers to the 95 percent confidence interval of the regression line that indicate areas of where methylmercury in sediments is unusually high given the SSC present. Following the conceptual model, the next question is whether those outliers result from elevated total mercury concentrations or elevated methylation efficiency.

Figure 11. Relationship Between Methylmercury in Water and Suspended Sediment Concentration



The relationship between total mercury and SSC helps estimate the total mercury concentration present in SSC (Figure 12). Samples from Marsh Creek and Antioch Creek have a slope of 0.163 ng total Hg per mg SSC, which equates to 0.163 micrograms per gram (µg/g). Again, following the metrics of the conceptual model, this indicates total mercury concentrations that would be expected in any normal, background Bay Area sediments. In contrast, the slope of the regression line for the influent samples at the BMP effectiveness evaluation along Cutting Boulevard in Richmond show a slope of 1.0 µg/g. This observation is consistent with prior measurements of total mercury in sediment samples collected from curbs, gutters and catch basins of the area (BASMAA, 2017). Stormwater samples from Richmond and San Pablo generally had lower SSC values and total mercury concentrations that fell more in line with the background conditions observed in Marsh Creek, East Antioch Creek, and West Antioch Creek. Thus, elevated total mercury only explains a few of the outliers above the regression line in Figure 11. The Cutting Boulevard stormwater samples having elevated total mercury in sediments include four samples above the 95 percent confidence interval of the regression in Figure 11. Other outliers, such as Marsh Creek, West Antioch Creek, and stormwater samples from Richmond, North Richmond, and San Pablo, are not explained by elevated total mercury concentrations in sediments.

Figure 12. Total Mercury vs. SSC as a Tool for Estimating Total Mercury in Suspended Sediment Concentrations



Although the outliers at West Antioch Creek, and stormwater samples from Richmond, North Richmond, and San Pablo are interesting, there is not enough temporal coverage to support a detailed analysis of what may cause enhanced methylation efficiency at those locations. Also, none of those locations are subject to the TMDL implementation goal of 0.06 ng/L. Marsh Creek, on the other hand, is subject to the TMDL implementation goal, and has a total of five monitored storms to provide a basis for comparison between storm events monitored.

As noted in Section 1.6, one of the questions of this study related to Marsh Creek is whether storm flows from the upper watershed carry sediments with elevated mercury or methylmercury. Table 5 shows that there is no statistically significant difference between the methylmercury to total mercury ratios found in suspended sediments collected from Marsh Creek when the Reservoir is flowing versus samples collected when it is not flowing. The only statistically significant difference observed was that the total mercury concentration of water is higher on average (44 ng/L) when the Reservoir is flowing compared to when it is not flowing (22 ng/L). Given the strong correlation shown in Figure 12 for the Marsh creek samples, and the close match between the total mercury to suspended sediments ratios from both sets, this indicates that the elevated total mercury concentration during periods when the Reservoir was flowing was caused by elevated SSC, likely caused by increased kinetic energy and therefore, transport of sediment, during periods of high flow.

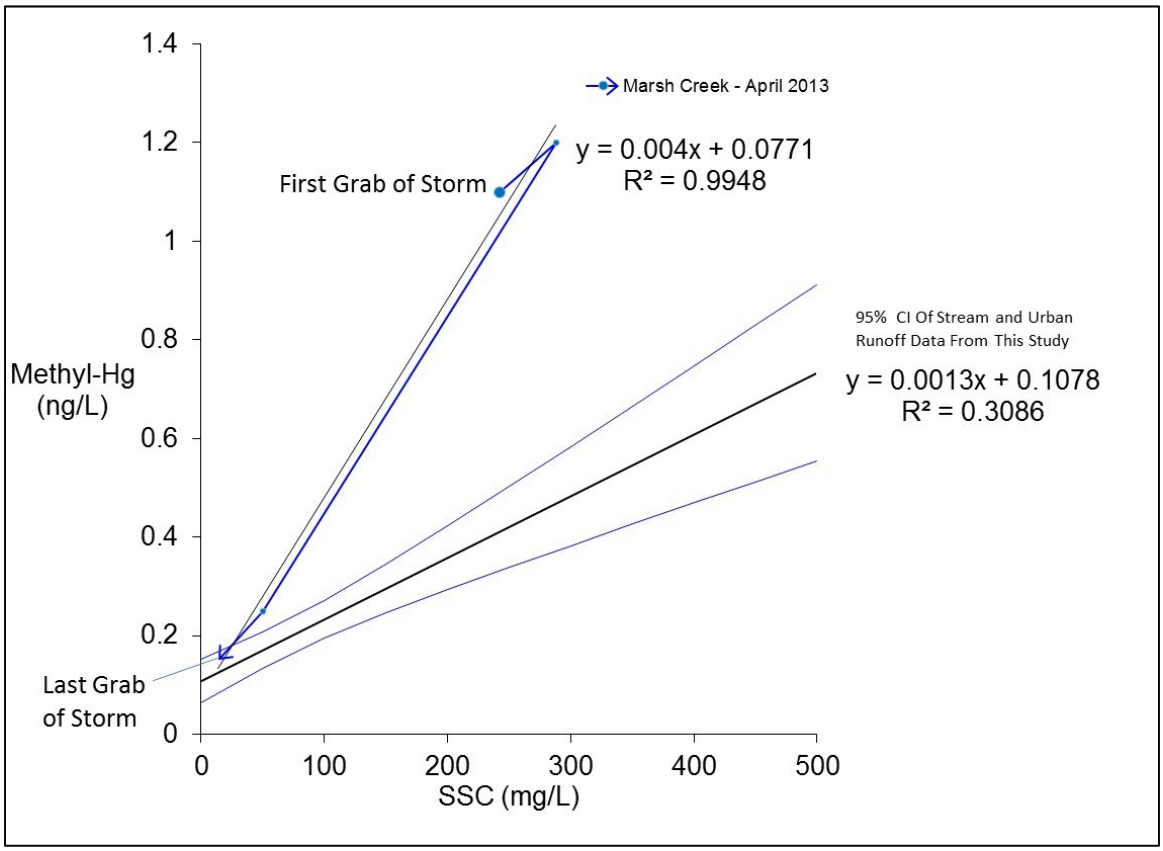
Table 5. Comparison of Percent Methylated, Total Mercury Ratios to SSC, and Methylmercury Ratios to SSC in Marsh Creek when Marsh Creek Reservoir (MAC) is Flowing vs. Not Flowing

	SSC (mg/L)	Total Hg (ng/L)	Total MeHg (ng/L)	MeHg to Hg Ratio (%)	THg/SSC (µ/g)	MeHg/SSC
MAC Flowing (n=6)	174 ± 161	**44 ± 35**	0.26 ± 0.21	0.7 ± 0.4	0.28 ± 0.09	1.7 ± 0.4
MAC Not Flowing (n=14)	147 ± 98	**22 ± 13**	0.32 ± 0.36	1.3 ± 0.8	0.21 ± 0.16	2.9 ± 2.7
P Value	0.64	**0.04**	0.68	0.07	0.35	0.29

Values in **Bold** indicate a statistically significant result (P Value ≤ 0.05)

The Marsh Creek outliers above the regression line in Figure 12 all occurred on the storm of April 4, 2013 (Figure 13). The timing of the sample grabs during that storm, with respect to the rise of the hydrograph and proximity to peak turbidity, was most similar to the timing of the grabs from the December 22, 2012 storm event, for which outliers were not observed (see Appendix C). This is an important point of comparison because it suggests that the elevated methylmercury to SSC ratio in the storm of April 4, 2013 is not due to the timing of the grab sample. With a peak flow of 80 cfs, the storm of April 4, 2013 was a small sized storm in comparison to other events sampled. The smallest events sampled had peaks flows of 40 cfs. Moderate sized events had peak flows from 180 to 500 cfs. Large events had peak flows exceeding 1,000 cfs.

Figure 13. Comparison of Methylmercury – SSC Relationships in Marsh Creek During Storm of 04/04/13 to all Other Stormwater Samples Analyzed in This Study



During the storm of April 4, 2013, methylmercury to total mercury ratios and methylmercury to SSC ratios were significantly higher compared to other storms (Table 6). Although the methylmercury to total mercury ratio of 2.4 percent does not indicate particularly high methylation efficiency, according to the metrics presented in Figure 3, the methylmercury to SSC ratio of 6 ng/g does suggest that the SSC in that storm was subject to moderately high methylation efficiency compared to other storms.

Table 6. Comparison of Percent Methylated, Total Mercury Ratios to SSC, and Methylmercury Ratios to SSC for the 04/04/13 Storm Event vs. All Other Storms Monitored

	SSC (mg/L)	Total Hg (ng/L)	MeHg (ng/L)	MeHg to Total Hg Ratio (%)	THg/SSC (µ/g)	MeHg/SSC
04/04/13 (n=4)	149 ± 137	**25** ± 17	0.68 ± 0.55	**2.4 ± 0.7**	0.30 ± 0.27	**6.1 ± 3.1**
All Other M2 Wet (n=16)	148 ± 121	**29** ± 27	0.21 ± 0.16	**0.9 ± 0.3**	0.22 ± 0.11	**1.7 ± 0.7**
P Value	0.90	**0.71**	0.01	**6.0E-07**	0.28	**2.1E-05**

Values in **Bold** indicate a statistically significant result (P Value ≤ 0.05)

The watershed assessment also sought evidence to determine whether Lake Alhambra, at the base of East Antioch Creek, is an area of increased methylation efficiency (Table 7). The data in Table 7 suggest that, during the dry season, there is not a significant difference in any of the parameters in East Antioch creek upstream of Lake Alhambra compared to downstream.

Table 7. Comparison of Methylmercury in Water and Percent Methylated Between Upstream vs. Downstream Locations at Lake Alhambra

	SSC (mg/L)	Total Hg (ng/L)	Total MeHg (ng/L)	MeHg to Hg Ratio (%)	THg/SSC (µ/g)	MeHg/SSC
Dry Season						
Upstream (n=3)	41 ± 35	8.5 ± 5.3	0.16 ± 0.07	2.7 ± 2.0	0.26 ± 0.09	8.3 ± 8.0
Downstream (n=3)	9 ± 6	2.2 ± 0.7	0.06 ± 0.02	2.8 ± 0.3	0.30 ± 0.17	8.2 ± 3.9
P Value	0.19	0.11	0.06	0.98	0.72	0.98
Wet Season						
Upstream (n=3)	30 ± 13	7.4 ± 4.6	**0.07 ± 0.02**	1.2 ± 0.5	**0.23 ± 0.05**	2.5 ± 0.6
Downstream (n=3)	24 ± 16	12 ± 8.8	**0.12 ± 0.01**	1.4 ± 0.9	**0.49 ± 0.09**	6.9 ± 5.4
P Value	0.66	0.47	**0.02**	0.74	**0.01**	0.24

Values in **Bold** indicate a statistically significant result (P Value ≤ 0.05)

In contrast, there is a statistically significant increase from upstream to downstream methylmercury concentrations during wet weather, and the difference appears to be driven by a statistically significant increase in the methylmercury to SSC ratio. There was not a statistically significant difference in SSC from upstream to downstream. East and West Antioch Creeks drain to the West Delta sub-area, which is not subject to the 0.06 ng/L implementation goal.

Key Points

- *Average dry and wet weather methylmercury concentrations were lower in Marsh Creek than East and West Antioch Creeks. Average wet weather methylmercury concentrations were lower in Marsh Creek than in Richmond and San Pablo.*
- *Methylmercury-total mercury ratios do not indicate high methylation efficiencies.*
- *Water from the Reservoir had elevated total mercury, likely caused by elevated SSC during periods of high flow rather than high mercury concentrations.*
- *There is evidence for increased methylation during late season storm events on Marsh Creek when algae blooms in check dam ponds are flushed during storm events.*
- *Lake Alhambra does not appear to be an area of increased methylation efficiency.*

3.2 Phase 2: BMP Effectiveness Evaluation

The BMP effectiveness evaluation revealed a surprising result. One of the two bioretention cells tested, identified as LAU3, showed substantial increases of methylmercury compared to influent concentrations (Figure 14). The differences were driven by statistically significant increases in the ratio of

methylmercury to total mercury, as well as the ratio of total mercury to SSC (Table 8). The combination of increased methylation efficiency and increased total mercury concentrations in particles of the effluent led to an astonishing increase in the methylmercury concentrations of SSC in the effluent, from 4.8 ng/g to 151 ng/g.

Figure 14. Effects of Treatment Via Bioretention on Methylmercury in Water in an Unusual Design

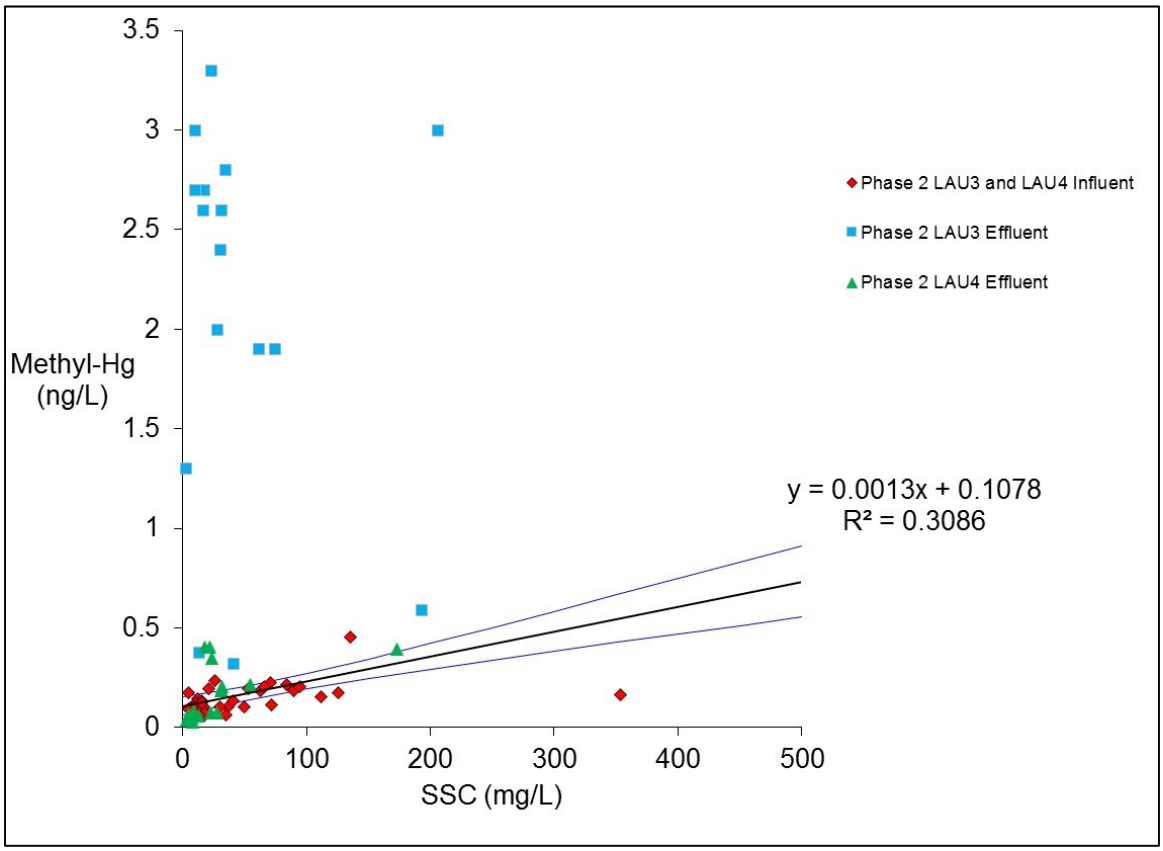


Table 8. Comparison of Bioretention Influent vs. Effluent Resulting from Two Unusual Designs

	SSC (mg/L)	Total Hg (ng/L)	Total MeHg (ng/L)	MeHg to Hg Ratio (%)	THg/SSC (µ/g)	MeHg/SSC
LAU3 Influent	68 ± 84	67 ± 93	**0.14 ± 0.05**	**0.5 ± 0.4**	**1.0 ± 0.6**	**4.3 ± 3.8**
LAU3 Effluent	49 ± 62	72 ± 89	**2.1 ± 1.0**	**4.3 ± 2.7**	**2.7 ± 2.4**	**122 ± 130**
P Value	0.48	0.89	**<0.001**	**<0.001**	**0.01**	**<0.001**
LAU4 Influent	36 ± 37	50 ± 56	0.16 ± 0.09	0.86 ± 0.83	1.8 ± 2.8	9.0 ± 9.8
LAU4 Effluent	57 ± 15	70 ± 23	0.22 ± 0.12	0.32 ± 0.27	1.5 ± 0.7	5.1 ± 6.3
P Value	0.07	0.21	0.93	0.10	0.85	0.70

Values in **Bold** indicate a statistically significant result (P Value ≤ 0.05)

Clearly, something is causing the media in LAU3 to be a strongly methylating area. Additionally, as shown Figure 12, the total mercury concentrations of SSC flowing into the bioretention cells at Cutting Boulevard are already elevated (around 1 µg/g) compared to Bay Area background conditions (0.1 to 0.3 µg/g). The increase of the total Hg to SSC ratio, from 1 µg/g in the influent to 3 µg/g after passing through the bioretention cell is perplexing. The outcomes are a clear demonstration of the potential risks of introducing mercury contaminated sediment to methylating areas.

The main feature of LAU3 that may explain its high methylation efficiency is the invert elevation, which is lower compared to LAU4. After construction, it was discovered that LAU3 was much more subject to tidal inundation compared to LAU4. The location at Cutting Blvd is very near sea level and, every two weeks or so, depending on the seasonal strength of the tides, peak tides can inundate the bioretention media in LAU3 from below. Tidal inundation was an unforeseen complication, but it could explain the elevated methylation efficiency by at least two mechanisms.

Bay water is salty, so sulfate would have been introduced to the bioretention media via tidal inundation. This could promote the growth of sulfate reducing bacteria, which are known to play a key role in mercury methylation (Compeau and Bartha, 1985). Also, wetting-drying cycles have been shown to increase methylation efficiency in tidal mudflats. The same process could be operant in LAU3.

Tidal inundation could also potentially explain the increase in the total mercury to SSC ratio. This may be an example of a situation where the ratio of mercury (or methylmercury) to SSC is not a perfect estimator of the particulate mercury or methylmercury concentration. Using the pollutant to SSC ratio to estimate particulate pollutant concentrations assumes that, in the sample analyzed, most of the pollutant is adsorbed on particles, instead of being in the dissolved phase. In the case of tidal inundation of LAU3, the inundation may have created anoxic conditions in the media that caused a sudden release of mercury and methylmercury when the system went from anoxic to oxic as stormwater flowed in. This is a known process in estuarine sediments (Mason et al., 2006) that could occur in the bioretention media for similar geochemical reasons.

The original intention was to compare the bioretention media between LAU3, which was a standard 60 percent sand and 40 percent compost mix, and LAU4, which had the standard mix augmented with 25 percent biochar. Biochar, a commercial form of activated carbon, has adsorption sites that may promote enhanced pollutant removal. Unfortunately, the influence of tidal inundation confounded the comparison between the different media types.

The methylation efficiency of LAU3 appeared to decrease over time (Figure 15). The highest methylmercury concentrations were noted in the first four storms monitored. There was not a consistent pattern across the storm hydrograph – one time the methylmercury concentration increased from the first grab to the last, three times it decreased, and once it went down and then back up again. The same pattern was observed for the methylmercury to total mercury ratio at LAU3 (Figure 16), although the ratio decreased substantially after the third storm (as compared to after the fourth storm for methylmercury concentrations). Both parameters increased again by the last storm monitored, although the increase was not to nearly the same levels as the first few storms.

Figure 15. Time Variability of Methylmercury Concentrations in Bioretention Effluent

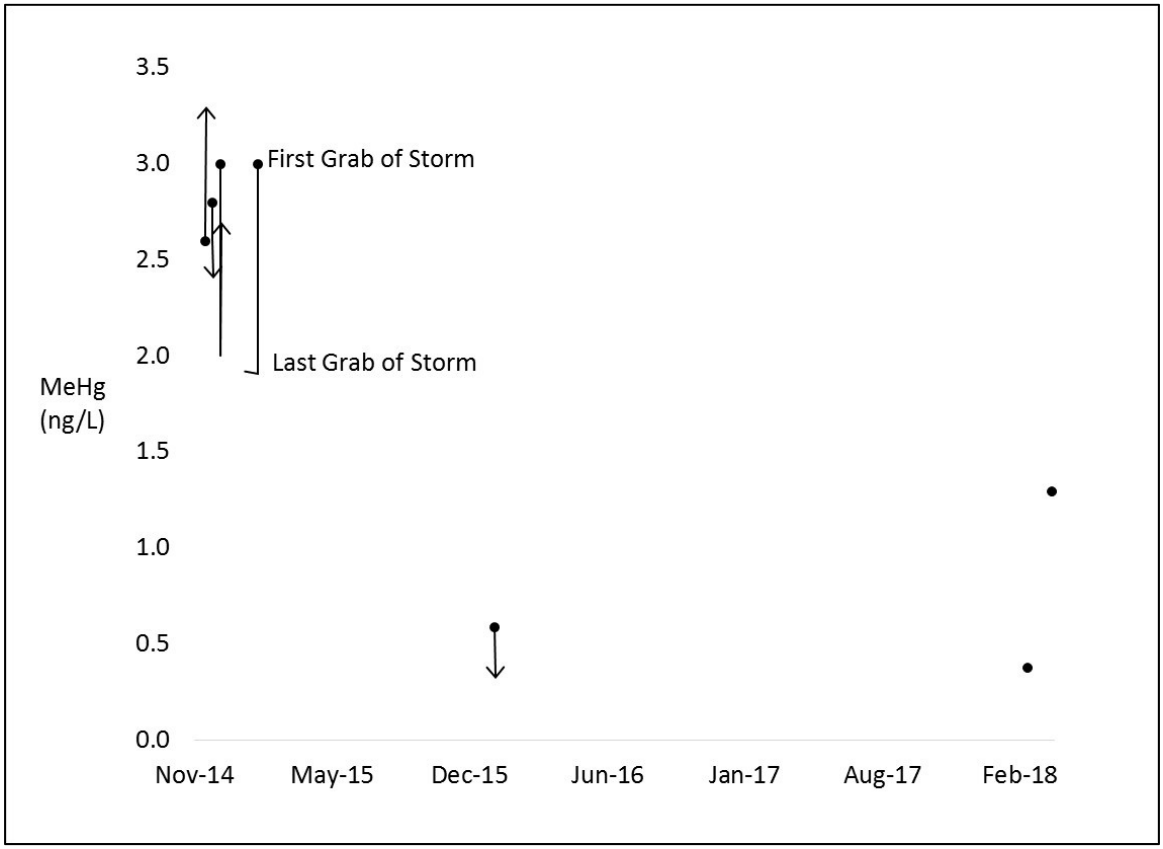
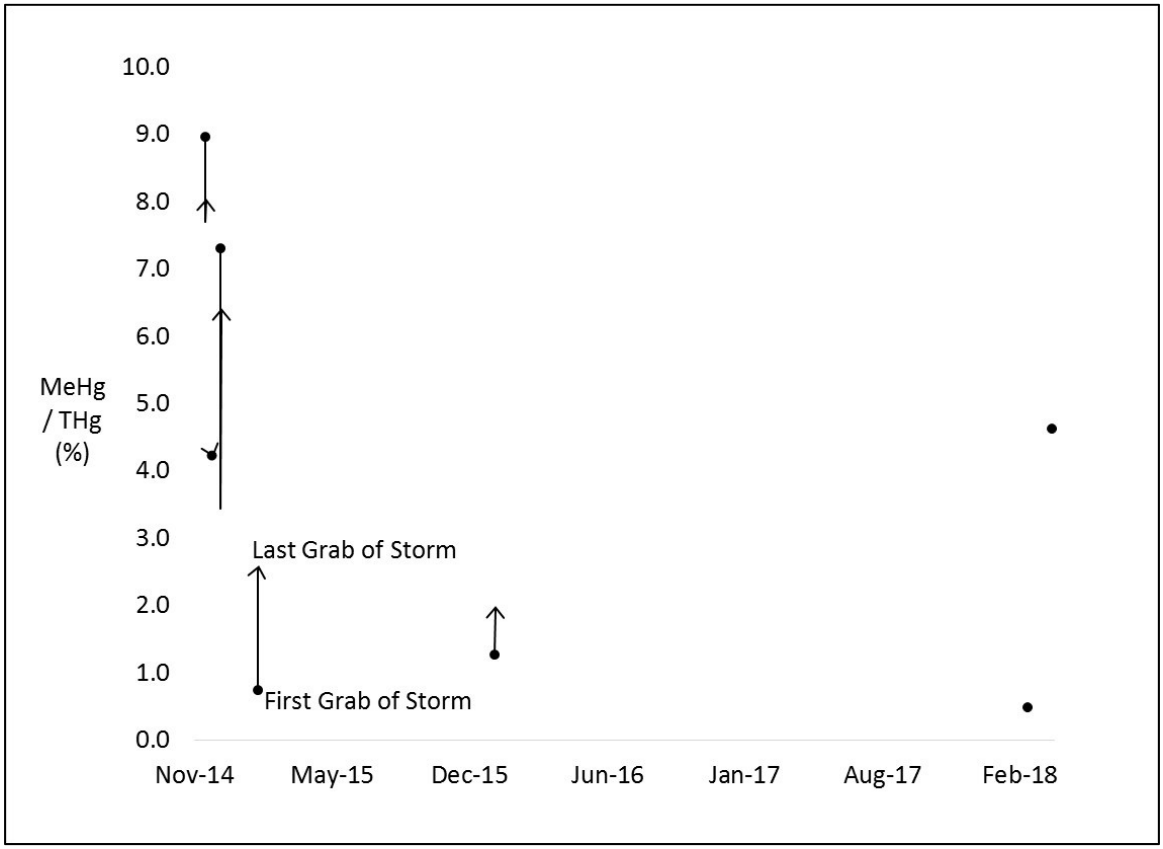


Figure 16. Time Variability of Methylmercury / Total Mercury Ratios in Bioretention Effluent



Key Points

- *The study was designed to compare bioretention media using standard mix and standard mix plus biochar.*
- *Bioretention cell LAU3 was strongly methylating, likely related to elevated total mercury in SSC and cyclical tidal inundation.*
- *The influence of tidal inundation confounded the comparison between media types.*

4. STUDY CONCLUSIONS

This study successfully fulfilled the requirements to complete a methylmercury control study. The study findings tend to support the alternate hypothesis: the variability of methylmercury concentrations in discharges from the Contra Costa County MS4 system is explained by both variability of SSC and enhanced methylation efficiency found within areas with standing or slow-moving water. About 30 percent of the variability in methylmercury concentrations results from SSC variability. The methylmercury to SSC ratio observed in this study was 1.3 ng/g, consistent with other Bay Area and national studies. This ratio establishes a floor that makes achieving the 0.06 ng/L implementation goal infeasible at most reasonable and foreseeable SSC concentrations in treated stormwater or natural streams.

This finding raises the question as to whether the observations cited in the Delta Methylmercury TMDL, that the Central and West Delta mostly achieve the TMDL implementation goal of 0.06 ng/L, simply reflects lower average SSC concentrations compared to other Delta sub-areas. The TMDL report is silent on this matter. During reevaluation of the TMDL, it is important to show an analysis similar to this study that differentiates between natural methylmercury variability caused by SSC and methylmercury increases associated with elevated methylmercury to SSC ratios and/or elevated methylmercury/total mercury ratios.

Section 4.1 explains the finding of infeasibility in more detail using quantitative analysis and conceptual logic. Section 4.2 describes the approach to refining the assessment of present day loads with respect to allocations, based on the new monitoring data in this study. Also in Section 4.2, the approach to estimating future achievable methylmercury load reductions is explained. Extant data gaps preclude meaningful improvements of the TMDL estimates or estimates of future load reductions at this time. Section 4.3 summarizes specific lessons learned from this study, including data gaps that inform the management actions and the monitoring and adaptive management strategy presented later in Section 5.

Key Points

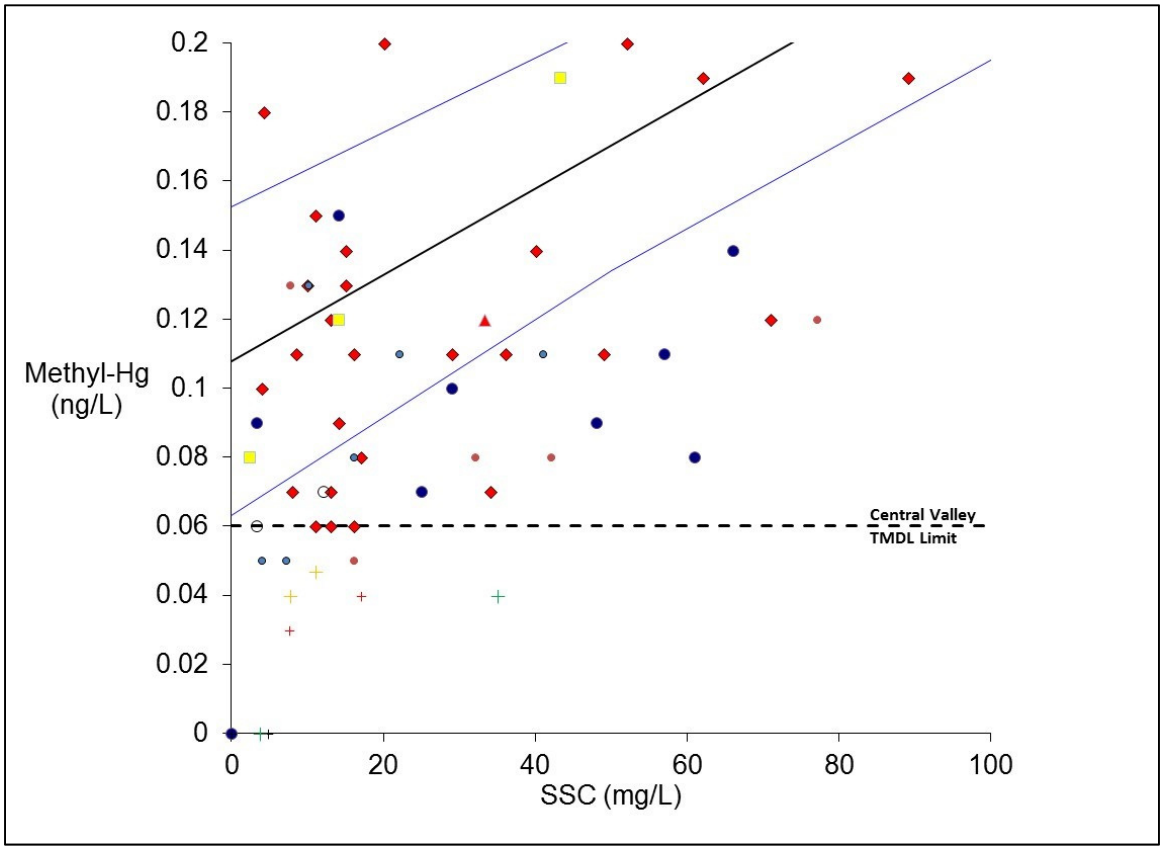
- *This study fulfilled the requirement to complete a methylmercury control study.*
- *Methylmercury variability in the Contra Costa County MS4 system is explained by SSC concentrations and enhanced methylation efficiency in areas with standing or slow-moving water.*
- *The methylmercury to SSC ratio of 1.3 ng/g was consistent with other Bay Area and national studies.*
- *It may be infeasible to meet the TMDL due to natural SSC concentrations in the Marsh Creek watershed.*

4.1 Infeasibility of Achieving Methylmercury Load Allocations for Marsh Creek or Wasteload Allocations for Stormwater Discharges in the Marsh Creek Sub-area

The infeasibility of ever achieving an annual average concentration of 0.06 ng/L in streams is demonstrated by this study data and substantiated by other studies. Figure 17 shows the same methylmercury versus SSC scatter plot for Phase 1 watershed data as Figure 12, only the scale is zoomed

to a maximum of 0.2 ng/L methylmercury and 100 mg/L SSC. The only samples with methylmercury concentrations below 0.06 ng/L are the ones with SSC concentrations below 40 mg/L, and most of the samples below 0.06 ng/L have SSC below 20 mg/L.

Figure 17. (Zoomed) Relationship Between Methylmercury in Water and Suspended Sediment Concentration



Note that the sample at the origin is Marsh Creek downstream of the Brentwood WTP during dry weather. At that time, non-detects were reported for both methylmercury and SSC. What is achievable in a stream that is mostly tertiary treated effluent, like lower Marsh Creek in dry weather, may not be achievable in natural streams or urban stormwater.

This "floor" established by SSC reflects the physical reality of the relationship between unfiltered methylmercury, SSC, and the methylmercury concentration of the suspended particles (see Figure 3):

Equation 1: MeHg (ng/L) = SSC (mg/L) x [MeHg/SSC ratio] (ng/g) / 1000 mg/g

Rearranging equation 1 to solve for SSC helps relate the 0.06 ng/L target to threshold SSC values based on the methylmercury to SSC ratio:

Equation 2: Threshold SSC (mg/L) = 0.06 ng/L / [MeHg/SSC ratio] (ng/g) x 1000 mg/g

Inspection of equation 2 reveals that a methylmercury concentration of 1 ng/g in SSC would lead to a threshold maximum of 60 mg/L SSC to attain 0.06 ng/L. Using the ratio of 1.3 ng/g from this study yields a threshold maximum of 46 mg/L SSC, consistent with the observations in Figure 17. It Is not reasonable or foreseeable to expect natural tributaries to the Delta to achieve SSC concentrations of 46 to 60 mg/L or less as a long-term average.

The estimate of 1.3 ng/g as a background concentration for methylmercury to SSC ratios in this study is consistent with a broader watershed assessment of 27 Bay Area watersheds (SFEI, 2016). The 10 watersheds with the lowest total mercury concentrations in suspended sediments (all less than 0.3 mg/kg total mercury) also had a median methylmercury to SSC ratio of 1.6 ng/g.

This study's estimate of 1.3 ng/g is a reasonable estimate for typical background methylmercury concentrations that could be expected in most United States watersheds, be they pristine or urbanized. In the conceptual model (see Section 1.4), Dr. David Krabbenhoft of the U.S. Geological Survey cited as evidence a national study supporting the assumption that 1 to 3 ng/g methylmercury in wetted soils and sediments is common in United States watersheds, and watersheds with elevated methylation efficiency typically have methylmercury in sediments exceeding 5 to 10 ng/g (Krabbenhoft, 1998).

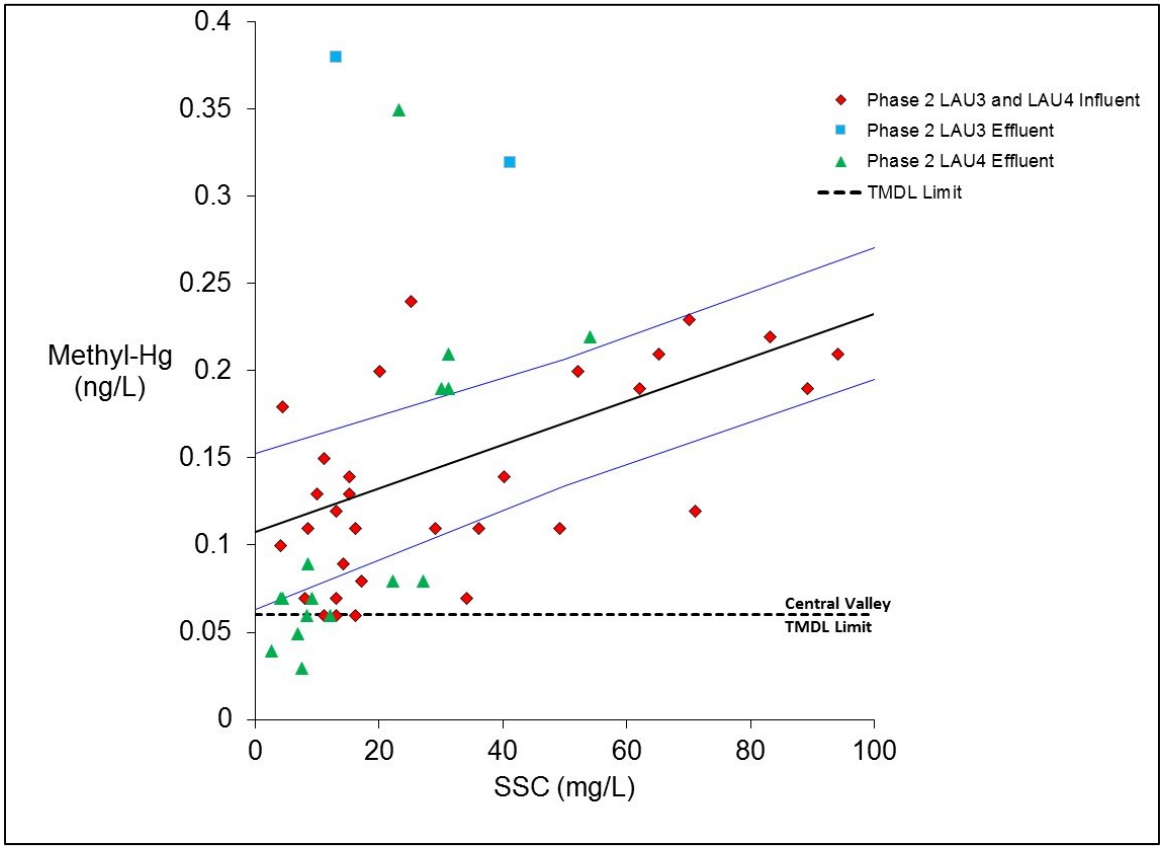
Dr. Krabbenhoft was part of the expert peer review panel for the Delta Methylmercury Control Study. These statements about infeasibility based on equation 2 and observed relationships between methylmercury and SSC were made in the Work Plan (CCCWP, 2013), which was peer reviewed by the expert peer review panel in 2013. The statements of infeasibility were repeated in the 2015 status report. At no point have the CVRWQCB staff or the peer reviewers questioned these assertions, nor have they countered the assumption that 1 to 3 ng/g methylmercury represents background.

The same observations hold true in the axis-zoomed plot of influent and effluent from the BMP effectiveness evaluations (Figure 18). The scale zooming essentially removes most of the anomalous LAU3 data and allows the eye to focus on LAU4 effluent data (the triangles). Again, the only samples in the data set achieving 0.06 ng/L unfiltered methylmercury had less than 20 mg/L SSC.

The discussion above partially addresses provision C.11.l.iii(2) of the permit requiring this study, by demonstrating the infeasibility of achieving the 0.06 ng/L implementation goal. The methylmercury allocation is the implementation goal multiplied by annual average flows. Demonstrating infeasibility of achieving the 0.06 ng/L implementation goal is one part of the infeasibility finding, the other part being limitations on volume reduction by infiltration.

Evaluation of the potential benefits of bioretention and infiltration helps complete the demonstration of infeasibility for achieving the wasteload allocations assigned to urban stormwater in the Marsh Creek sub-area. Referring to Table 3, the CVRWQCB assumption that urban stormwater has 0.24 ng/L methylmercury is reasonable for present day conditions. By equation 2, a methylmercury concentration of 0.24 corresponds to an SSC concentration of 185 mg/L. Using equation 1 and a methylmercury to SSC ratio of 1.3 ng/g, and if stormwater treatment by bioretention can reliably achieve average SSC concentrations of 50 mg/L, the average methylmercury concentration in stormwater treated by bioretention would be 0.065, very close to the implementation goal.

Figure 18. (Zoomed) Effects of Treatment Via Bioretention on Methylmercury in Water in an Unusual Design



Assuming stormwater treatment via bioretention can achieve methylmercury concentrations close to or even below the implementation goal, the time frame to achieve widespread stormwater treatment via green infrastructure is very long. Bioretention or other approved treatment is required of new development and redevelopment projects that exceed a certain size (regulated projects). Redevelopment will eventually bring treatment to developed private commercial, multifamily residential, and public parcels and rights-of-way. Because of the pace of redevelopment, it is not feasible to achieve such widespread stormwater treatment in the area prior to the year 2030. The fiscal resources for retrofit ahead of redevelopment are beyond the means of the community. Thus, the quantitative analysis of the results from this study and some basic common-sense reasoning about infiltration capacity support the argument that the assigned wasteload allocations are infeasible.

Key Points

- *Background methylmercury to SSC ratio in this study was estimated at 1.3 ng/g.*
- *National and local studies confirm 1 to 3 ng/g methylmercury background for wetted soils and sediments (analogous to SSC).*
- *The presence of background methylmercury concentrations in suspended sediments means that achieving the 0.06 ng/L in surface waters of the Marsh reek sub-area is infeasible, because it would require SSC concentrations 40 to 50 mg/L, which is not normal or natural for that any tributary of appreciable size during wet weather.*
- *Stormwater treatment may be able to achieve 0.06 ng/L by reducing SSC, but the number of acres that would need to be treated to meet TMDL wasteload allocations is still infeasible before the year 2030.*

4.2 Data Gaps and the Approach to Refining Present Day Load Estimates and Potential Future Load Reductions

There are several data gaps that preclude updates to the existing TMDL load estimates for the Marsh Creek subarea and potential methylmercury future load reductions. Permit language allowing a demonstration of infeasibility is accompanied by the expectation that East Count Permittees will communicate what load reductions are achievable and by when. To be responsive to the permit direction, this section outlines the approach to resolve data gaps, update present day load estimates, and predict potential future loads reductions that are reasonable and foreseeable. The approach will define some of the monitoring and adaptive management actions in the methylmercury control plan (see Section 5).

The approach to refining present day load estimates will begin by separating the analysis into wet and dry weather conditions. The TMDL assumes constant methylmercury concentrations of 0.24 ng/L are discharged from urban areas during wet and dry weather. The receiving water monitoring data from this study (see Table 5) shows average wet weather concentrations of 0.30 ng/L and dry weather concentrations of 0.03 ng/L, as measured at location M2 (see Figure 5) upstream of the Brentwood WTP.

Dry weather flow patterns are complex in Marsh Creek and will therefore require further thoughtful assessment and analysis. As noted in Section 1.6, East County Permittees have learned through the development of the Marsh Creek SSID study that intermittent dry weather flows upstream of the wastewater treatment plant create ponded habitat between check dams. Methylmercury formed in these ponds would only reach the Delta when dry weather flows are sufficiently high to push water out of the ponds into the reaches downstream of the treatment plant, as occurred during the storm of April 4, 2013 (a wet weather event).

In the case of dry weather flows from ponded areas of Marsh Creek, the flows mix with the generally larger flows from the Brentwood WTP before they reach the Delta. Flows from the Brentwood WTP have very low methylmercury concentrations, resulting in dry weather flows attaining the 0.06 ng/L implementation goal before reaching the Delta. The two dry weather samples from M1, downstream of

the treatment plant, validate this for the period collected. The dry weather samples were collected in January and February of 2015, at a time of year when algal abundance in the ponded areas of intermittent flows is visibly much lower compared to the April through September time frame. A data gap that will be addressed through monitoring will be to monitor downstream of the Brentwood WTP during the algal bloom season of April through September at times of no dry weather flows upstream of the treatment plant, and compare to times when there is upstream dry weather flow, to determine if there are instances during dry weather when flows exceeding the implementation goal reach the Delta or cause significant increases in the methylmercury concentration compared to baseline periods with no dry weather flow.

Marsh Creek wet weather flows and loads are also complex for several reasons. The loads monitoring point at M2 (see Figure 5) represents comingled runoff from urban areas and agricultural areas in the Marsh Creek watershed, as well as atmospheric wet deposition. It also includes runoff from open spaces and undeveloped areas that at times flow from tributaries upstream of the legal Delta boundary into Marsh Creek and its tributaries. The "at times" qualifier acknowledges the presence of detention basins upstream of every tributary draining into Marsh Creek (see Figure 4), in addition to the Marsh Creek reservoir. The basins shave peak flows and in smaller storms stop upper watershed flow altogether, as in the case of Marsh Creek Reservoir. These detention basins also likely affect water quality by reducing SSC.

To address these complexities, the next steps will be to focus on parsing the loads from urban areas. This is necessary to distinguish them from the upstream contributions of tributaries outside the Delta legal boundary, agricultural runoff, and atmospheric deposition. Updated catchment delineation, hydrologic modeling, and some additional assessment of urban runoff are necessary to better quantify urban loads of methylmercury in relation to TMDL wasteload allocations.

Updated catchment delineation is necessary because the TMDL analysis is based on land use layers from 1990. The lands of Marsh Creek watershed have experienced tremendous development since 1990. Much of that development was subject to the requirements of Provision C.3 of the MRP or its predecessors in previous permits. Thus, much of the acreage that was deemed non-urban land use in the TMDL has been developed. A subset of those lands developed since 1990 are already designed to treat urban stormwater to the standards in effect at the time of development.

The drainage configuration may have changed during development over the past 28 years. Figure 19 shows the outline of the Marsh Creek sub-area clipped to a map of East County Permittee's jurisdictions. If that Marsh Creek sub-area outline in Figure 19 represents the delineations and assumptions of the TMDL, it will need to be updated. The bold black line in the figure illustrates the 2006 boundary of the Marsh Creek watershed. Unincorporated County lands east of the contemporary Marsh Creek watershed boundary that lie inside the yellow outline of the TMDL-defined Marsh Creek sub-area are predominantly agricultural. If those lands were included in the original TMDL analysis as part of the Marsh Creek sub-area, the effect of updating the drainage delineation would be to shift most of the agricultural runoff load allocation over to the West Delta or Central Delta sub-areas. This would significantly change the overall assessment of the current Marsh Creek sub-area load and the resulting

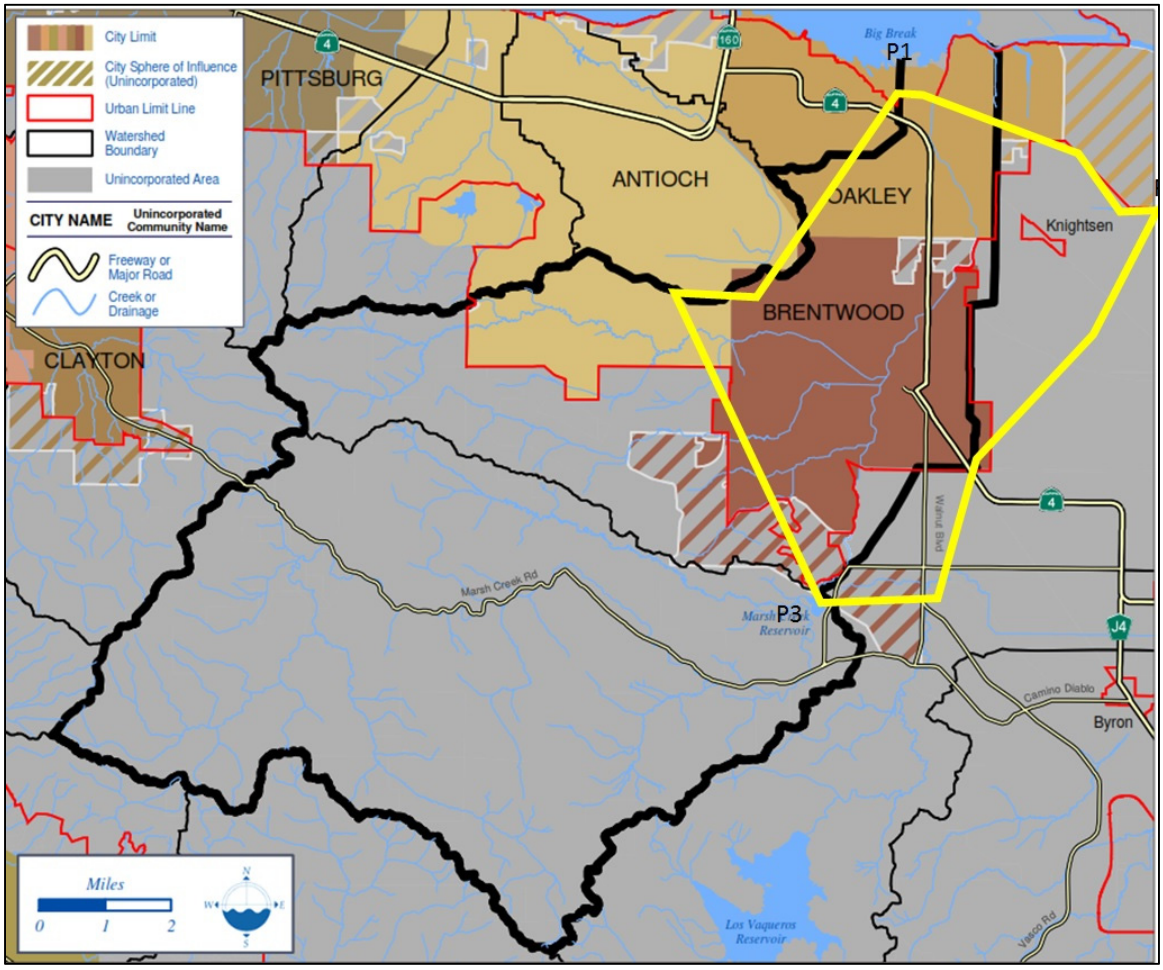
calculations of assimilative capacity and the load reductions needed from the Marsh Creek sub-area. Updating the catchment delineation is effort that would be undertaken by CCCWP and East County Permittees. The outputs of that effort would help CVRWQCB staff when they choose to review and update the TMDL.

Updated drainage delineation and land use layers will support hydrologic modeling to obtain more representative volumes of runoff from urban and other land use areas within the watershed. Modeling is needed to translate the concentration data obtained from monitoring to methylmercury loads. A translation to accurate contemporary loads is needed to establish a baseline for responding to the question, "what load reductions are possible?"

The modeling approach also needs to have the capability to assess how developed lands not subject to C.3 requirements at the time of development may change as green infrastructure retrofits are implemented. This transformation would occur either through redevelopment (on very long-time scales) or through green infrastructure retrofits in high priority areas identified through implementation of a green infrastructure plan (still long timescales, but possibly shorter than waiting out redevelopment).

A combination of hydrologic and water quality modeling will also help refine the understanding of Marsh Creek methylmercury loads to the Delta. The approach would be to first analyze the relationship of turbidity to SSC, so that continuous turbidity records developed while CCCWP monitored Marsh Creek from 2012 to 2014 in compliance with MRP and East County Permit requirements can be used to develop estimates of the continuous SSC over the monitoring period. This would enable a water quality model that assumes methylmercury concentrations based on the stage of the hydrograph – rising, falling, or base flow. The refined hydrologic and water quality model would yield an improved estimate of the Marsh Creek watershed methylmercury load, and how that load varies according to hydrologic conditions. From the perspective of the East County Permittees responsible for methylmercury control measures, the benefit is contextualizing the urban runoff methylmercury loads and setting realistic expectations for the future loads expected from the Marsh Creek watershed.

Figure 19. Superposition of Marsh Creek Sub-Area Outline on Jurisdictional Map of the East County Permittees



Yellow outline indicates Marsh Creek sub-area traced from Figure 2. P1 and P3 indicate geographic reference points used to clip the outline to the jurisdictional map. Jurisdictional map from the Contra Costa County Watershed Atlas (Contra Costa County Community Development Department, 2006)

The modeling would also need to account for the potential influence of late spring pulses of water with elevated methylmercury, as seen in the identification of the anomalous storm event highlighted in Figure 13. What sets the storm of April 4, 2013 apart from all others monitored is that it occurred the latest in the monitoring season. All five of the storms monitored had sufficient antecedent rainfall in the two weeks prior to the events, such that the ponds between check dams in the reaches of Marsh Creek above the Brentwood WTP would all have been full or nearly full. The storm of April 4, 2013 occurred at a time in the spring when algae blooms begin in that reach of the creek. A possible explanation for the elevated methylmercury in suspended sediments during the storm of April 4, 2013 may be increased mercury methylation efficiency in the ponds between check dams because of increased microbiological activity, followed by a flushing during the onset of the storm. The implications of this are discussed further in the conclusions section (Section 3.3).

Before going too far with modeling the effect of methylmercury in late spring storms, it would be necessary to confirm that the single anomalous storm event in April of 2013 is indeed a consistent,

recurring late-spring phenomenon. Practically, this means capturing at least two more such late-spring events. Similarly, although the monitoring results from the two storms where upper watershed flows were captured are reassuring, it would be helpful to confirm by capturing a third storm. If the inferred watershed functions – late spring pulses of methylmercury, but no significant increase of methylmercury to SSC ratios during upper watershed flow – are confirmed over three storm events, there would be sufficient confidence to include those processes in modeling. The benefit of doing so would be to answer the questions:

- If management actions could reduce low dissolved oxygen and associated increased methylation in Marsh Creek during late spring, what would be the methylmercury load reduction benefit?
- What is the true long-term tributary load allocation that should be assigned to Marsh Creek above the Reservoir, accounting for intermittent flow and the relationship between flow and methylmercury concentrations and loads?

In summary, there are substantial, but resolvable, data gaps that preclude a meaningful comparison of real-world methylmercury loads to TMDL assumptions. The data gaps are well outside the scope of the original methylmercury control plan, and some of them (e.g., late spring methylmercury pulses) could not have been foreseen and still need to be validated. For these reasons, at this time, to submit a methylmercury control study final report timely and move forward with important implementation planning, the question of what methylmercury load reductions are achievable is answered with an approach rather than a numeric expression of current and potential future loads.

Key Points

- *Data gaps preclude updating TMDL load estimates and predicting future load reductions:*
  - *Checking the repeatability of the April 2013 pulse of elevated methylmercury in Marsh Creek*
  - *Evaluating potential source areas of methylmercury with slow or stagnant water*
  - *Parsing loads from urban areas by catchment delineation updates*
  - *Hydrologic modeling*

4.3 Lessons Learned that Inform Actions, Monitoring, and Adaptive Management

The BMP effectiveness evaluation yielded one surprise, in that one of the BMPs evaluated increased methylmercury. This is the nature of applied research. The lesson learned that bioretention near sea level is problematic adds value to long-term planning for green infrastructure implementation. For future modeling purposes, it would be best to assume methylmercury load reductions occur only via infiltration. For modeling treatment via bioretention with an underdrain, the recommended assumption is that treatment neither increases nor decreases methylmercury. The basis for this assumption is that designs which increase methylmercury, like the one in this study, would be avoided. The insight that bioretention at sea level may be problematic is intriguing in combination with the delineation of the Marsh Creek sub-area “above the zone of tidal influence.” It means that, when developing a Green infrastructure plan, the City of Oakley could consider guidance to avoid bioretention where bioretention

media may be tidally inundated. It also may lead the City of Oakley to prioritize green infrastructure projects above the zone of tidal influence.

The watershed characterization was successful on several fronts. First, the study showed the monitoring tools deployed are appropriate to identifying source areas for total mercury and methylmercury. Applying the tools at Alhambra Lake (East Antioch Creek) showed no sign that the artificial lake is a methylating environment. This was an important due diligence step. No further methylmercury assessments are recommended in the Antioch drainages, because the West Delta sub-area does not include methylmercury wasteload allocations for urban stormwater below current loads discharged. The evidence for this is that the average methylmercury concentrations measure in East and West Antioch Creeks are below the 0.24 ng/L methylmercury concentration assumed for establishing the wasteload allocations. This outcome is beneficial to any future efforts on the part of the CVRWQCB to review and update the TMDL, which noted no methylmercury load estimates were made for the Antioch drainage owing to a lack of monitoring data.

Second, the watershed characterization showed, for the large storms sampled in Marsh Creek, there was no evidence for elevated total mercury to SSC ratios or methylmercury to SSC ratios. It is difficult to prove a negative and, unlike East and West Antioch Creek, Marsh Creek does have a wasteload allocation for urban runoff that is well below current loads. Thus, it may be necessary to revisit the question of flows and loads from the upper watershed at some point in the future. As the question really relates to the Mount Diablo Mercury Mine, located upstream of Marsh Creek Reservoir, it may make more sense to focus future assessments on the mine site itself, and its tributary drainage Dunn Creek. Before scoping any such study, a next step in this matter would be to review progress of the remedial investigation and any associated monitoring. This is not considered to be a high priority for the near term, based on the reassuring results from this study. At a minimum, at least one more upper watershed flow event would be sampled in the future, so the assessment of upper watershed flows is based on a total of three storms.

Following up on the observation of increased methylation efficiency in Marsh Creek prior to the storm of April 4, 2013 is a high priority for future monitoring and assessment. It is only one storm and it took four others to provide enough context to identify that event as anomalous. We have not established a definitive link to known conditions of algae blooms and low dissolved oxygen present in the reach of ponded intermittent flow upstream of the Brentwood WTP. We have not even demonstrated that the observations of April 4, 2013 are repeatable.

The observations of April 4, 2013 do make sense, in context. Because of the existing SSID study in Marsh Creek, CCCWP is already actively monitoring dissolved oxygen in Marsh Creek and assessing potential causes of low dissolved oxygen. Some additional monitoring is warranted to better understand how ponded water in Marsh Creek under low flow conditions affects methylmercury loads transported downstream to the Delta, especially during late season storms, when algae blooms increase. This monitoring can be coordinated with the SSID project and other CCCWP monitoring requirements to achieve efficiencies. Beyond monitoring, it is difficult to forecast what implementation actions would be

taken in the matter of ponded water in Marsh Creek, because the outcomes of the SSID study are unknown at present.

In conclusion, the study was an overall success in characterizing watershed processes that affect methylmercury in urban drainages of Contra Costa County. Suspended sediment concentration is an important parameter, controlling about 30 percent of the variability in methylmercury concentrations in urban stormwater. Because of the controlling effect of suspended sediments, it is infeasible to expect all urban stormwater to achieve 0.06 ng/L methylmercury as a long-term average.

Consequently, volume reduction via infiltration is the surest pathway to making progress toward methylmercury wasteload allocations. Regardless of whether the method of treatment is bioretention with an underdrain to reduce sediment, or bioretention with a raised underdrain to promote infiltration, or other types of filtration and infiltration BMPS, widespread application of such measures across the urban landscape of East County urbanized areas is daunting from a planning and fiscal perspective. In the next section, the plan and schedule for developing green infrastructure in East County communities is described, along with other control measures and recommended monitoring strategy.

Key Points

- *This study successfully characterized watershed processes controlling methylmercury concentrations.*
- *SSC concentrations account for about 30 percent of methylmercury variability, making attainment of the 0.06 ng/L implementation goal infeasible.*
- *Stormwater volume reduction is the most reasonable path for load reductions.*
- *Bioretention BMPs should be planned in areas above the zone of tidal influence.*
- *Assume load reductions are only from infiltration in bioretention BMPs.*
- *No further methylmercury assessments are recommended for Antioch drainages.*
- *Future studies should be designed to examine the observation of increased methylation efficiency in Marsh Creek.*

This page intentionally blank

5. METHYLMERCURY CONTROL PLAN

This section describes the East County Permittees' plan and schedule for reducing methylmercury loads. Total mercury source control measures are described in Section 5.1. Volume reduction via green infrastructure is described in Section 5.2; this section also describes the process and time frame to determine what load reductions are achievable. The evaluation of low dissolved oxygen and potential linkages to methylmercury in Marsh Creek is described in Section 5.3. The monitoring and adaptive management plan is described in Section 5.4. The Permittee's commitment to continue methylmercury exposure reduction through communication and outreach is expressed in Section 5.5. Section 5.6 briefly summarizes the limited information available on costs, effectiveness, potential environmental effects, and feasibility of methylmercury control measures. An overall schedule of actions for the plan is presented in Section 6.

5.1 Total Mercury Source Control

The study has not identified any specific new opportunities for controlling total mercury sources to the municipal separate storm sewer system, other than suspended sediment reduction by green infrastructure. Existing total mercury source control BMPs performed by Permittees in compliance with their permit and other requirements will continue. These activities include business inspections and operation of household hazardous waste facilities to promote proper collection of mercury-containing products, such as fluorescent lights, batteries, and other electrical devices. The household hazardous waste program includes multi-lingual communication to reach the widest possible audience (Figure 20).

East County Permittees are aware the CVRWQCB staff desire assurance that erosion and sediment control BMPs are expected at construction sites. This activity reduces methylmercury by reducing sediments in stormwater. East County Permittees have a robust program of construction site inspection, including legal authority for effective site management and enforcement response plans, as required under the extant East County Permit (order No. R5-2010-0102). Identical language in the MRP assures CVRWQCB that East County Permittees will continue to inspect and enforce construction sites and summarize activities in their annual report. Other sediment control activities that will continue include street sweeping, catch basin cleanouts, and desilting of detention basins.

Contra Costa County will continue to monitor and track progress on remediation of the Mount Diablo Mercury Mine. The County has been engaged with the CVRWQCB on this matter (e.g., by providing written comments in support of regulatory actions by the CVRWQCB to hold legacy responsible parties accountable for the cost of remediation). While this is an important watershed management action overall, it relates more to the health of Marsh Creek Reservoir and Marsh Creek between the mine and the Reservoir, if the past two upper watershed flow events are representative of upper watershed flows in general.

Figure 20. Excerpts from Delta Household Hazardous Waste Collection Brochures in English and Spanish

Key Points

- *Ongoing source control activities include pollution prevention, erosion and sediment control, maintenance of catch basins and detention basins, and further scrutiny of Mount Diablo Mercury Mine.*

5.2 Runoff Volume and Methylmercury Load Reduction via Green Infrastructure

In the long term, development and implementation of green infrastructure plans is likely the most effective pathway to reducing pollutants, including methylmercury, from urban stormwater discharges. East County Permittees, when they switch over to coverage under the SFRWQCB's MRP, will be required through Provision C.3.j to develop green infrastructure plans for their respective jurisdictions. Obviously, the first procedural step is for SFRWQCB to amend the MRP to name East County Permittees.

The first step for Permittees in development of green infrastructure plans is adoption of a framework, which is a work plan describing specific tasks and timeframes for development of green infrastructure.

The work plan must be approved by the governing body for each Permittee. Unincorporated Contra Costa County has already approved its work plan because of existing coverage under the MRP. The cities of Oakley, Antioch, and Brentwood will need time to prepare their work plans and have them approved by their respective city councils. The tentative due date for that, in discussions with both SFRWCQB and CVRWQCB staff, is December 31, 2019.

The next step is development of the green infrastructure plan itself. The green infrastructure plan is required to provide a mechanism for prioritizing areas for green infrastructure, targets for impervious surface to be retrofitted, and time schedules for implementation. The plans are required to include a process for mapping and tracking completed projects. Additional details on the requirements of MRP Provision C.3.j that will drive this methylmercury control action are shown in Appendix D.

The CVRWQCB stipulates that a finding of infeasibility for achieving methylmercury wasteload allocations is to be accompanied by a statement of what load reductions are achievable. As noted in Section 4.2, there is not sufficient information to quantify what load reductions are achievable and by when. The process for answering that question for a complex pollutant in a large TMDL watershed is known as a Reasonable Assurance Analysis (RAA). The MRP requires an RAA of all Permittees through provisions C.11 and C.12, which address TMDLs for mercury and PCBs in San Francisco Bay.

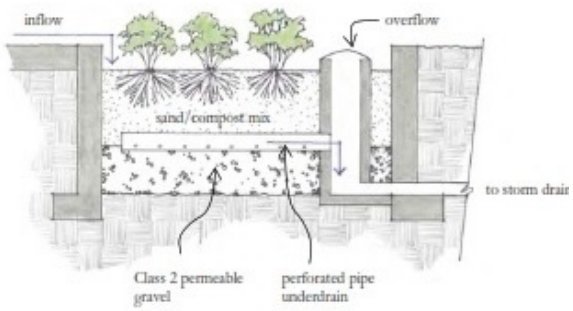
CCCWP is conducting an RAA as a countywide project on behalf of all other Permittees. The geographic scope of the RAA includes East County. However, the output of the RAA relevant to the Delta Methylmercury TMDL is limited to hydrology modeling. Water quality modeling of methylmercury is outside the scope of the existing RAA project. Some additional moderate level of effort will be needed to adapt RAA modeling tools to methylmercury in the Marsh Creek watershed. As water noted above in Section 4.2, the water quality modeling could include new insights about late spring pulses of methylmercury if the April 2013 event proves to be representative.

Green infrastructure will achieve volume reduction through infiltration and SSC reduction through treatment by filtration of water through the soil media. The CCCCWP's C.3 guidebook includes many applications for developers to consider. Bioretention is often chosen for residential and commercial developments and redevelopment projects (Figure 21). For green streets projects, parking areas, and other similarly constrained areas, porous pavement and self-retaining areas are examples of tools for infiltrating stormwater to reduce runoff volumes (Figure 22).

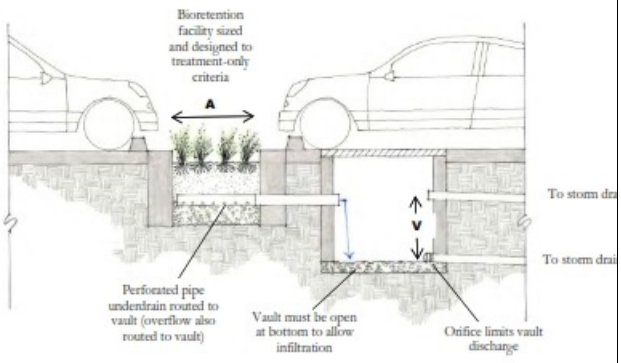
Key Points

- *Low Impact Development is the preferred method of stormwater treatment in Contra Costa County.*
- *There are numerous, proven applications of green infrastructure to reduce runoff volume that are detailed in the CCCWP C.3 guidebook.*
- *East County Permittees will be committed by the Provision C.3 of the MRP to develop and implement green infrastructure plans.*
- *An RAA will provide the quantitative information requested by the CVRWQCB as to what methylmercury load reductions are possible, by when, and at what cost.*

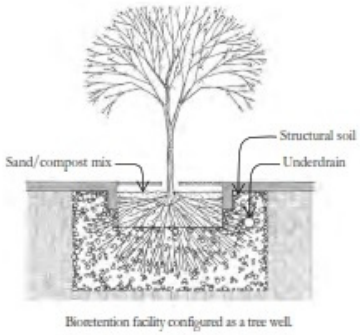
Figure 21. Examples of Bioretention Facilities from the CCCWP C.3 Guidebook



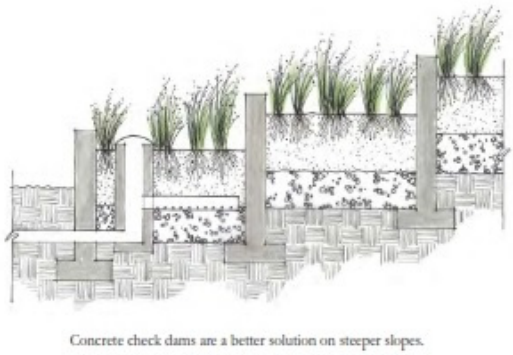
Typical application



Bioretention with vault to promote infiltration

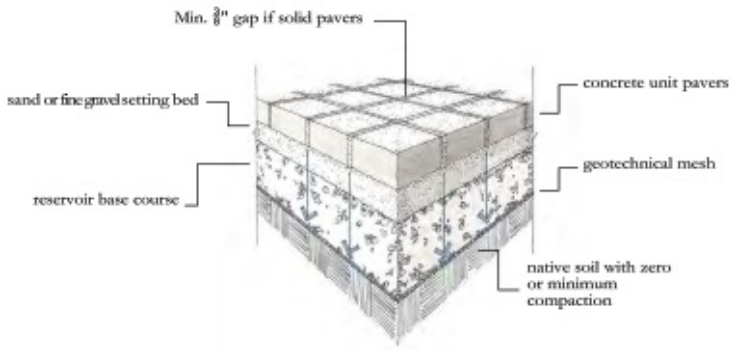


Bioretention with a tree planter

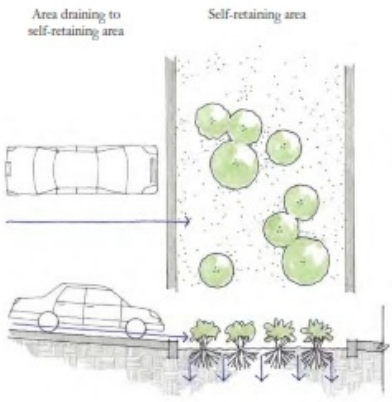


Bioretention on a steep slope

Figure 22. Examples of Porous Pavement and Self-Retaining Areas from the CCCWP C.3 Guidebook.



Standard detail of porous pavement



Conceptual design of self-retaining area

5.3 Additional Investigation of Ponded Areas Upstream of the Brentwood WTP

East County Permittees have already initiated an SSID study of areas that pond upstream of the Brentwood WTP during dry weather (Figure 23). As noted, the primary purpose of the SSID study is to determine if eutrophication in the ponded areas causes recurrent fish kills observed over the past 12 years. Eutrophication and low dissolved oxygen are also risk factors for increased mercury methylation. Beginning in 2019, the Marsh Creek SSID study can be coordinated with the data gaps related to methylmercury by adding methylmercury as a monitoring parameter.

Figure 23. Visible Unattached Algae in Marsh Creek as Seen from the Ground and Above

Additionally, as noted in Section 4.2, the repeatability of the methylmercury pulse observed in the spring of 2013 will be evaluated by capturing two more late spring storm events. The monitoring will be staged such that methylmercury in ponded water will be sampled prior to forecast late spring storm events, to the extent possible. This sampling design will help relate conditions in stagnant ponded water prior to storm events to conditions observed during the rising and falling hydrograph.

In addition to evaluating the repeatability of the methylmercury pulse observed in April 2013, the potential source area will need to be evaluated in more detail. Although there is good evidence for ponded, stagnant water in the channel of Marsh Creek upstream of the Brentwood WTP, that is not the only area where quiescent waters can promote the microbial process that increase methylmercury. The Upper Sand Creek Basin Restoration Project, for example, included creation of valuable wetland habitat (Figure 24). The possibility that this habitat area is the source of elevated methylmercury observed in April 2013 cannot be ruled out at this time. This highlights a potential challenge that proponents of Delta wetland restoration projects are familiar with: the value of enhanced wetland habitats sometimes is associated with the risk of increased methylmercury production.

Figure 24. Wetland Habitat Created as Part of the Upper Sand Creek Basin Restoration Project

Image from http://www.cccounty.us/5836/Upper-Sand-Creek-Basin

Key Points

- *CCCWP has an existing SSSID study investigating eutrophication and low dissolved oxygen as a potential cause of fish kills.*
- *Because of the link between low dissolved oxygen, the SSID study will be augmented with methylmercury measurements beginning in 2019.*
- *Other potential areas that could create methylmercury that is flushed out in late spring include wetland habitat in detention basins. These will also be investigated.*

5.4 Monitoring and Adaptive Management

The current MRP stipulates a certain level of effort dedicated to monitoring mercury to be completed annually and during each five-year permit term. Assuming a similar floor of effort is established in future permits, this, along with CCCWP's history of monitoring programs, provides the CVRWQCB assurance that mercury and methylmercury monitoring will continue in the future as needed. CCCWP has implemented a coordinated countywide monitoring program for the past two decades. During the implementation of the first version of the MRP, from 2009 through 2014, CCCWP successfully coordinated with Bay Area municipal stormwater peers through BASMAA, as well as SFRWQCB and CVRWQC staff, to align MRP and East County Permit requirements and thereby implement a cohesive countywide monitoring program that addressed the interests of both regional water quality control boards. The results included successful monitoring projects, both in Marsh Creek and in western Contra Costa County, which produced the data used in this report (Figure 25).

Figure 25. CCCWP's Robust Monitoring Program Includes Continuous Monitoring of Water Quality in Marsh Creek

CCCWP will continue to fulfill monitoring requirements established under the MRP through a coordinated countywide approach that addresses TMDLs in both the San Francisco Bay and the Central Valley Region. The management questions that will guide monitoring to address the Delta Methylmercury TMDL have been discussed in detail above and are briefly summarized below:

- Are methylmercury to SSC ratios within East County Permittee MS4 systems consistent with the regional background established to date by this study and by the findings of Mckee et al. (2016)?
- What is the annual average methylmercury load from the Marsh Creek watershed?
- How much of the Marsh Creek methylmercury load results from discharges from the MS4 system?
- What methylmercury load reductions from the MS4 system are achievable by implementation of reasonable, foreseeable control measures to the maximum extent practicable?
- Does eutrophication and low dissolved oxygen increase methylmercury in ponded areas of Marsh Creek during low flow periods, and if so:
  - Do those effects reach the Delta during later season storms?
  - Are there reasonable and foreseeable management actions to ameliorate that condition?

These management questions will be addressed by directing a subset of the annual mercury monitoring requirements to the Marsh Creek watershed, and by amending the existing SSID study to include mercury and methylmercury measurements beginning in fiscal year 2019-2020.

CCCWP contributes to the annual operating budget for the Regional Monitoring Program for Water Quality in San Francisco Bay (SF Bay RMP). The CCCWP share of the overall Bay Area stormwater program's collective contribution is calculated on a population weighted basis. East County Permittees account for about 20 percent of the CCCWP contribution to the SF Bay RMP. These contributions fulfill the requirements of MRP Provision C.8.c (San Francisco Estuary Receiving Water Monitoring). CCCWP staff and consultants also devote many hours per year coordinating with the SF Bay RMP staff and managers, providing constructive input on the SF Bay RMP work plan as it addresses stormwater program needs and providing review and comment on SF Bay RMP deliverables. This commitment to supporting receiving water monitoring will continue as East County Permittees shift to coverage under the MRP.

When the Delta Regional Monitoring Program (Delta RMP) was initiated, East County Permittees were invited to join and contribute financial resources, as well as commit staff time for engagement and coordination. This would not only have meant decreasing CCCWP's contribution to the SF Bay RMP but would double the coordination and engagement workload of CCCWP staff.

Although waters of the Delta are directly offshore from East County Permittees, the Bay is downstream and therefore more likely a better place to look for long-term environmental processes, such as mercury bioaccumulation in fish. If there is ever a desire for a receiving water study in the Delta offshore of East County, this could be scoped and executed as a special study of the SF Bay RMP, with effort proportional to the East County Permittee's contributions. Coordination between the Delta RMP and the SF Bay RMP on monitoring needs and the scope of special studies conducted by the SF Bay RMP should be straightforward, because both programs are run by the San Francisco Estuary Institute.

CCCWP proposed to both the SFRWQCB and the CVRWQCB that it was most efficient and appropriate for East County Permittees to remain with the SF Bay RMP. This was agreed by staff from both the SFRWQCB and the CVRWQCB. The extant East County Permit language states that Permittees will contribute to the SF Bay RMP, so there was no need to document the agreement at that time. When East County Permittees switch to coverage under the MRP, the permit amendment should include revisions to the fact sheet noting that East County Permittees are contributing to the SF Bay RMP in lieu of the Delta RMP, based on the above rationale.

Adaptive management in the East Count Permittees' methylmercury control program means adjusting the methylmercury control actions in response to lessons learned about the key management questions identified above. Practically, the vehicles for communicating lessons learned is the CCCWPs' annual submittal of an urban creeks monitoring report, and the once per permit term submittal of an integrated monitoring report. Each of these submittals is a requirement of the MRP that is expected to continue. After East County Permittees obtain coverage under the MRP, future urban creeks monitoring reports

and integrated monitoring reports will include a separate section describing progress and lessons learned related to the East County Permittees' methylmercury control plan.

Permittee annual report submittals communicate what specific actions have been conducted by permittees to comply with their permit in the past fiscal year. Future annual reports from East County Permittees (beginning in October 2019) will include a separate section describing management actions related to the Delta methylmercury control plan. The Report of Waste Discharge (ROWD) is the appropriate vehicle to communicate how lessons learned inform management actions. The ROWD is a legally required submittal due six months before the expiration of the MRP (or any other individual NPDES permit subject to reissuance). The ROWD describes the discharger, the geography, the legally responsible parties, the nature of the discharges, and the program of control measures to prevent pollution in discharges in compliance with NPDES regulations. The ROWD is essentially the work plan for the next permit cycle. Future ROWD submittals will include a separate section discussing progress, next steps, and management actions related to the Delta methylmercury control program. Copies of the ROWD, the urban creeks monitoring report, and annual reports will be provided to the CVRWQCB along with submittal to the SFRWQCB.

Key Points

- *CCCWP has a robust ongoing monitoring program for pollutants of concern.*
- *CCCWP will continue monitoring mercury and methylmercury to address management questions raised by this study.*
- *CCCWP will also continue to contribute to the San Francisco Bay RMP.*
- *Delta receiving water monitoring needs offshore of East County Permittees can be addressed, if needed, through pilot and special studies of the San Francisco Bay RMP.*
- *The five-year cycle of completing an integrated monitoring report and submitting a Report of Waste Discharge establishes a formal process for adaptive management.*
- *The CVRWQCB will be involved in the adaptive management process by review of CCCWP reports and through comment on MRP reissuance.*

5.5 Mercury Risk Reduction Program

The Delta Methylmercury TMDL, and the San Francisco Bay TMDLs for mercury and PCBs include policies requiring dischargers to participate in risk reduction programs. This means developing effective communication and outreach tools to inform the public who fish the Bay or the Delta for food about appropriate consumption guidelines. The idea behind this policy is that reducing mercury concentrations in fish is a long-term program, with measurable change in fish expected to come slowly, on the timescale of decades. Because of this long-time frame for recovery, a socially responsible management action by dischargers who have some unavoidable amount of mercury in their discharges is to make sure people who fish receiving waters for food have clear risk guidance available to them.

These TMDL policies manifested as requirements in Provisions C.11.e and C.12.h of MRP 2.0 (2015) and also appeared in MRP 1.0 (2009). Bay Area stormwater programs, including the East County Permittees,

implemented a regional collaborative project to meet these requirements under MRP 1.0. Among other beneficial outcomes of the project, compelling brochures were developed in multiple languages that provide clear information on which fish species to avoid altogether, which ones to limit consumption, and which ones are safe for unlimited consumption (Figure 26). CCCWP visits a regular list of marinas, bait and tackle stores, and fishing piers along the entire Contra Costa County shoreline, including East County, to restock the brochures.

This risk reduction program was also required in the East County Permit through Provision C.11.i, addressing risk reduction in the geographic area of the Delta. In response to this requirement, in 2013 CCCWP contributed to the Delta Methylmercury Risk Reduction Program on behalf of East County Permittees commensurate with pro rata funding guidelines established by the CVRWQCB. The funding guidelines stated that contribution was for five years' worth of participation. When East County Permittees obtain coverage under the MRP, it is not expected that the permit amendment would include a requirement to participate in a duplicative risk reduction program. East County Permittees are currently communicating to the public about mercury exposure risks by the actions of CCCWP to make fish consumption guidance prominently available at fishing locations along the Delta shoreline of Contra Costa County. It is not clear why they should be obligated to extend their social responsibility activities upstream of their discharges.

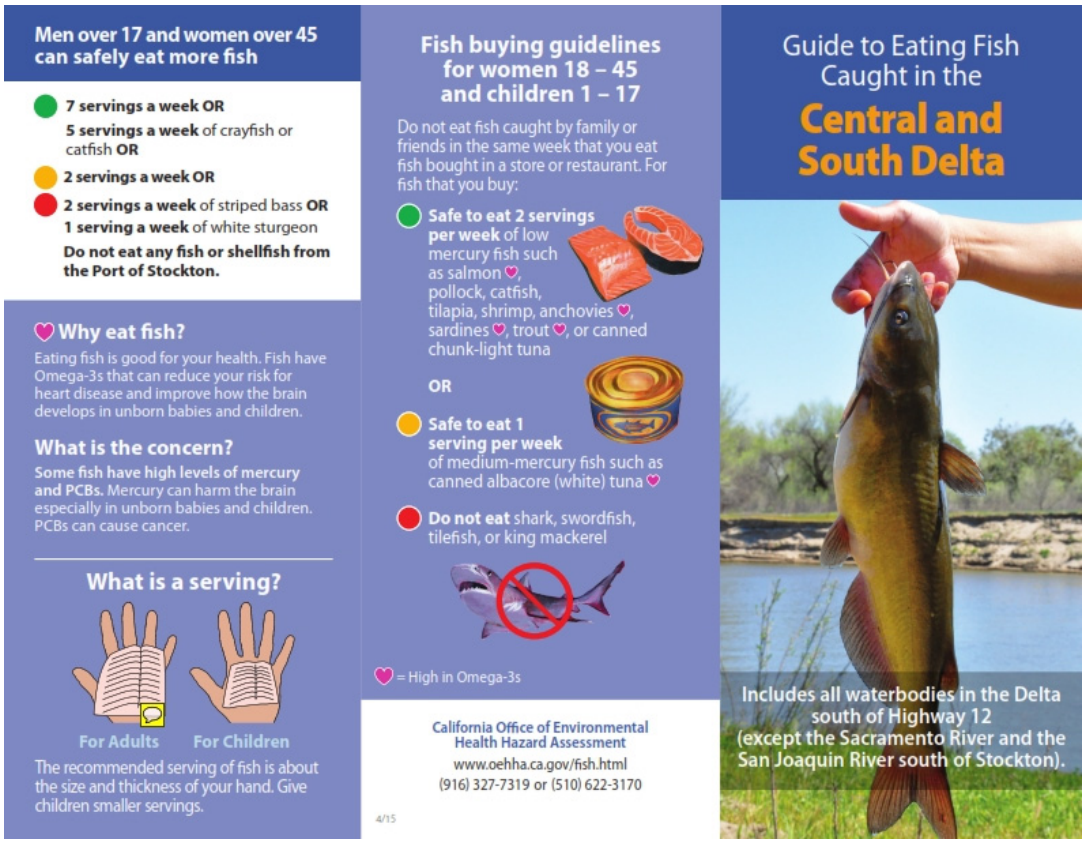
Key Points

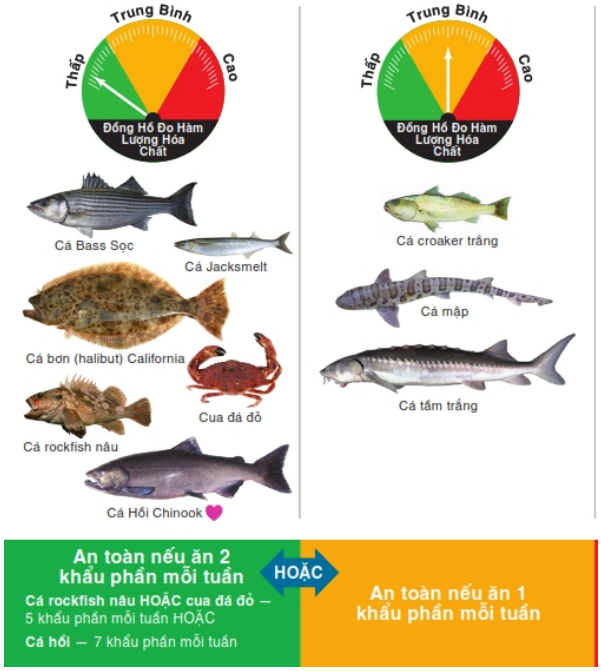
- *CCCWP participates in risk reduction programs as required by the MRP and the East County Permit.*
- *CCCWP distributes fish consumption guidance in multiple languages to marinas, piers, and bait and tackle shops.*

5.6 Preliminary Assessment of Costs, Effectiveness, Environmental Effects, and Overall Feasibility

Provision C.11.l of the extant East County Permit includes the direction to discuss costs, effectiveness, potential environmental effects, and the overall feasibility of methylmercury control measure plan implementation. As evident from the preceding discussion, the implementation strategies are too preliminary to provide detailed analysis for any of those four parameters. Below is a summary of what can be stated, and where uncertainties exist, the approach, and expected time frame to resolve uncertainties and develop more specific information. Section 5.6.1 discusses costs. Section 5.6.2 briefly summarizes effectiveness. Potential environmental effects are discussed in Section 5.6.3. Overall feasibility is summarized in Section 5.6.4

Figure 26. Risk Communication Guidance in Multiple Languages is Distributed by CCCWP to Marinas, Piers and Bait Shops





5.6.1 Analysis of Costs and Summary of Uncertainties Related to Costs

The costs of the two major potential control measures contemplated, green infrastructure plan development and potential management actions to abate low dissolved oxygen in Marsh Creek, are unknown at present. It is not certain at present whether addressing low dissolved oxygen is a *bona-fide* methylmercury control measure, or whether there are reasonable and foreseeable remedies for low dissolved oxygen in Marsh Creek. The SSID study addressing low dissolved oxygen and other water quality concerns in Marsh creek only recently started in July of 2018. With the water quality problem investigation phase incomplete, it is difficult to speculate solutions and predict costs. The implementation cost of a substantive green infrastructure plan is likewise elusive until the plan is complete, other than to state that transformations of the landscape by retrofit at a scale needed to provide infiltration of up to 75 percent of urban stormwater would require capital investments that are beyond the East County Permittee's resources.

Programmatic costs of near-term implementation are more readily defined. CCCWP believes the necessary monitoring, implementation tracking, and reporting activities described in this work plan can be performed within CCCWP's current operating budget framework. For example, the overall cost of implementing this study was budgeted at $150,000 in 2013. CCCWP has completed this work within that budgeted amount, amortized over the past five years. This effort did not directly require an increase of CCCWP's overall annual budget as a result of the fiscal impacts. As noted in Section 5.4 (monitoring and adaptive management), the future monitoring needs anticipated by this study are assumed to be covered through a subset of the annual mercury monitoring required under the MRP. Monitoring to assess low dissolved oxygen in Marsh Creek is already planned and budgeted through 2020, which is a quarter of a million-dollar commitment. The annual contribution to the SF Bay RMP is currently around $150,000. Twenty percent of that, or $30,000 per year, represents the portion coming from East County Permittees, and therefore sets the approximate scale that would be appropriate to a pilot or special study by the SF Bay RMP addressing receiving waters of the Delta offshore of East County.

Development of green infrastructure plans and performing an RAA of the plans will have their own costs. Consultant contracts to deliver RAAs have been procured for Bay Area Phase 1 countywide programs in the range of $200,000 to $500,000 per program. The scope and budget for that RAA work does not include development of the green infrastructure plans. In contrast, the smaller Solano County Phase 1 cities of Vallejo, Fairfield and Suisun recently collaborated to award a single consultant contract for an RAA and green infrastructure plans in each city for about $300,000 in total. The scale of the Solano Permittees is closer to East County in terms of population and acres, compared to countywide programs in the Bay Area. Cities who recently have bid out consultant contracts for green infrastructure plans only (no RAA in the scope) received bids in the range of $150,000 to $350,000.

The cost of performing an RAA on green infrastructure plans developed in East County should be mitigated by the fact that CCCWP is already developing a countywide RAA for the PCBs and mercury TMDLs. The geographic scope includes East County, but the approach to modeling methylmercury loads and load reductions may be somewhat different. Also, the numerous detention basins and bifurcated flow regime of the watershed may require some adjustments to the modeling approach. Thus, the RAA

on green infrastructure plans developed in East County should be a smaller effort compared to previous work at the larger, countywide scale.

CCCWP has invested $500,000 in matching funds for a grant-funded project to develop a Contra Costa County Stormwater Resources Plan. The plan names and prioritizes specific projects to improve stormwater quality. This plan will provide a foundation for the Permittee's green infrastructure plans. The Contra Costa County Stormwater Resources Plan will be complete in January 2019.

5.6.2 Control Measure Effectiveness

One clear lesson learned about effectiveness in this study is that filtration through the root zones of plants has a floor of performance with respect to SSC, which sets a floor of effectiveness for methylmercury concentrations. This was confirmed by a recent bioretention study by Caltrans that included methylmercury in the analyte list (Caltrans, 2014). The Clean Watersheds for a Clean Bay project, which funded the construction and monitoring of the bioretention cells evaluated in this study among others, also showed that treatment by bioretention established a floor of SSC in effluent (BASMAA, 2016). As noted in the conclusions (Section 4.1), the presence of SSC in bioretention effluent may limit the feasibility of achieving 0.06 ng/L methylmercury in water treated by bioretention alone, with no infiltration.

Infiltration, in contrast, is known to provide essentially 100 percent pollutant removal for the capture stormwater, where site soils allow for infiltration. The question of effectiveness then becomes more of the programmatic effectiveness of green infrastructure plan implementation. That is the expected output of the RAA.

It is premature to speculate on the effectiveness of any attempt to manage low dissolved oxygen in ponded areas of Marsh Creek, as that issue is still in the problem investigation stage. There are real world examples of lakes with low dissolved oxygen and elevated methylmercury that were artificially oxygenated, leading to a reduction in methylmercury in water (e.g., McCord et al., 2016). Beyond stating that manipulating dissolved oxygen can reduce mercury methylation, no more can be said about effectiveness until the problem investigation is complete.

5.6.3 Potential Environmental Effects

Multiple environmental benefits make green infrastructure an attractive a long-term solution. In addition to reducing pollutant impacts to receiving waters via infiltration, green infrastructure promotes groundwater replenishment and can enhance the visual aesthetic of public spaces (Figure 27). Projects designed for stormwater harvest and use can increase water conservation if the use replaces potable sources. Some designs can also reduce heat island effects. Larger projects often serve a dual function, such as recreation outside the rainy season.

Figure 27. Examples of Porous Pavement and Self-Retaining Areas from the CCCWP C.3 Guidebook

Installed application of bioretention

Installed application of porous pavement

There are potential risks and downsides to green infrastructure. Infiltration has the potential to destabilize hillslopes in geotechnically sensitive areas. Infiltration of stormwater to groundwater can raise contaminant concerns near potable aquifers. Those types of risks would be addressed and either avoided or mitigated to less than significant during the programmatic environmental review, as well as during project-specific environmental review.

Again, it is premature to state the potential effects of a project addressing low dissolved oxygen in ponded areas of Marsh Creek, because the problem investigation has only just begun. On the face of it, a project to improve eutrophication and dissolved oxygen would seem to provide multiple benefits in addition to methylmercury reduction. In fact, the primary motivation for such a management action would be addressing the low dissolved oxygen itself and its more immediate consequences for habitat value and aquatic life.

Any project to modify Marsh Creek, alter flows, or otherwise change conditions to improve low dissolved oxygen would have to be analyzed for negative environmental impacts. First and foremost, the primary mandate of the lead Permittee on this potential management action, the Contra Costa Flood Control and Water Conservation District (District) is to protect life and property from flooding. Any project would have to evaluate potential for impacts on that mandate, as well as habitat, water consumption and conservation, aesthetics, recreation, and all other relevant items from the California Environmental Quality Act checklist.

5.6.4 Overall Feasibility

At a high planning level, both of the most substantive management actions – green infrastructure planning and addressing low dissolved oxygen – should be considered feasible. Communities do develop and implement green infrastructure plans. Water managers do evaluate and abate low dissolved oxygen in lakes and streams. To claim either of those activities infeasible would be inviting rebuttal with a host of successful project examples.

The feasibility question for both management actions is mostly a matter of schedule expectations. It is infeasible to expect a project to be completed to address low dissolved oxygen in ponded areas of Marsh Creek within the next five years when the problem investigation has only just begun. Even if enough information is developed in the next year to motivate action, pilot studies, planning, permitting, design, and construction can take up to a decade or more, depending on the nature of the project, which is yet undefined.

The schedule expectations should be set even longer for implementation of green infrastructure plans. There simply are not sufficient resources to implement widespread retrofits on developed public lands in a short time frame. Achieving treatment through Provision C.3 requirements on redeveloped lands will take a long time, particularly in relatively new developments that are common in East County. Short-term funding for retrofits on public lands would need to be secured through grants and partnerships. Such short-term funding strategies would only provide a small fraction of the total treatment needed to achieve a 75 percent reduction in the volume of stormwater discharged. This is a common theme among municipal stormwaters across the state and throughout the nation who are planning for compliance with TMDLs and other requirements for improving stormwater quality.

In summary, if a dissolved oxygen management action is identified, there is likely a feasible solution to address low dissolved oxygen. The time scale of a decade or more to complete may be feasible, depending on the project details. In contrast, the feasibility of achieving any meaningful volume reductions by green infrastructure within 10 to 20 years is low. The overall cost, feasibility, expected benefits, and time frame will come out in more detail as green infrastructure plans and an RAA are completed.

Key Points

- *Implementation costs are uncertain at present.*
- *Need to complete RAA to understand green infrastructure plan implementation costs.*
- *Need better project definition, if there is a project, to quantify costs of abating potential methylating conditions in slow or stagnant waters in the Marsh Creek watershed.*
- *Infiltration is known to be effective for pollutant load reduction.*
- *There are potential positive and negative environmental effects of the actions contemplated.*
- *Negative effects can be avoided, minimized, or mitigated.*
- *The overall feasibility is a matter of schedule.*
- *2030 is not a realistic time frame to achieve the required methylmercury load reductions.*

This page intentionally blank

6. SCHEDULE

Table 9. Schedule for Methylmercury Control Plan Implementation

Date	Activity	By Whom
10/20/18	Submit Final Methylmercury Control Study Final Report	CCCWP
01/21/19	Amend MRP 2.0 to include East County Permittees	SFRWQCB
01/31/19	Complete Stormwater Resources Plan	CCCWP
03/31/19	Submit Urban Creeks Monitoring Report with Marsh Creek SSID Study results	CCCWP
09/15/19*	Submit Annual Report to CVRWQCB and SFRWQCB	CCCWP
10/15/19*	Submit POC Report to CVRWQCB and SFRWQCB	CCCWP
12/31/19	Complete Green Infrastructure Work Plans	East County Permittees
03/31/20	Submit Integrated Monitoring Report including Delta Methylmercury updates	CCCWP
05/22/20	Submit Report of Waste Discharge, including Delta Methylmercury TMDL updates	CCCWP
2020	Review of Numeric Targets and Associated Load and Wasteload Allocations for TMDL	CVRWQB
07/22/20	Provide input to SFRWQCB on MRP provisions for East Count Permittees	CVRWQCB
11/19/20	Re-issue MRP	SFRWQCB
12/31/20	Complete Green Infrastructure Plans	East County Permittees
01/01/21	Commence Green Infrastructure Plan Implementation	East County Permittees
03/15/21	Complete RAA of Green Infrastructure Plans	East County Permittees
03/31/21*	Submit Urban Creeks Monitoring Report including Delta Methylmercury updates	CCCWP
03/31/25	Submit Integrated Monitoring Report including Delta Methylmercury updates	CCCWP
05/22/25	Submit Report of Waste Discharge, including Delta Methylmercury updates	CCCWP
07/22/25	Provide input to SFRWQCB on MRP provisions for East Count Permittees	CVRWQCB
11/20/25	Re-issue MRP	SFRWQCB

*Indicates activities that will recur annually in the same month
Shaded rows indicate the recurring steps in the five-year permit re-issuance process

The first milestone on the implementation schedule (Table 9) after submittal of this report is amendment of the MRP to include the East County Permittees as named dischargers covered under the permit. Soon after that, the Contra Costa Stormwater Resources Plan will be complete, which lays a foundation for the green infrastructure plans and enables state bond-funded programs as potential funding mechanisms.

In February 2019, the work plan for the SSID study will be amended to include methylmercury. The timing will enable monitoring methylmercury in late season storms to see if the prior observations of elevated methylmercury in late season storms are repeatable. The first follow-up report that will inform the CVRWQCB about findings from the Marsh Creek SSID study will be transmitted in March 2019. That report will declare the outcomes of the first year of the problem investigation, including detailed information about the nature of dissolved oxygen cycling in Marsh Creek.

Following submittal of the 2019 urban creeks monitoring report, the East County Permittees will decide whether it is necessary to continue with the Marsh Creek SSID for determining the causes of fish kills, or

whether the causes have been identified and the SSID study activities investigating the cause of fish kills can end. In the latter event, assessment of methylmercury in relation to dissolved oxygen would continue as part of CCCWP's countywide requirements to monitor mercury. Urban creeks monitoring reports are submitted annually, except for the fifth year of the permit when an integrated monitoring report covering the past five years of monitoring is submitted.

Starting in September of 2019, the East County Permittees' annual reports will be submitted to both the SFRWQCB, as the lead regulatory agency for the MRP, and to CVRWQCB, as an interested party with respect to TMDL implementation. Annual reports will include information for the CVRWQCB about specific mercury or methylmercury control activities (other than monitoring) that East County Permittees have conducted related to this methylmercury control plan during the preceding fiscal year. Annually, one month after the annual reports are submitted, POC reports are submitted which describe monitoring and abatement activities for pollutants of concern conducted during the preceding fiscal year, as well as planned activities for the coming year.

Green infrastructure work plans will be completed by December of 2019. In March of 2019, the first step process to reissue the MRP will commence with the submittal of an integrated monitoring report. That report, which compiles lessons learned from the previous five years of monitoring to inform the next permit, will include a section on the methylmercury monitoring in relation to the Delta Methylmercury TMDL. This is followed by a Report of Waste Discharge, which formally begins the permit reissuance process. Based on these submittals, CVRWQCB would provide information to the SFRWCQB as to expectations for TMDL implementation by East County Permittees that would appear in the next permit. The MRP is expected be reissued in November of 2020.

Green infrastructure plans will be completed by December 2020 and implementation of the plans will commence soon after in January of 2021. Beyond those fixed dates, the annual reporting cycles and five-year permit reissuance process are the only events that can be scheduled with certainty. The schedule shows committed dates for green infrastructure plan development anticipated to be included in the permit amendment when East County Permittees shift to coverage under the MRP. The specifics of what green infrastructure will be implemented, where and by when will appear in the green infrastructure plans themselves.

Activities related to investigating low dissolved oxygen as a potential cause of elevated methylmercury cannot be foreseen beyond the first two years of the Marsh Creek SSID study. The next steps would depend on what is discovered through the investigation phase.

In summary, this schedule shows committed dates for the two major activities this study has identified: green infrastructure planning and investigation of low dissolved oxygen as a potential cause of elevated methylmercury in Marsh Creek. Additionally, the schedule shows three different types of annual report submittals that will include updates on methylmercury monitoring and control activities by East County Permittees and be transmitted to the CVRWQCB. Every five years, the four-step permit reissuance process will begin with transmittal of reports to the CVRWQCB that include specific updates on the Delta Methylmercury TMDL that will help CVRWQCB provide input to the SFRWQCB on any permit provisions

needed to address East County TMDL requirements. This orderly process will enable continuous progress toward TMDL goals for urban stormwater through the iterative, adaptive process with full involvement of the CVRWQCB.

This page intentionally blank

7. REFERENCES

Aquatic Science Center, 2018. Delta Regional Monitoring Program – Monitoring Design Summary. Prepared on behalf of the Delta Regional Monitoring Program. November 3, 2014; Revised May 30, 2018. Last accessed August 2018. https://www.waterboards.ca.gov/centralvalley/water_issues/delta_water_quality/delta_regional_monitoring/wq_monitoring/drmp_monitoring_design.pdf

Bay Area Stormwater Management Agencies Association (BASMAA). 2017. Clean Watersheds for a Clean Bay – Final Report. Prepared by Geosyntec and EOA on behalf of BASMAA. May 2017. Oakland, California. Last accessed July 31, 2018. http://basmaa.org/Portals/0/documents/Project%20Reports/Final_Report/CW4CB%20Project%20Report_No_Appendices_.pdf

California Department of Fish and Wildlife. 2018. License Statistics. Last accessed July 2018. https://www.wildlife.ca.gov/Licensing/Statistics.

California Department of Transportation. 2014. Caltrans, District 4, San Francisco-Oakland Bay Bridge (SFOBB) Bioretention Pilot Project Final Report. CTSW-RT-14-288.05.3D. Sacramento, California. September 2014.

California Regional Water Quality Control Board, Central Valley Region (CVRWQCB). 2010a. Sacramento-San Joaquin River Delta Estuary TMDL for Methylmercury – Staff Report. Rancho Cordova, California. April 2018. Last accessed July 2018. 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.

California Regional Water Quality Control Board, Central Valley Region (CVRWQCB). 2010b. 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 Staff Report. Rancho Cordova, California. Last accessed July 2018. https://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/archived_delta_hg_info/april_2010_hg_tmdl_hearing/apr2010_bpa_staffrpt_final.pdf

California Regional Water Quality Control Board, Central Valley Region (CVRWQCB). 2012. Methylmercury Control Study Guidance for the Delta Methylmercury Control Program Implementation Phase I. May 15, 2012. Last accessed August 2018. https://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/control_studies/2012_0515_hg_controlstudy.pdf

California State Water Resources Control Board. 2016. Fact Sheet: Statewide Mercury Control Program for Reservoirs. www.waterboards.ca.gov/water_issues/programs/mercury/reservoirs/, last accessed 10/5/2018.

Clary, J., Jones, J., Leisenring, M., P. Hobson and E. Strecker. 2017. International Stormwater BMP Database: 2016 Summary Statistics. Water Environment and Reuse Foundation, Alexandria, VA. www.bmpdatabase.org, last accessed 10/5/2018.

Contra Costa Clean Water Program (CCCWP) 2013. Methylmercury Control Study Work Plan. April 2013.

Contra Costa Clean Water Program (CCCWP) 2015. Methylmercury Control Study Progress Report. October 2015. Last accessed August 2018. https://www.cccleanwater.org/userfiles/kcfinder/files/Methlymercury_Control_Studies_Progress_Report_FINAL_Oct2015%281%29.pdf

Contra Costa Clean Water Program (CCCWP). 2017. Stormwater C.3 Guidebook – Stormwater Quality Requirements for Development Applications, 7th Edition. Prepared with assistance from Dan Cloak Consulting and Restoration Design Group. Martinez, California. May 17, 2017.

Contra Costa Clean Water Program (CCCWP). 2018. Marsh Creek Stressor and Source Identification Study. Prepared on behalf of CCCWP by Wood Environment & Infrastructure Solutions and ADH Environmental. Martinez, California. July 2018.

Contra Costa County Community Development Department. 2003. Contra Costa County Watershed Atlas. Martinez, California. November 2003.

Compeau, G.C. and Bartha, R. 1985. Sulfate-reducing bacteria: principal methylators of mercury in anoxic estuarine sediment. *Applied and environmental microbiology*, *50*(2), pp.498-502.

Krabbenhoft, D. P., Wiener, J. G., Brumbaugh, W. G., Olson, M. L., DeWild, J. F., & Sabin, T. J. March. 1999. A national pilot study of mercury contamination of aquatic ecosystems along multiple gradients. In *U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting*. Charleston, South Carolina (vol. 2, pp. 147-160).

Larry Walker Associates. 2015a. Sacramento Stormwater Quality Partnership Delta TMDL Phase I Methylmercury Control Study Progress Report. Davis, California. October 19, 2015. Last accessed July 31, 2018. https://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/control_studies/

Larry Walker Associates. 2015b. City of Stockton and County of San Joaquin Methylmercury Control Study Progress Report. Davis, California. October 20, 2015. Last accessed July 31, 2018. https://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/control_studies/

Larry Walker Associates. 2015c. City of Sacramento Combined Sewer System Delta TMDL Phase I Methylmercury Control Study Progress Report. Davis, California. October 19, 2015. Last accessed July 31, 2018.

https://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/control_studies/

Mason, R.P., Kim, E.H., Cornwell, J. and Heyes, D. 2006. An examination of the factors influencing the flux of mercury, methylmercury and other constituents from estuarine sediment. *Marine Chemistry*, 102(1-2), pp.96-110.

McCord, S.A., Beutel, M.W., Dent, S.R. and Schladow, S.G. 2016. Evaluation of mercury cycling and hypolimnetic oxygenation in mercury-impacted seasonally stratified reservoirs in the Guadalupe River watershed, California. *Water Resources Research*, 52(10), pp.7726-7743.

McKee, L.J. Gilbreath, N., Hunt, J.A., Wu, J., and Yee, D. 2016. Sources, Pathways and Loadings: Multi-Year Synthesis with a Focus on PCBs and Hg. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). SFEI Contribution No. 773. San Francisco Estuary Institute, Richmond, CA.

Robertson-Bryan, Inc. (RBI). 2015. Methylmercury Control Study Progress Report. Prepared on behalf of the Port of Stockton. Elk Grove, California. October 13, 2015. Last accessed July 31, 2018. https://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/control_studies/

This page intentionally blank

APPENDIX A: CURRENT REQUIREMENTS TO IMPLEMENT A METHYLMERCURY CONTROL STUDY

From Current East County Permit, Order No. R5-2010-0102 Provision C.11.l

This page intentionally blank

Provision C.11.l of the Eastern Contra Costa County NPDES Permit

C.11.l Methylmercury Control Studies

i. **Task Description –** After US EPA approves the Delta Mercury Control Program (methylmercury TMDL), the Permittees shall conduct methylmercury control studies to monitor and evaluate the effectiveness of existing BMPs on the control of methylmercury, and shall develop and evaluate additional BMPs as needed to reduce mercury and methylmercury discharges to the Delta and meet methylmercury waste load allocations. The studies shall quantify methylmercury loads and loads reduced through source control, treatment and other management measures as required in Provision C.8.g.

ii. **Implementation Level –** The Permittees shall demonstrate progress toward completing the methylmercury control studies by submitting a Control Study Work plan by [nine months after the US EPA Delta methylmercury TMDL approval date]. The control study workplan shall include details for:

1) Control Studies can be developed through a stakeholder group approach or other collaborative mechanism, or by the Permittees. The Permittees are not required to do individual studies if the Permittees join a collaborative study group(s).

2) Control Studies shall be implemented through Control Study Workplan(s). The Control Study Workplan(s) shall provide detailed descriptions of how methylmercury control methods will be identified, developed, and monitored, and how effectiveness, costs, potential environmental effects, and overall feasibility will be evaluated for the control methods.

3) The Control Study Work Plan(s) shall include details for organizing, planning, developing, prioritizing, and implementing the Control Studies.

4) The Control Studies shall evaluate existing control methods and, as needed, additional control methods that could be implemented to achieve methylmercury load and waste load allocations. The Control Studies shall evaluate the feasibility of reducing sources more than the minimum amount needed to achieve allocations.

5) The Control Studies also may include an evaluation of innovative actions, watershed approaches, offsets projects, and other short and long-term actions that result in reducing inorganic (total) mercury and methylmercury to address the accumulation of methylmercury in fish tissue and to reduce methylmercury exposure.

6) Permittees may evaluate the effectiveness of using inorganic (total) mercury controls to control methylmercury discharges.

7) Permittees may conduct characterization studies to inform and prioritize the Control Studies. Characterization studies may include, but not be limited to, evaluations of methylmercury and total mercury concentrations and loads in source waters, receiving waters, and discharges, to determine which discharges act as net sources of methylmercury, and which land uses result in the greatest net methylmercury production and loss.

iii. Reporting – The Permittees shall submit reports in compliance with the following schedule to the Central Valley Water Board:

1) By [four years after the US EPA Delta methylmercury TMDL approval date] the Permittees shall submit a Control Studies progress report.

2) By [seven years after US EPA Delta methylmercury TMDL approval date], the Permittees shall complete the Control Studies and submit a Final Report that present the results and descriptions of methylmercury control options, their preferred methylmercury controls, and proposed methylmercury management plan(s) (including implementation schedules), for achieving methylmercury allocations. Final reports for Control Studies shall include a description of methylmercury and/or inorganic (total) mercury management practices identified in during the studies; an evaluation of the effectiveness, and costs, potential environmental effects, and overall feasibility of the control actions. Final reports shall also include proposed implementation plans and schedules to comply with methylmercury allocations as soon as possible.

3) If the Control Study results indicate that achieving a given methylmercury allocation is infeasible, then the Permittees shall provide detailed information in the Final Report on why full compliance is not achievable, what methylmercury load reduction is achievable, and an implementation plan and schedule to achieve partial compliance.

APPENDIX B: RESULTS FROM WATERSHED CHARACTERIZATION AND BMP EFFECTIVENESS EVALUATION

This page intentionally blank

Table B1. Results from Watershed Characterization and BMP Effectiveness Evaluation

Site ID	Wet or Dry Weather	Date	Time	SSC (mg/L)	Total Hg (ng/L)	Total MeHg (ng/L)	MeHg to Hg Ratio (%)
A1	Dry	01/14/15	1300	3.3	2.1	0.06	2.9
A1	Wet	02/08/15	1200	164	27	0.21	0.8
A1	Dry	02/26/15	1350	12	2.2	0.07	3.2
A1	Wet	04/07/15	1000	104	24	0.47	2.0
A2	Dry	01/14/15	1245	4	2	0.05	2.5
A2	Wet	02/08/15	1145	41	22	0.11	0.5
A2	Dry	02/26/15	1330	7.1	1.6	0.05	3.1
A2	Wet	04/07/15	0935	22	8.6	0.11	1.3
A2	Wet	04/25/15	0705	10	5.5	0.13	2.4
A2	Dry	06/09/15	1530	16	3.0	0.08	2.7
A3	Dry	01/14/15	1215	38	9.8	0.24	2.4
A3	Wet	02/08/15	1115	42	12	0.08	0.7
A3	Dry	02/26/15	1300	77	13	0.12	0.9
A3	Wet	04/07/15	0915	32	7.4	0.08	1.1
A3	Wet	04/25/15	0650	16	2.9	0.05	1.7
A3	Dry	06/09/15	1600	7.6	2.7	0.13	4.8
M1	Dry	01/14/15	1130	< 2	0.9	< 0.02	NA
M1	Dry	02/26/15	1220	4.7	1.1	< 0.02	NA
M2	Wet	03/16/12	2247	180	32.4	0.19	0.6
M2	Wet	03/16/12	2337	260	36.7	0.24	0.7
M2	Wet	03/17/12	0839	61	9.41	0.08	0.9
M2	Wet	03/17/12	0131	130	17.4	0.17	1.0
M2	Wet	11/30/12	0343	29	11	0.10	0.9
M2	Wet	11/30/12	1640	108	12	0.12	1.0
M2	Wet	11/30/12	1155	241	25	0.24	1.0
M2	Wet	12/01/12	0950	25	6.9	0.07	1.0
M2	Wet	12/22/12	1500	66	9.9	0.14	1.4
M2	Wet	12/22/12	1153	205	19	0.22	1.2
M2	Wet	12/22/12	0858	223	39	0.38	1.0
M2	Wet	12/22/12	2124	464	91	0.66	0.7
M2	Wet	04/04/13	1326	14	9.8	0.15	1.5
M2	Wet	04/04/13	1051	50	11	0.25	2.3
M2	Wet	04/04/13	0711	242	35	1.10	3.1
M2	Wet	04/04/13	0738	288	43	1.20	2.8
M2	Wet	01/08/17	0920	48	15	0.09	0.6
M2	Wet	01/08/17	1220	57	23	0.11	0.5
M2	Wet	01/08/17	1445	174	47	0.23	0.5
M2	Wet	01/08/17	1745	236	80	0.3	0.4
M2	Dry	05/30/13	1400	3.3	1.9	0.09	4.7
M2	Dry	12/05/13	1310	< 2	1.1	< 0.02	NA

Table B1. Results from Watershed Characterization and BMP Effectiveness Evaluation

Site ID	Wet or Dry Weather	Date	Time	SSC (mg/L)	Total Hg (ng/L)	Total MeHg (ng/L)	MeHg to Hg Ratio (%)
M3	Dry	01/14/15	1030	7.5	1.4	0.03 *J*	2.1
M3	Dry	02/26/15	1130	17	1.8	0.04 *J*	2.2
M4	Dry	01/14/15	1017	7.7	3	0.04 *J*	1.3
M4	Dry	02/26/15	1150	11	3.4	0.047 *J*	1.4
M5	Dry	01/14/15	0942	3.7	1.1	< 0.02	NA
M5	Dry	02/26/15	1100	35	2	0.04 *J*	2.0
LAU3-I	Wet	11/22/14	0530	36 *B*	28	0.11	0.4
LAU3-I	Wet	11/22/14	0600	29 *B*	20	0.11	0.6
LAU3-I	Wet	11/22/14	0645	13 *B*	11	0.07	0.6
LAU3-I	Wet	12/02/14	1045	49	43	0.11	0.3
LAU3-I	Wet	12/02/14	1130	125	130	0.18	0.1
LAU3-I	Wet	12/02/14	1230	89	110	0.19	0.2
LAU3-I	Wet	12/15/14	0100	11	32	0.15	0.5
LAU3-I	Wet	12/15/14	0300	40	8.5	0.14	1.6
LAU3-I	Wet	12/15/14	2330	52	41	0.20	0.5
LAU3-I	Wet	02/06/15	1105	70	86	0.23	0.3
LAU3-I	Wet	02/06/15	1615	111	120	0.16	0.1
LAU3-I	Wet	02/06/15	1700	353	380	0.17	0.04
LAU3-I	Wet	01/17/16	1716	11	13	0.06	0.5
LAU3-I	Wet	01/17/16	1800	16	7	0.06	0.9
LAU3-I	Wet	03/01/18	0840	9.9	17	0.13	0.76
LAU3-I	Wet	04/06/18	0745	71.0	25	0.12	0.48
LAU3-E	Wet	11/22/14	0535	16 *B*	29	2.60	9.0
LAU3-E	Wet	11/22/14	0605	17 *B*	35	2.70	7.7
LAU3-E	Wet	11/22/14	0650	23 *B*	41	3.30	8.0
LAU3-E	Wet	12/02/14	1050	34	66	2.80	4.2
LAU3-E	Wet	12/02/14	1140	31	61	2.60	4.3
LAU3-E	Wet	12/02/14	1240	30	57	2.40	4.2
LAU3-E	Wet	12/15/14	0115	9.4	41	3.00	7.3
LAU3-E	Wet	12/15/14	0310	28	58	2.00	3.4
LAU3-E	Wet	12/15/14	2345	10	42	2.70	6.4
LAU3-E	Wet	02/06/15	1105	206	400	3.00	0.8
LAU3-E	Wet	02/06/15	1625	61	75	1.90	2.5
LAU3-E	Wet	02/06/15	1705	74	73	1.90	2.6
LAU3-E	Wet	01/17/16	1725	193	46	0.59	1.3
LAU3-E	Wet	01/17/16	1811	41	16	0.32	2.0
LAU3-E	Wet	03/01/18	0845	13	77	0.38	0.49
LAU3-E	Wet	04/06/18	0750	2.8 *J*	28	1.3	4.64
LAU4-I	Wet	12/02/14	1050	83	87	0.22	0.3
LAU4-I	Wet	12/02/14	1140	62	63	0.19	0.3

Table B1. Results from Watershed Characterization and BMP Effectiveness Evaluation

Site ID	Wet or Dry Weather	Date	Time	SSC (mg/L)	Total Hg (ng/L)	Total MeHg (ng/L)	MeHg to Hg Ratio (%)
LAU4-I	Wet	12/02/14	1520	135	160	0.46	0.3
LAU4-I	Wet	12/15/14	0005	4.2	6.6	0.18	2.7
LAU4-I	Wet	12/15/14	0150	13	5	0.12	2.4
LAU4-I	Wet	12/15/14	0320	8.4	6.3	0.11	1.7
LAU4-I	Wet	02/06/15	1555	94	93	0.21	0.2
LAU4-I	Wet	02/06/15	1643	34	85	0.07	0.1
LAU4-I	Wet	02/06/15	1737	15	23	0.14	0.6
LAU4-I	Wet	04/07/15	0440	16	15	0.11	0.7
LAU4-I	Wet	04/07/15	0455	14	28	0.09	0.3
LAU4-I	Wet	01/05/16	0230	20	11	0.2	1.8
LAU4-I	Wet	01/05/16	0325	15	200	0.13	0.1
LAU4-I	Wet	01/05/16	0410	4.0	5.1	0.1	2.0
LAU4-I	Wet	01/17/16	1722	17	18	0.08	0.4
LAU4-I	Wet	01/17/16	1900	13	9.9	0.06	0.6
LAU4-I	Wet	01/17/16	2205	7.9	10	0.07	0.7
LAU4-I	Wet	03/01/18	0820	65.0	90	0.21	0.23
LAU4-I	Wet	04/06/18	0800	54	30	0.22	0.73
LAU4-E	Wet	12/02/14	1055	21	39	0.41	1.1
LAU4-E	Wet	12/02/14	1150	23	40	0.35	0.9
LAU4-E	Wet	12/02/14	1530	17	33	0.41	1.2
LAU4-E	Wet	12/15/14	0030	4	11	0.07	0.6
LAU4-E	Wet	12/15/14	0205	4.3	16	0.07	0.4
LAU4-E	Wet	12/15/14	0330	8.4	22	0.09	0.4
LAU4-E	Wet	02/06/15	1610	30	65	0.19	0.3
LAU4-E	Wet	02/06/15	1657	31	53	0.19	0.4
LAU4-E	Wet	02/06/15	1746	31	50	0.21	0.4
LAU4-E	Wet	04/07/15	0420	22	25	0.08	0.32
LAU4-E	Wet	04/07/15	0447	27	34	0.08	0.24
LAU4-E	Wet	01/05/16	0245	7.3	10	0.03	0.30
LAU4-E	Wet	01/05/16	0335	6.7	12	0.05	0.42
LAU4-E	Wet	01/05/16	0400	12	14	0.06	0.43
LAU4-E	Wet	01/17/16	1745	2.4	7.5	0.04	0.53
LAU4-E	Wet	01/17/16	1930	8.2	9.1	0.06	0.66
LAU4-E	Wet	01/17/16	2217	9.0	14	0.07	0.50
LAU4-E	Wet	03/01/18	0820	65	90	0.21	0.23
LAU4-E	Wet	04/06/18	0755	25.0	61	0.24	0.39
CHS102	Wet	01/08/17	0915	14	5.53	0.12	2.17
CHS103	Wet	01/08/17	0920	13.7	13.8	0.25	1.81
CHS104	Wet	01/08/17	0925	7.6	20.1	0.58	2.89
CHS106	Wet	01/08/17	1020	8.3	38.6	0.76	1.97

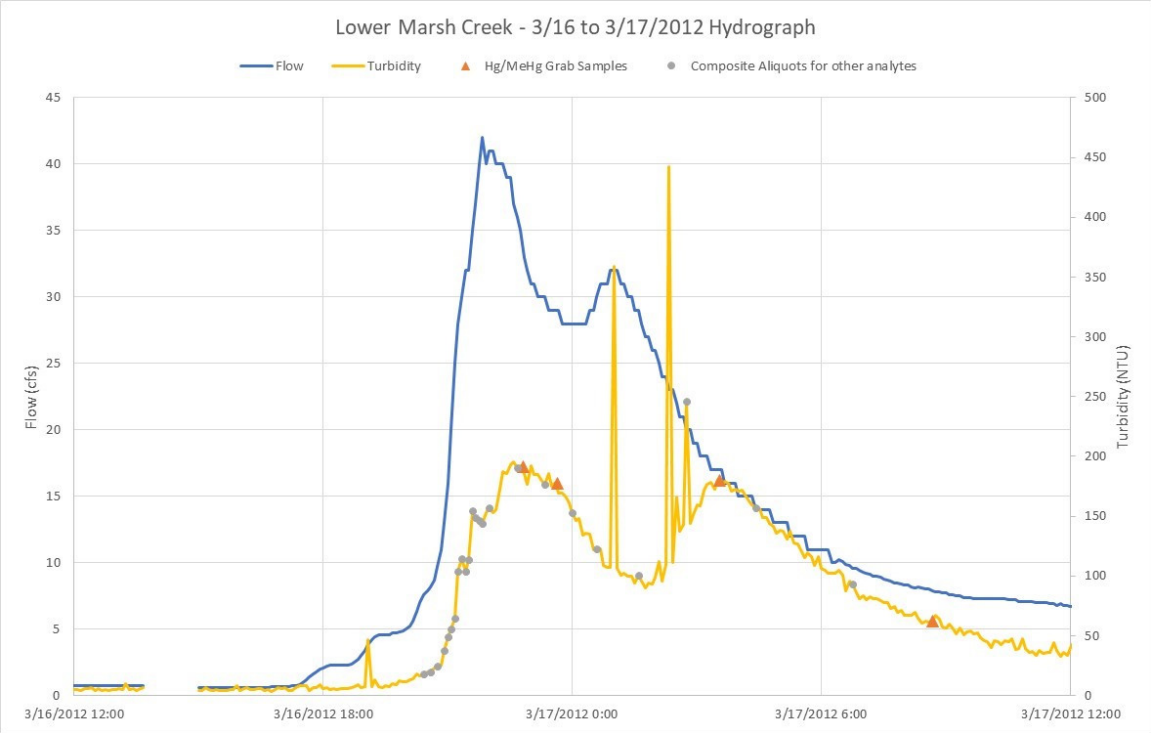
Table B1. Results from Watershed Characterization and BMP Effectiveness Evaluation

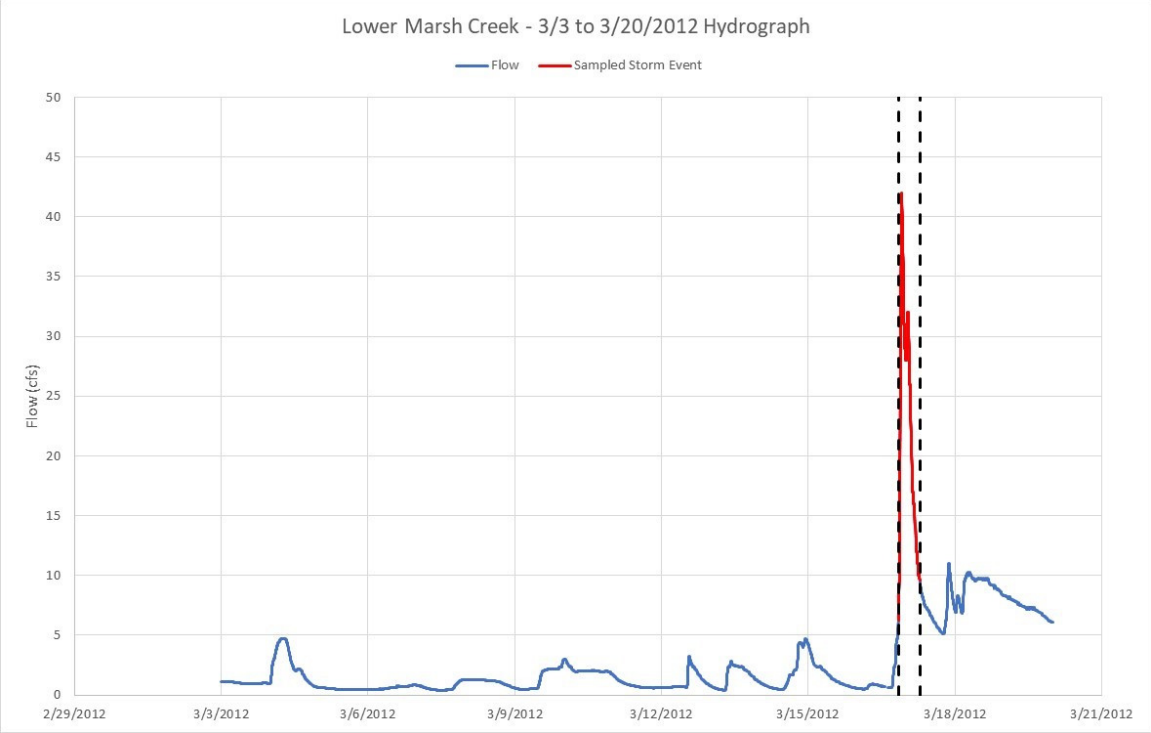
Site ID	Wet or Dry Weather	Date	Time	SSC (mg/L)	Total Hg (ng/L)	Total MeHg (ng/L)	MeHg to Hg Ratio (%)
KEL105	Wet	01/08/17	1005	15.1	21.1	0.28	1.33
MKT100	Wet	01/08/17	0815	33.2	12.1	0.12	0.99
RUM101	Wet	01/08/17	0845	9.3	10.2	0.38	3.73
RUM108	Wet	01/08/17	1045	43.2	2.23	0.19	8.52
RUM109	Wet	01/08/17	1110	215.0	13.5	0.41	3.04
SUT107	Wet	01/08/17	1035	2.4	6.28	0.08 *J*	1.27

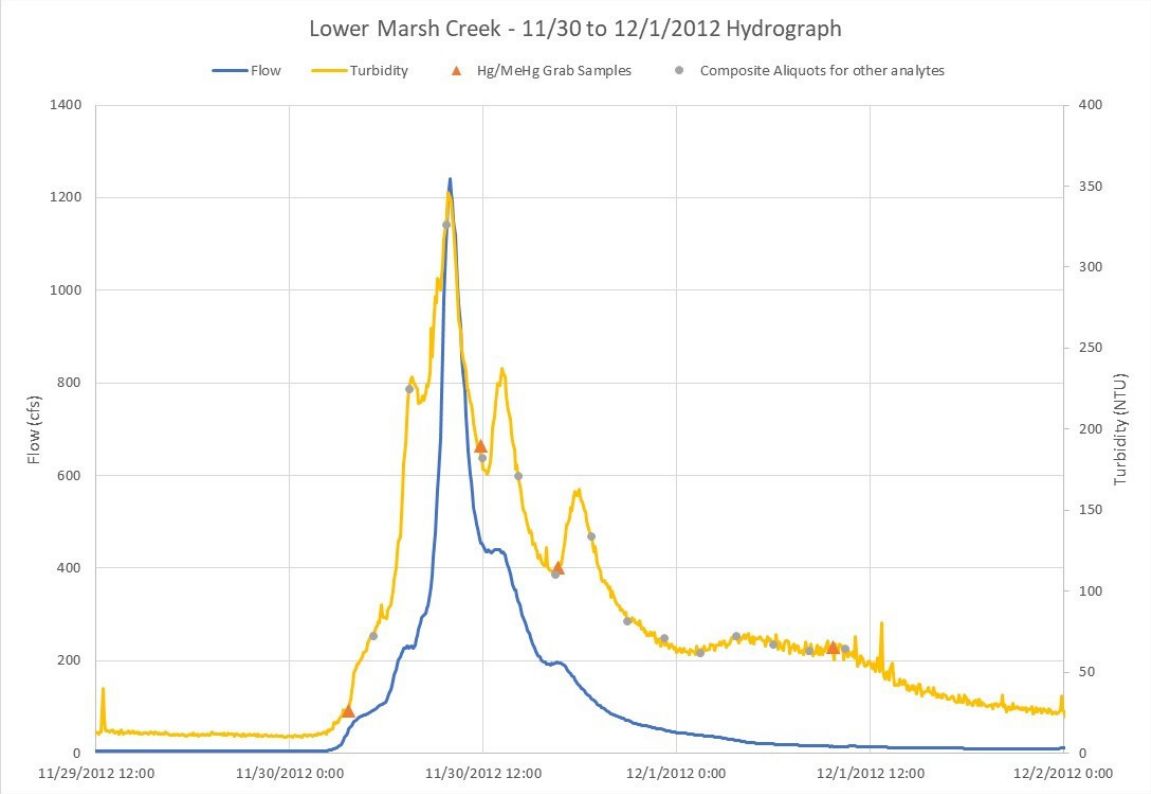
SSC = suspended sediment concentration
A1 = West Antioch Creek, above tidal influence
A2 = East Antioch Creek, discharge from Lake Alhambra tide gate
A3 = East Antioch Creek, upstream of Lake Alhambra
M1 = Marsh Creek, downstream of Brentwood WTP
M2 = Marsh Creek at fish ladder, upstream of Brentwood WTP
M3 = Sand Creek, tributary to Marsh Creek
M4 = Deer Creek, tributary to Marsh Creek
M5 = Dry Creek, tributary to Marsh Creek
LAU3-I = Influent, biofiltration cell #3 at First Street and Cutting Boulevard. in the City of Richmond
LAU3-E = Effluent, biofiltration cell #3 at First Street and Cutting Boulevard in the City of Richmond
LAU4- I = Influent, biofiltration cell #4 at First Street and Cutting Boulevard in the City of Richmond
LAU4- E = Effluent, biofiltration cell #4 at First Street and Cutting Boulevard in the City of Richmond
CHS102 = Drop Inlet at Chesley Avenue near Rumrill Boulevard in the City of San Pablo
CHS103 = Drop Inlet at Chesley Avenue near Rumrill Boulevard in the City of Richmond
CHS104 = Drop Inlet at Chesley Avenue and Fillmore Street in the City of Richmond
CHS106 = Drop Inlet at Chesley Street and 7th Street in North Richmond
KEL105 = Drop Inlet at Lesley Street near Hensley Street in the City of Richmond
MKT100 = Drop Inlet at Market Avenue near Rumrill Boulevard in the City of Richmond
RUM101 = Drop Inlet at Rumrill Boulevard and Bush Avenue in the City of San Pablo
RUM108 = Drop Inlet at Rumrill Avenue and Sutro Avenue in the City of San Pablo
RUM109 = Drop Inlet at Rumrill Avenue and Emeric Avenue in the City of San Pablo
SUT107 = Drop Inlet at Sutro Avenue and Fillmore Street in the City of San Pablo
J = Estimated value: measurement falls between the MDL and the MRL
NA = Not applicable
B = Method blank for this batch was detected at the RL value (3 mg/L), therefore the associated field results may be slightly high-biased
< = Analyte not detected at or above the MDL; numeric value following the "<" symbol is the associated MDL value

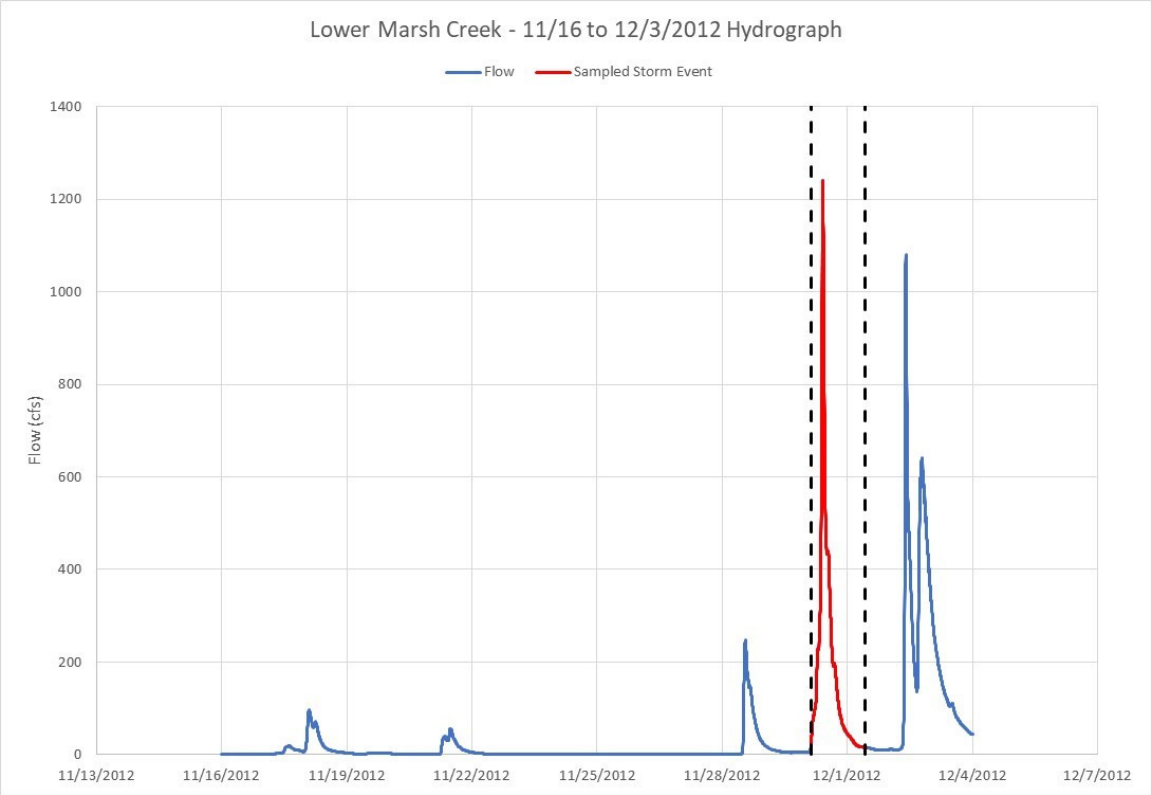
APPENDIX C: MARSH CREEK STORM SAMPLING HYDROGRAPHS AND GRAB SAMPLE TIMING

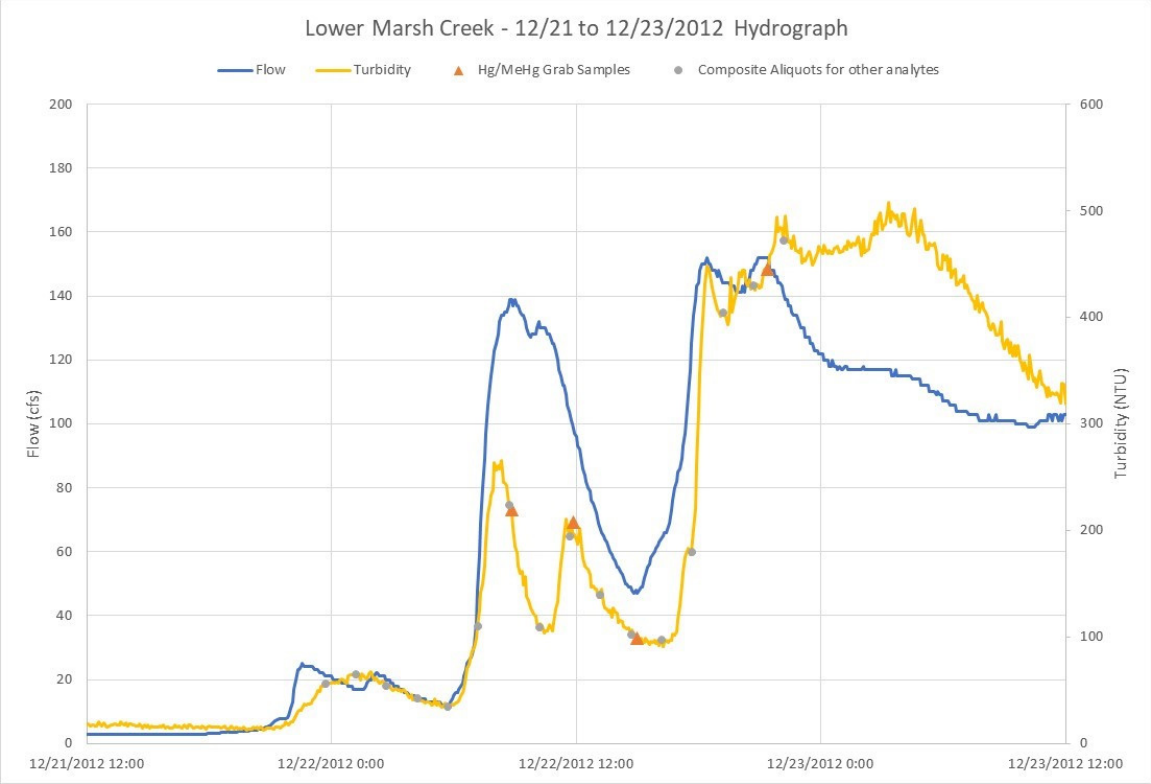
This page intentionally blank

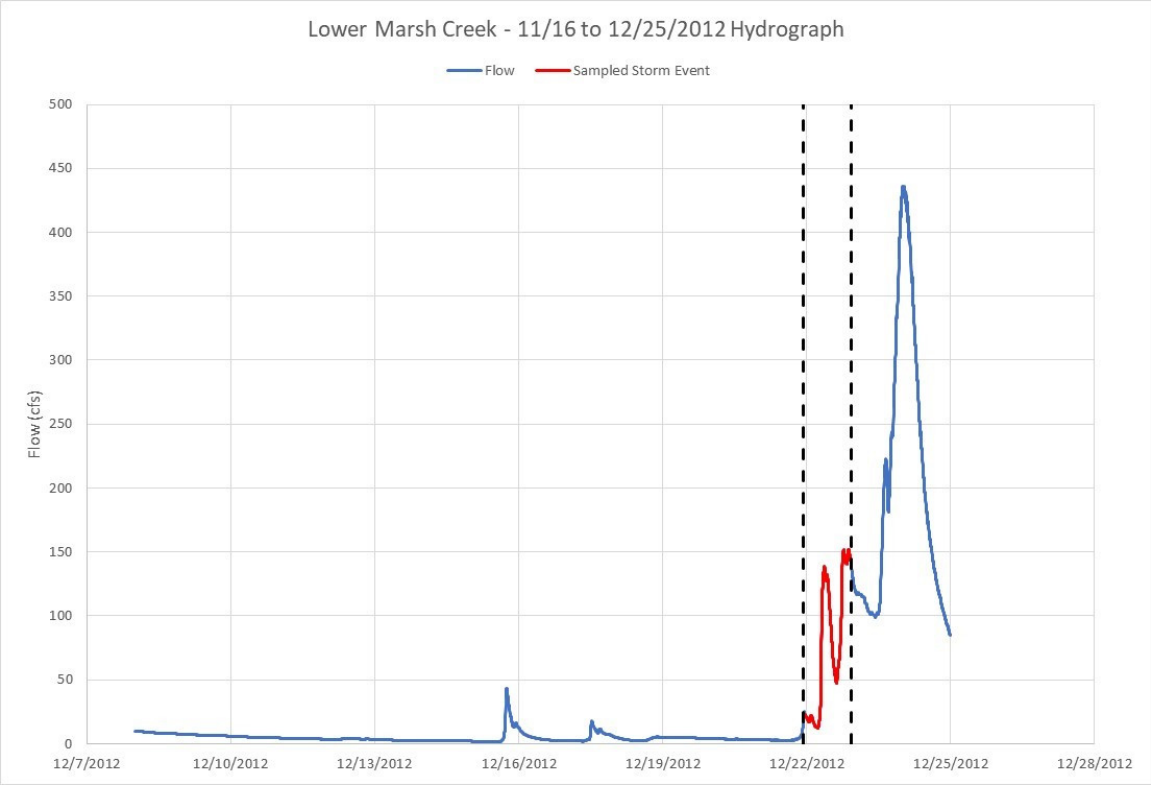

Lower Marsh Creek - 3/16 to 3/17/2012 Hydrograph
Flow
Turbidity
Hg/MeHg Grab Samples
Composite Aliquots for other analytes
Flow (cfs)
Turbidity (NTU)
0
5
10
15
20
25
30
35
40
45
0
50
100
150
200
250
300
350
400
450
500
3/16/2012 12:00
3/16/2012 18:00
3/17/2012 0:00
3/17/2012 6:00
3/17/2012 12:00

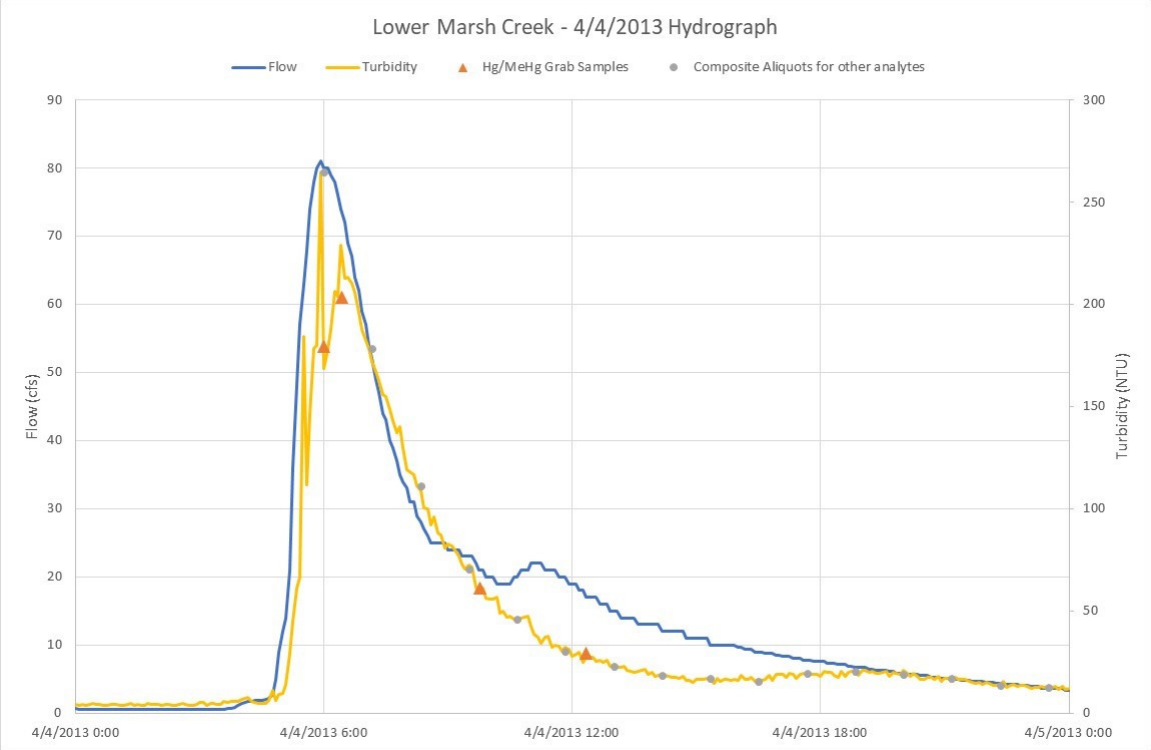

Lower Marsh Creek - 3/3 to 3/20/2012 Hydrograph
Flow
Sampled Storm Event
Flow (cfs)
0
5
10
15
20
25
30
35
40
45
50
2/29/2012
3/3/2012
3/6/2012
3/9/2012
3/12/2012
3/15/2012
3/18/2012
3/21/2012

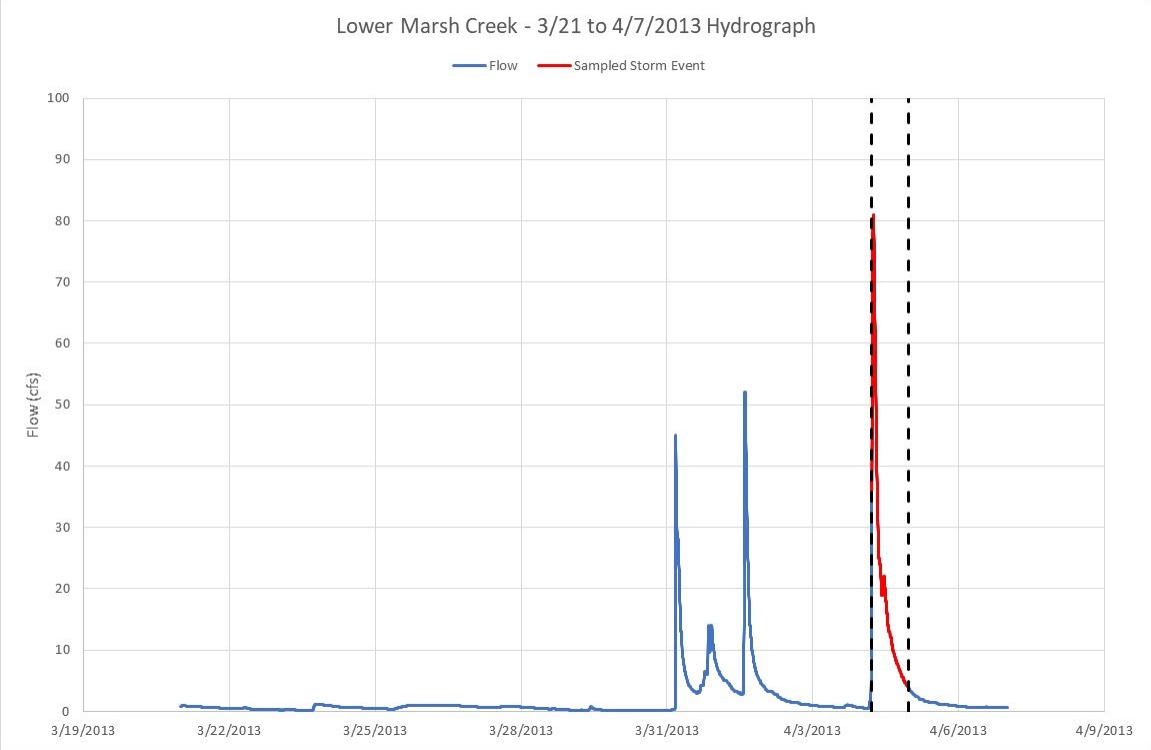

Lower Marsh Creek - 11/30 to 12/1/2012 Hydrograph
Flow
Turbidity
Hg/MeHg Grab Samples
Composite Aliquots for other analytes
Flow (cfs)
Turbidity (NTU)
0
200
400
600
800
1000
1200
1400
0
50
100
150
200
250
300
350
400
11/29/2012 12:00
11/30/2012 0:00
11/30/2012 12:00
12/1/2012 0:00
12/1/2012 12:00
12/2/2012 0:00

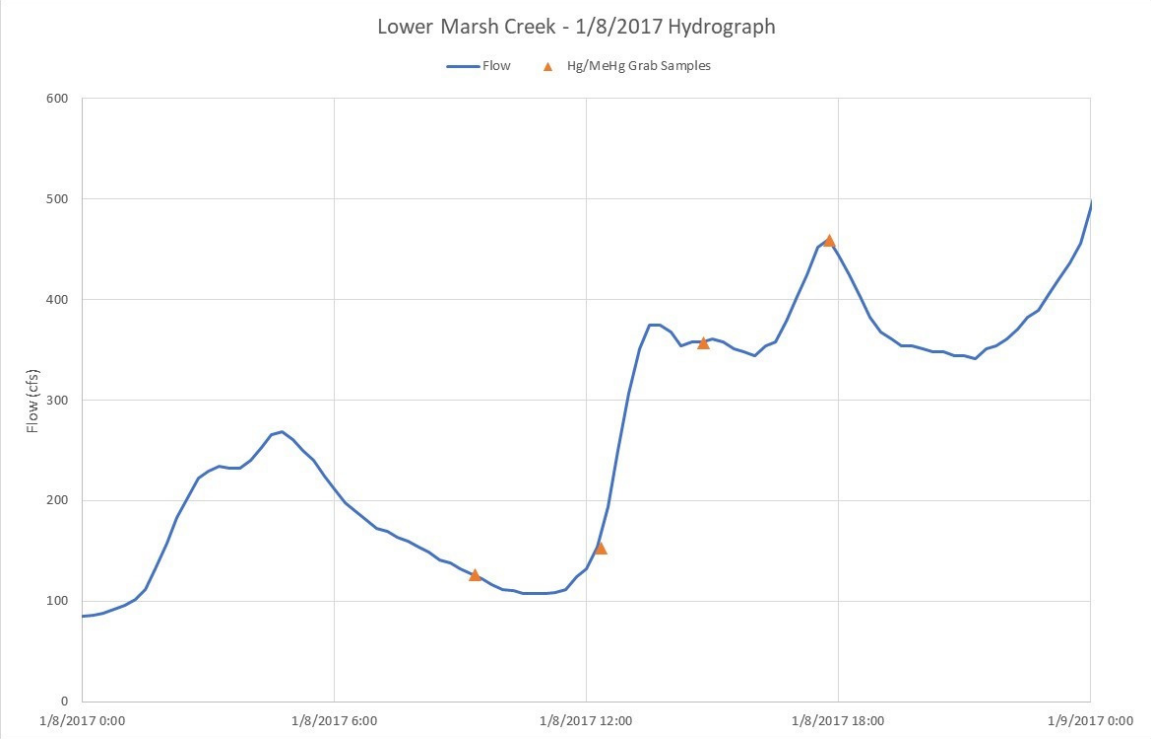

Lower Marsh Creek - 11/16 to 12/3/2012 Hydrograph
Flow
Sampled Storm Event
Flow (cfs)
0
200
400
600
800
1000
1200
1400
11/13/2012
11/16/2012
11/19/2012
11/22/2012
11/25/2012
11/28/2012
12/1/2012
12/4/2012
12/7/2012

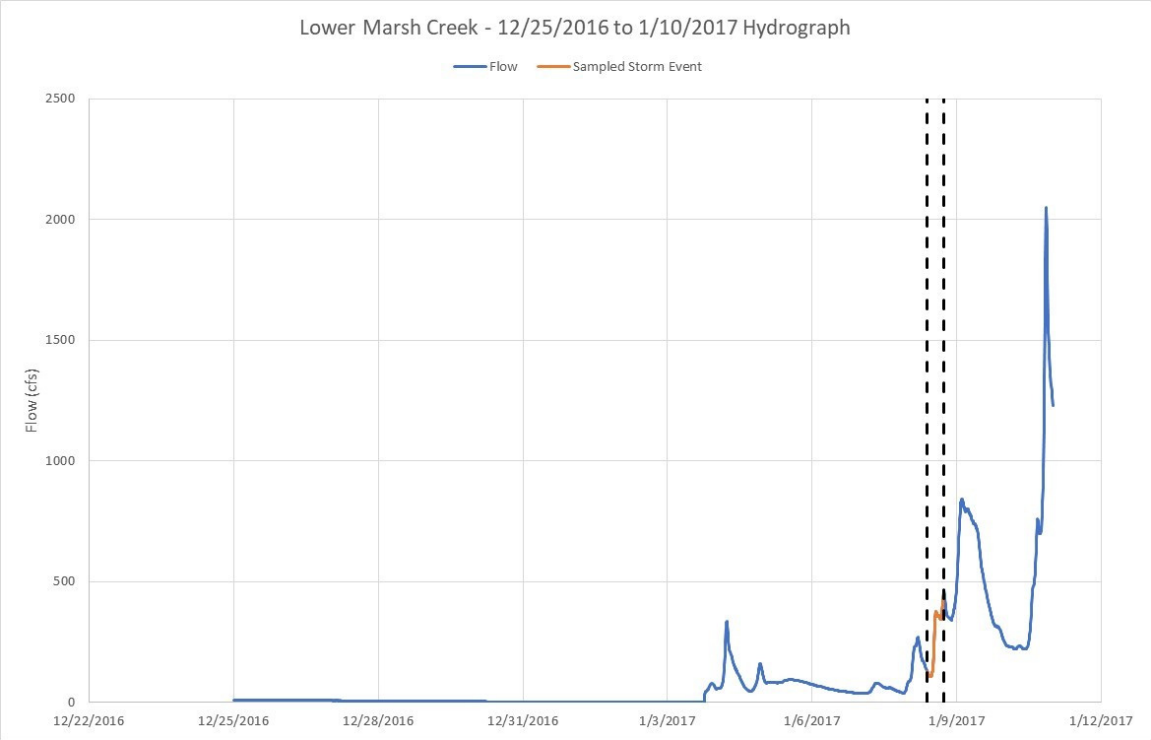

Lower Marsh Creek - 12/21 to 12/23/2012 Hydrograph
Flow
Turbidity
Hg/MeHg Grab Samples
Composite Aliquots for other analytes
Flow (cfs)
Turbidity (NTU)
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
12/21/2012 12:00
12/22/2012 0:00
12/22/2012 12:00
12/23/2012 0:00
12/23/2012 12:00


Lower Marsh Creek - 11/16 to 12/25/2012 Hydrograph
Flow
Sampled Storm Event
Flow (cfs)
0
50
100
150
200
250
300
350
400
450
500
12/7/2012
12/10/2012
12/13/2012
12/16/2012
12/19/2012
12/22/2012
12/25/2012
12/28/2012


Lower Marsh Creek - 4/4/2013 Hydrograph
Flow
Turbidity
Hg/MeHg Grab Samples
Composite Aliquots for other analytes
Flow (cfs)
Turbidity (NTU)
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
4/4/2013 0:00
4/4/2013 6:00
4/4/2013 12:00
4/4/2013 18:00
4/5/2013 0:00


Lower Marsh Creek - 3/21 to 4/7/2013 Hydrograph
Flow
Sampled Storm Event
Flow (cfs)
0
10
20
30
40
50
60
70
80
90
100
3/19/2013
3/22/2013
3/25/2013
3/28/2013
3/31/2013
4/3/2013
4/6/2013
4/9/2013


Lower Marsh Creek - 1/8/2017 Hydrograph
Flow
Hg/MeHg Grab Samples
Flow (cfs)
600
500
400
300
200
100
0
1/8/2017 0:00
1/8/2017 6:00
1/8/2017 12:00
1/8/2017 18:00
1/9/2017 0:00


Lower Marsh Creek - 12/25/2016 to 1/10/2017 Hydrograph
Flow
Sampled Storm Event
Flow (cfs)
2500
2000
1500
1000
500
0
12/22/2016
12/25/2016
12/28/2016
12/31/2016
1/3/2017
1/6/2017
1/9/2017
1/12/2017

This page intentionally blank

APPENDIX D: ANTICIPATED FUTURE REQUIREMENTS TO DEVELOP A GREEN INFRASTRUCTURE PLAN

From Current Municipal Regional Stormwater NPDES Permit, Order No. R2-2015-0049, Provision C.3.j

This page intentionally blank

C.3.j. Green Infrastructure Planning and Implementation

The Permittees shall complete and implement a Green Infrastructure Plan for the inclusion of low impact development drainage design into storm drain infrastructure on public and private lands, including streets, roads, storm drains, parking lots, building roofs, and other storm drain infrastructure elements.

The Plan is intended to serve as an implementation guide and reporting tool during this and subsequent Permit terms to provide reasonable assurance that urban runoff TMDL wasteload allocations (e.g., for the San Francisco Bay mercury and PCBs TMDLs) will be met, and to set goals for reducing, over the long term, the adverse water quality impacts of urbanization and urban runoff on receiving waters. For this Permit term, the Plan is being required, in part, as an alternative to expanding the definition of Regulated Projects prescribed in Provision C.3.b to include all new and redevelopment projects that create or replace 5,000 square feet or more of impervious surface areas and road projects that just replace existing imperious surface area. It also provides a mechanism to establish and implement alternative or

[11] **Detached single-family home project** – The building of one single new house or the addition and/or replacement of impervious surface to one single existing house, which is not part of a larger plan of development.

in-lieu compliance options for Regulated Projects and to account for and justify Special Projects in accordance with Provision C.3.e.

Over the long term, the Plan is intended to describe how the Permittees will shift their impervious surfaces and storm drain infrastructure from gray, or traditional storm drain infrastructure where runoff flows directly into the storm drain and then the receiving water, to green—that is, to a more-resilient, sustainable system that slows runoff by dispersing it to vegetated areas, harvests and uses runoff, promotes infiltration and evapotranspiration, and uses bioretention and other green infrastructure practices to clean stormwater runoff.

The Plan shall also identify means and methods to prioritize particular areas and projects within each Permittee's jurisdiction, at appropriate geographic and time scales, for implementation of green infrastructure projects. Further, it shall include means and methods to track the area within each Permittee's jurisdiction that is treated by green infrastructure controls and the amount of directly connected impervious area. As appropriate, it shall incorporate plans required elsewhere within this Permit, and specifically plans required for the monitoring of and to ensure appropriate reductions in trash, PCBs, mercury, and other pollutants.

The Permittees may comply with any requirement of this Provision through a collaborative effort.

i. Green Infrastructure Program Plan Development

Each Permittee shall:

(1) Prepare a framework or workplan that describes specific tasks and timeframes for development of its Green Infrastructure Plan. This framework or workplan shall be approved by the Permittee's governing body, mayor, city manager, or county manager by June 30, 2017. At a minimum, the framework or workplan shall include a statement of purpose, tasks, and timeframes to complete the elements listed in Provision C.3.j.i.(2) below.

(2) Prepare a Green Infrastructure Plan, subject to Executive Officer approval, that contains the following elements:

(a) A mechanism (e.g., SFEI's GreenPlanIT tool or another tool) to prioritize and map areas for potential and planned projects, both public and private, on a drainage-area-specific basis, for implementation over the following time schedules, which are consistent with the timeframes for assessing load reductions specified in Provisions C.11. and C.12:

(i) By 2020;

(ii) By 2030; and

(iii) By 2040.

The mechanism shall include criteria for prioritization (e.g., specific logistical constraints, water quality drivers (e.g., TMDLs), opportunities to treat runoff from private parcels in retrofitted street

right-of-way) and outputs (e.g., maps, project lists) that can be incorporated into the Permittee's long-term planning and capital improvement processes.

(b) Outputs from the mechanism described above, including, but not limited to, the prioritization criteria, maps, lists, and all other information, as appropriate. Individual project-specific reviews completed using these mechanisms are not required to be submitted with the Plan, but shall be made available upon request.

(c) Targets for the amount of impervious surface, from public and private projects, within the Permittee's jurisdiction to be retrofitted over the following time schedules, which are consistent with the timeframes for assessing load reductions specified in Provisions C.11. and C.12:

(i) By 2020;

(ii) By 2030; and

(iii) By 2040.

(d) A process for tracking and mapping completed projects, public and private, and making the information publically available (e.g., SFEI's GreenPlanIT tool).

(e) General guidelines for overall streetscape and project design and construction so that projects have a unified, complete design that implements the range of functions associated with the projects. For example, for streets, these functions include, but are not limited to, street use for stormwater management, including treatment, safe pedestrian travel, use as public space, for bicycle, transit, vehicle movement, and as locations for urban forestry. The guidelines should call for the Permittee to coordinate, for example, street improvement projects so that related improvements are constructed simultaneously to minimize conflicts that may impact green infrastructure.

(f) Standard specifications and, as appropriate, typical design details and related information necessary for the Permittee to incorporate green infrastructure into projects in its jurisdiction. The specifications shall be sufficient to address the different street and project types within a Permittee's jurisdiction, as defined by land use and transportation characteristics.

(g) Requirement(s) that projects be designed to meet the treatment and hydromodification sizing requirements in Provisions C.3.c. and C.3.d. For street projects not subject to Provision C.3.b.ii. (i.e., non-Regulated Projects), Permittees may collectively propose a single approach with their Green Infrastructure Plans for how to proceed should project constraints preclude fully meeting the C.3.d sizing requirements. The single approach can include different options to address specific issues or scenarios. That is, the approach shall identify the specific constraints that would preclude meeting the sizing requirements and the design approach(es) to take in that

situation. The approach should also consider whether a broad effort to incorporate hydromodification controls into green infrastructure, even where not otherwise required, could significantly improve creek health and whether such implementation may be appropriate, plus all other information, as appropriate (e.g., how to account for load reduction for the PCBs or mercury TMDLs).

(h) A summary of the planning documents the Permittee has updated or otherwise modified to appropriately incorporate green infrastructure requirements, such as: General Plans, Specific Plans, Complete Streets Plans, Active Transportation Plans, Storm Drain Master Plans, Pavement Work Plans, Urban Forestry Plans, Flood Control or Flood Management Plans, and other plans that may affect the future alignment, configuration, or design of impervious surfaces within the Permittee's jurisdiction, including, but not limited to, streets, alleys, parking lots, sidewalks, plazas, roofs, and drainage infrastructure. Permittees are expected to complete these modifications as a part of completing the Green Infrastructure Plan, and by not later than the end of the permit term.

(i) To the extent not addressed above, a workplan identifying how the Permittee will ensure that green infrastructure and low impact development measures are appropriately included in future plans (e.g., new or amended versions of the kinds of plans listed above).

(j) A workplan to complete prioritized projects identified as part of a Provision C.3.e Alternative Compliance program or part of Provision C.3.j Early Implementation.

(k) An evaluation of prioritized project funding options, including, but not limited to: Alternative Compliance funds; grant monies, including transportation project grants from federal, State, and local agencies; existing Permittee resources; new tax or other levies; and other sources of funds.

(3) Adopt policies, ordinances, and/or other appropriate legal mechanisms to ensure implementation of the Green Infrastructure Plan in accordance with the requirements of this provision.

(4) Conduct outreach and education in accordance with the following:

(a) Conduct public outreach on the requirements of this provision, including outreach coordinated with adoption or revision of standard specifications and planning documents, and with the initiation and planning of infrastructure projects. Such outreach shall include general outreach and targeted outreach to and training for professionals involved in infrastructure planning and design.

(b) Train appropriate staff, including planning, engineering, public works maintenance, finance, fire/life safety, and management staff on the requirements of this provision and methods of implementation.

(c) Educate appropriate Permittee elected officials (e.g., mayors, city council members, county supervisors, district board members) on the requirements of this provision and methods of implementation.

(5) Report on Green Infrastructure Planning as follows:

(a) Each Permittee shall submit documentation in the 2017 Annual Report that its framework or workplan for development of its Green Infrastructure Plan was approved by its governing body, mayor, city manager, or county manager by June 30. 2017.

(b) Each Permittee shall submit its completed Green Infrastructure Plan with the 2019 Annual Report.

(c) Each Permittee shall submit documentation of its legal mechanisms to ensure implementation of its Green Infrastructure Plan with the 2019 Annual Report.

(d) Each Permittee shall submit a summary of its outreach and education efforts in each Annual Report.

ii. Early Implementation of Green Infrastructure Projects (No Missed Opportunities)

Each Permittee shall:

(1) Prepare and maintain a list of green infrastructure projects, public and private, that are already planned for implementation during the permit term and infrastructure projects planned for implementation during the permit term that have potential for green infrastructure measures.

(2) Submit the list with each Annual Report and a summary of planning or implementation status for each public green infrastructure project and each private green infrastructure project that is not also a Regulated Project as defined in Provision C.3.b.ii. Include a summary of how each public infrastructure project with green infrastructure potential will include green infrastructure measures to the maximum extent practicable during the permit term. For any public infrastructure project where implementation of green infrastructure measures is not practicable, submit a brief description of the project and the reasons green infrastructure measures were impracticable to implement.

iii. Participate in Processes to Promote Green Infrastructure

(1) The Permittees shall, individually or collectively, track processes, assemble and submit information, and provide informational materials and presentations as needed to assist relevant regional, State, and federal agencies to plan, design, and fund incorporation of green infrastructure measures into local infrastructure projects, including transportation projects. Issues to be addressed include coordinating the timing of funding from different sources, changes to standard designs and design criteria, ranking and prioritizing projects for funding, and implementation of cooperative in-lieu programs.

(2) In each Annual Report, Permittees shall report on the goals and outcomes during the reporting year of work undertaken to participate in processes to promote green infrastructure.

(3) In the 2019 Annual Report, Permittees shall submit a plan and schedule for new and ongoing efforts to participate in processes to promote green infrastructure.

iv. Tracking and Reporting Progress

(1) The Permittees shall, individually or collectively, develop and implement regionally-consistent methods to track and report implementation of green infrastructure measures including treated area and connected and disconnected impervious area on both public and private parcels within their jurisdictions. The methods shall also address tracking needed to provide reasonable assurance that wasteload allocations for TMDLs, including the San Francisco Bay PCBs and mercury TMDLs, and reductions for trash, are being met.

(2) In each Annual Report, Permittees shall report progress on development and implementation of the tracking methods.

(3) In the 2019 Annual Report, Permittees shall submit the tracking methods and report implementation of green infrastructure measures including treated area, and connected and disconnected impervious area on both public and private parcels within their jurisdictions.