CONTRA COSTA
CLEAN WATER
PROGRAM

Urban Creeks Monitoring Report
Water Year 2017
(October 2016 – September 2017)

Submitted to the San Francisco Bay and
Central Valley Regional Water Quality Control Boards
in Compliance with NPDES Permit
Provisions C.8.h.iii and C.8.g.iii

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A Program of Contra Costa County, its Incorporated Cities and Towns,
and the Contra Costa Flood Control & Water Conservation District

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This report is submitted by the agencies of the

Program Participants:

- Cities and Towns of: Antioch, Brentwood, Clayton, Concord, Danville (Town), El Cerrito, Hercules, Lafayette, Martinez, Moraga (Town), Oakley, Orinda, Pinole, Pittsburg, Pleasant Hill, Richmond, San Pablo, San Ramon and Walnut Creek
- Contra Costa County
- Contra Costa County Flood Control & Water Conservation District

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List of Acronyms and Abbreviations

ACCWP	Alameda County Clean Water Program
BASMAA	Bay Area Stormwater Management Agencies Association
B-IBI	benthic index of biological integrity
BMI	benthic macroinvertebrate
BMP	best management practice
CCCWP	Contra Costa Clean Water Program
CCFCD	Contra Costa Flood Control District
CSCI	California Stream Condition Index
CVRWQCB	Central Valley Regional Water Quality Control Board
CV Permit	East Contra Costa County Municipal NPDES Permit, Order No. R5-2010-0102
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
FSURMP	Fairfield-Suisun Urban Runoff Management Program
GI plan	green infrastructure plan
IBI	index of biological integrity
IMS	information management system
IPM	integrated pest management
MCL	maximum contaminant level
mg/L	milligram per liter
MMI	multi-metric index
MPC	BASMAA Monitoring and Pollutants of Concern Committee
MRP	Municipal Regional Permit
MRP 1.0	Order R2-2009-0079
MRP 2.0	Order R2-2015-0049
MWAT	maximum weekly average temperature
NPDES	National Pollutant Discharge Elimination System
pH	hydrogen ion concentration
PHab	physical habitat
P/S Studies	Pilot and Special Studies
PCBs	polychlorinated biphenyls
POC	pollutants of concern
QAPP	quality assurance project plan
RMC	BASMAA Regional Monitoring Coalition
RMP	Regional Monitoring Program for Water Quality in the San Francisco Estuary
RWQCB	regional water quality control board
S&T Program	Status & Trends Monitoring Program
SAP	sampling and analysis plan
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SFEI	San Francisco Estuary Institute
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
SOP	standard operating procedure
SSID	stressor/source identification
STLS	small tributaries loading strategy
SWAMP	Surface Water Ambient Monitoring Program
TMDL	total maximum daily load
TU	toxicity units

UCMR	Urban Creeks Monitoring Report
WLA	wasteload allocation
WQO	water quality objective
WY	water year

Table 1. Water Year 2017 Summary Table

Site ID	Creek Name	Land Use	Latitude	Longitude	Bioassessment	Nutrient	Chlorine	Water Column Toxicity (dry)	Sediment Toxicity & Chemistry	Pathogen Indicators	Temperature Loggers	General Water Quality	Water Column Pesticides and Toxicity (wet)[1]
204R01412	West Branch Alamo Creek	Region 2, Urban	37.99069	-122.13252				X	X	X			
207R01447	Franklin Creek	Region 2, Urban	37.99069	-122.13252							X		
207R01547	Grayson Creek	Region 2, Urban	37.98729	-122.06967	X								
207R01591	Tributary of Walnut Creek	Region 2, Urban	37.99442	-122.03566	X								
207R01595	Mt. Diablo Creek	Region 2, Urban	37.95949	-121.96674	X								
207R01643	Mt. Diablo Creek	Region 2, Urban	37.92581	-121.92104	X								
207R01675	Sans Crainte Creek	Region 2, Urban	37.87660	-122.02369	X					X			
207R01812	Sycamore Creek	Region 2, Urban	37.81161	-121.98097	X								
204R01819	Tributary of Laguna	Region 2, Urban	37.85246	-122.12644	X								
207R01847	Pine Creek	Region 2, Urban	37.96457	-122.04116	X								
207R01860	Sycamore Creek	Region 2, Urban	37.81677	-121.92161	X								
207R01931	San Ramon Creek	Region 2, Urban	37.86655	-122.03974	X								
207R02635	Las Trampas Creek	Region 2, Urban	37.89031	-122.07461							X	X	
207R02891	Las Trampas Creek	Region 2, Urban	37.88673	-122.09715						X	X		
207R03403	Walnut Creek	Region 2, Urban	37.90381	-122.05921						X			
207R04544	Alhambra Creek	Region 2, Urban	38.00026	-122.12993						X	X	X	

1 Per RMC decision, with Regional Water Board staff concurrence, in accordance with MRP 2.0 provision C.8.g.iii.(3), this monitoring will commence in WY 2018.

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Executive Summary

This Urban Creeks Monitoring Report (UCMR) was prepared by the Contra Costa Clean Water Program (CCCWP) per the Municipal Regional Permit (MRP) for urban stormwater issued by the San Francisco Bay Regional Water Quality Control Board (SFRWQCB; Order No. R2-2015-0049, MRP 2.0) and the East Contra Costa County Municipal NPDES Permit (Central Valley Permit) issued by the Central Valley Regional Water Quality Control Board (CVRWQCB; Order No. R5-2010-0102). This report, including all appendices and attachments, fulfills the requirements of MRP 2.0 provision C.8.h.iii (and C.8.g.iii for Central Valley Permit) for interpreting and reporting monitoring data collected during water year (WY) 2017 (October 1, 2016-September 30, 2017). Monitoring discussed herein was performed in accordance with the Central Valley Permit and MRP 2.0. Key technical findings are summarized below and presented in more detail in the body of the report and in its corresponding appendices.

Coordination of Third Party Monitoring (C.8.a)

In WY 2017, Contra Costa Clean Water Program (CCCWP) worked with third-party water quality monitoring partners to benefit local, regional and statewide monitoring efforts. Provisions C.8.a.iii allows Permittees to work with third-party organizations such as the State Water Quality Control Board, or Department of Pesticide Regulation to fulfill monitoring requirements provided that data meets water quality objectives described in Provision C.8.b. Two locations in Contra Costa were sampled as part of the Surface Water Ambient Monitoring Program (SWAMP); Kirker Creek and Walnut Creek were assessed for pesticide pollution and toxicity through the Stream Pollution Trends (SPoT) Program. SPoT monitors trends in sediment toxicity and sediment contaminant concentrations in selected large rivers throughout California, and relate contaminant concentrations and toxicity to watershed land uses.

CCCWP staff and other designated representatives participated with the Regional Monitoring Program for Water Quality in San Francisco Bay's (RMP) Small Tributaries Loading Strategy (STLS) to conduct monitoring at Contra Costa sites. A summary report of the RMP data is presented in the Pollutants of Concern Reconnaissance Monitoring, Water Years 2015, 2016, and 2017, Draft Progress Report (Appendix 5), and are used to supplement some of the compliance required in Provision C.8.

In addition, CCCWP supports efforts by local creek groups to monitor San Pablo, Wildcat, Walnut, Grayson, and Marsh Creek Watersheds.

Monitoring Protocols and Data Quality (C.8.b)

Permittees are required to report annually on water quality data collected in compliance with MRP 2.0. For creek status monitoring, the Regional Monitoring Coalition (RMC) adapted existing creek status monitoring Standard Operating Protocols (SOPs) and Quality Assurance Project Plan (QAPP) developed by the Surface Water Ambient Monitoring Program (SWAMP) to document the field procedures necessary to maintain comparable, high quality data among RMC participants. Additionally, the RMC participants developed an Information Management System (IMS) to provide SWAMP-compatible storage and import/export of creek status data for all RMC programs.

For POC loads monitoring, BASMAA contracted with Dan Sterns to configure a design and maintain an IMS for management of POC data collected by the RMC programs. Local agencies conduct quality assurance review of the data collected by RMC programs, consistent with the QAPP for data collected. The IMS provides standardized data storage formats which allow RMC participants to share data among themselves and to submit data electronically to the SFBRWQCB and CVRWQCB.

San Francisco Estuary Receiving Water Monitoring (C.8.c)

The CCCWP contributes to the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). Specifically, the Status & Trends Monitoring Program (S&T Program) and the Pilot and Special Studies (P/S Studies) efforts are useful tools for the CCCWP. Brief descriptions of the S&T Program and P/S Studies are provided below. Findings of Status & Trends Monitoring and Pilot and Special Studies results are summarized and/or referenced in the body of this report.

RMP Status Trends Monitoring Program

The S&T Program is the long-term contaminant monitoring component of the RMP. The S&T Program was initiated as a pilot study in 1989 and was redesigned in 2007 based on a more rigorous statistical design aimed to enable the detection of trends. In WY 2017, the S&T Program was composed of the 5 following program elements:

1. Long-term water, sediment, and bivalve monitoring
2. Episodic toxicity monitoring
3. Sport fishing monitoring
4. USGS hydrographic and sediment transport studies
    a. Factors controlling suspended sediment in San Francisco Bay
    b. USGS monthly water quality data
5. Triennial bird egg monitoring (cormorant and tern)

Additional information on the S&T Program and associated monitoring data are available for download via the RMP website using the Status and Trends Monitoring Data Access Tool at http://www.sfei.org/rmp#tab-1-2.

RMP Pilot and Special Studies

The RMP conducts pilot and special studies on an annual basis through committees, workgroups and strategy teams. Studies usually are designed to investigate and develop new monitoring measures related to anthropogenic contamination or contaminant effects on biota in the estuary. Special studies address specific scientific issues that RMP committees and standing workgroups identify as priority for further study. These studies are developed through an open selection process at the workgroup level and are selected for further funding through RMP committees. Results and summaries of the most pertinent pilot and special studies can be found on the RMP web site (http://www.sfei.org/rmp).

Participation in Committees, Workgroups and Strategy Teams

In WY 2017, CCCWP and BASMAA staff participated in some of the RMP committees and workgroups:

- Steering Committee (SC)
- Technical Review Committee (TRC)
- Sources, Pathways and Loadings Workgroup (SPLWG)
- Emergent Contaminant Workgroup (ECWG)
- Nutrient Technical Workgroup
- Strategy teams (e.g., Small Tributaries, PCBs)

Committee and workgroup representation was provided by CCCWP, storm water program staff and/or individuals designated by RMC participants and the BASMAA board of directors. Representation included participation in meetings, review of technical reports and work products, co-authoring or review of articles included in the RMP's *Pulse of the Estuary*, and general program direction to RMP staff. Representatives of the RMC also provided timely summaries and updates to and received input from stormwater program representatives (on behalf of the permittees) during meetings of the MPC and/or BASMAA board of directors to ensure the permittees' interests were represented.

Creek Status Monitoring (C.8.d)

Creek status monitoring is intended to assess the chemical, physical, and biological impacts of urban runoff on receiving waters. The monitoring required by this provision is intended to answer the following questions:

- Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers and tributaries?
- Are conditions in local receiving waters supportive of or likely to be supportive of beneficial uses?

The RMC monitoring strategy for complying with MRP 2.0 requirements includes continuing a regional ambient/probabilistic monitoring (Appendix 1) component, and a component based on local/targeted monitoring (Appendix 2), as in the previous permit term. During WY 2017, 10 sites were monitored under the regional/probabilistic design for bioassessment, physical habitat, and related water chemistry parameters. One of the 10 bioassessment sites from WY 2016 was targeted for monitoring of water and sediment toxicity and sediment chemistry. In WY 2017, within Contra Costa County, targeted monitoring was conducted at four continuous water temperature monitoring locations, two general water quality monitoring locations, and five pathogen indicator monitoring locations. Findings from this monitoring are summarized in the body of this report and described in detail in the appendices.

Stressor/Source Identification (SSID) Projects (C.8.e)

MRP 2.0 requires stressor/source identification (SSID) projects to be considered when any monitoring result(s) trigger a candidate for a follow-up project. A summary of the BASMAA RMC SSID projects initially proposed for MRP 2.0 is attached as Appendix 3.

With agreement of the SFBRWQCB and CVRWQCB staff, CCCWP will be investigating the potential causes of fish kills observed in lower Marsh Creek as its MRP 2.0 SSID study. Over the past twelve years, nine fish kill occurrences were documented in lower Marsh Creek in the City of Brentwood. These events have been often associated with intermittent flows with various antecedent dry periods. The most recent event occurred in October 2017. The CVRWQCB has directed the City of Brentwood to develop a plan to conduct additional monitoring near the City's wastewater treatment plant (WWTP) and stormwater discharges to Marsh Creek. The storm event sampling shall occur during the first rain event and any other rain event of the water year forecasted for at least 0.10 inch in a twenty-four (24) hour period that is preceded by at least 30 days of dry weather.

In addition to potentially low in-stream dissolved oxygen (DO) levels, pesticide contaminants may have played a role in the fish kills. A conceptual model identifies data gaps that need to be addressed through monitoring. The conceptual model for Marsh Creek fish kills includes the assumption that low DO is the most common cause of fish kills, but also that there are other potential causative factors in Marsh Creek that are not exclusive of low DO. An investigation of the potential role of pyrethroid pesticides, daily oscillations of DO and hydrogen ion concentration (pH), variations in temperature, storm events and episodic dry weather discharges will be conducted. Monitoring of stormwater and dry weather discharges will include flow or turbidity triggered sampling to capture samples from dry weather discharge events to characterize the types and concentrations of toxic pollutants, with an emphasis on pyrethroids and other pesticides used in the watershed. As part of developing this work plan, a more detailed analysis of the fish kill history will be developed that includes the timing of fish kills, along with antecedent weather and flow conditions. The daily variation of water quality downstream of the WWTP is a data gap that will be addressed through monitoring in this study.

The work plan for this SSID investigation is currently under development. The project planning takes into consideration related studies performed elsewhere within the San Francisco Bay Area, including prior SSID projects performed as part of MRP 1.0 compliance by the Santa Clara Valley Pollution Prevention Program in Guadalupe River (relating to fish kills and reports of low DO readings) and Coyote Creek (low DO readings), as well as monitoring data generated by CCCWP during both MRP 1.0 and MRP 2.0, involving pesticides and toxicity to aquatic species.

Pollutants of Concern Monitoring (C.8.f)

Pollutants of concern (POC) load monitoring is intended to assess inputs of POCs to the bay from local tributaries and urban runoff, assess progress toward achieving wasteload allocations (WLAs) for total maximum daily loads (TMDLs), and help resolve uncertainties associated with loading estimates for these pollutants. An updated QAPP and SOP were developed in WY 2016 to implement the POC, toxicity, and pesticide monitoring requirements in MRP 2.0 provisions C.8.f and C.8.g.

Since 2014, CCCWP and permittee staff has conducted source area to delineate high opportunity parcels and areas for consideration of property referrals and focused implementation planning for PCBs and mercury load reductions. Street dirt, drop inlet sediments and stormwater runoff were sampled to locate high opportunity areas for PCBs source property referral and abatement. Additionally, stormwater monitoring was conducted in targeted locations for copper, nutrients and methylmercury. Infiltration monitoring was performed at bioretention treatment facilities to build data on infiltration potential for stormwater treatment. A summary report of these data is presented in the Pollutants of Concern Monitoring Report: Water Year 2017 Sampling and Analysis (Appendix 4).

MRP 2.0 places an increased focus on finding watersheds, source areas, and source properties potentially more polluted and upstream from sensitive bay margin areas (high leverage). To support this focus, a stormwater characterization monitoring program was developed and implemented beginning in WY 2015 by the RMP. This same design was implemented in the winter of WY 2017 at the following five locations: Kirker Creek (Pittsburg), East Antioch Creek (Antioch), Little Bull Valley (Carquinez Shoreline, East Bay Parks), Refugio Creek (Hercules), and Rheem Creek at Giant Road (Richmond/San Pablo border). In addition, the RMP is piloting an effort and exploring the use of alternative, un-manned remote suspended sediment samplers. The UCMR summarizes the WY 2017 findings and provides a preliminary interpretation of data collected during WY 2017 (the detailed report is included as Appendix 5). The RMP's POC report is designed to be updated in subsequent years as more data are collected.

CCCWP began implementation of a methylmercury control study in 2012 to fulfill requirements of the Central Valley Permit (c.11.l). A methylmercury control study work plan was prepared 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 waste load allocations. The progress report submitted to the CVRWQB on October 30, 2015 presents preliminary findings of the methylmercury control study work plan monitoring efforts from spring 2012 through spring 2015. A final report will be submitted in October 2018 which will incorporate monitoring efforts conducted since spring 2015.

Pesticides and Toxicity Monitoring (C.8.g)

Pesticides and toxicity monitoring are separated into their own sub-provision in MRP 2.0 (C.8.g). The pesticides/toxicity monitoring requirements are further separated into:

- C.8.g.i. Toxicity in Water Column - Dry Weather
- C.8.g.ii. Toxicity, Pesticides and Other Pollutants in Sediment - Dry Weather, and
- C.8.g.iii. Wet Weather Pesticides and Toxicity Monitoring

The dry weather samples are required at one site in Contra Costa County annually, and accordingly, samples were collected at one site on West Branch Alamo Creek in July 2017, and analyzed for water and sediment toxicity, plus sediment chemistry. All toxicity test results were determined not to be toxic except the *Ceriodaphnia dubia* chronic effects assay for reproduction in the water sample. However, at only 27 percent effect, this test was not required to be repeated by the follow-up provisions of MRP provision C.8.g.iv. (toxicity test results which are less than 50 percent of the control).

Per RMC decision, with Water Board staff concurrence, in accordance with MRP 2.0 provision C.8.g.iii., Wet Weather Pesticides and Toxicity Monitoring will commence in WY 2018 (fall/winter 2017/2018).

In early 2016, the State Water Board began developing “Urban Pesticide Amendments” to the statewide Water Quality Control Plans for the control of pesticide discharges from MS4s, as a project under the statewide Strategy to Optimize Resource Management of Storm Water (Storm Water Strategy; AKA “STORMS”). The STORMS Urban Pesticides Amendments project involves the active participation of CA Department of Pesticide Regulation (DPR) and CASQA, working collaboratively with the Water Boards, and includes three components: (1) MS4 permit requirements, (2) regulatory coordination, and (3) a monitoring program. These three components are expected to provide an appropriate regulatory and scientific framework from which to address the underlying issues of pesticides pollution and associated toxicity in urban receiving waters. The RMC programs help support these efforts by contributing funding through BASMAA to support CASQA’s participation in developing the Amendments.

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1. Introduction

This Urban Creeks Monitoring Report (UCMR) was prepared by the Contra Costa Clean Water Program (CCCWP) per the Municipal Regional Permit (MRP) for urban stormwater issued by the San Francisco Bay Regional Water Quality Control Board (SFRWQCB; Order No. R2-2015-0049) and the East Contra Costa County Municipal NPDES Permit (Central Valley Permit) issued by the Central Valley Regional Water Quality Control Board (CVRWQCB; Order No. R5-2010-0102). This report, including all appendices and attachments, fulfills the requirements of MRP 2.0 (provision C.8.h.iii) and the Central Valley Permit (provision C.8.g.iii) for interpreting and reporting monitoring data collected during water year (WY) 2017 (October 1, 2016-September 30, 2017). All monitoring data presented in this report were submitted electronically to the Water Boards by CCCWP and may be obtained via the San Francisco Bay Area Regional Data Center (http://www.sfei.org/sfeidata.htm).

This report provides brief summaries of the urban creeks monitoring accomplished during WY 2017 in compliance with provision C.8 of the MRP 2.0 and Central Valley Permit. Summaries are organized by the sub-provisions of MRP provision 8, and are grouped as follows:

1. Introduction (C.8.a)
2. Monitoring Protocols and Data Quality (C.8.b)
3. San Francisco Estuary Receiving Water Monitoring (C.8.c)
4. Creek Status Monitoring (C.8.d)
5. Stressor/Source Identification (SSID) Projects (C.8.e)
6. Pollutants of Concern Monitoring (C.8.f)
7. Pesticides and Toxicity Monitoring (C.8.g)

The detailed methods and results associated with these report sections are provided in the appendices to this report, as referenced within the applicable sections of the main body of this report.

Provision C.8.a of the MRP and Central Valley Permit allows permittees to address monitoring requirements either through regional collaboration or individually through their area-wide stormwater programs. In June 2010, permittees notified the SFBRWQCB and CVRWQCB in writing of their agreement to participate in a regional monitoring collaboration to address requirements in provision C.8. The collaboration is known as the Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC), with membership as shown in Table 2. The RMC Work Group is a subgroup of the BASMAA Monitoring and Pollutants of Concern Committee (MPC), which meets and communicates regularly to coordinate planning and implementation of monitoring-related activities. RMC Work Group meetings are coordinated by a RMC coordinator funded by the participating county stormwater programs. This workgroup includes staff from the SFBRWQCB at two levels – those generally engaged with the MRP, as well as those working regionally with the State of California's Surface Water Ambient Monitoring Program (SWAMP). Through the RMC Work Group, the BASMAA RMC developed a Quality Assurance Program Plan (QAPP; BASMAA, 2016a), Standard Operating Procedures (SOPs; BASMAA, 2016b), data management tools, and reporting templates and guidelines. Regionally-implemented activities of the RMC are conducted under the auspices of BASMAA, a 501(c)(3) non-profit organization comprised of the municipal stormwater programs in the San Francisco Bay Area. MRP permittees, through their stormwater program representatives on the board of directors and its subcommittees, collaboratively authorize and participate in BASMAA regional projects and tasks. Regional project costs are shared by either all BASMAA members or among those Phase I municipal stormwater programs subject to MRP 2.0[1].

Table 2. Regional Monitoring Coalition Participants

Stormwater Programs	RMC Participants
Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)	Cities of Campbell, Cupertino, Los Altos, Milpitas, Monte Sereno, Mountain View, Palo Alto, San Jose, Santa Clara, Saratoga, Sunnyvale, Los Altos Hills, and Los Gatos; Santa Clara Valley Water District; and Santa Clara County
Alameda Countywide Clean Water Program (ACCWP)	Cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City; Alameda County; Alameda County Flood Control and Water Conservation District; and Zone 7 Water Agency
Contra Costa Clean Water Program (CCCWP)	Cities/Towns of Antioch, Brentwood, Clayton, Concord, El Cerrito, Hercules, Lafayette, Martinez, Oakley, Orinda, Pinole, Pittsburg, Pleasant Hill, Richmond, San Pablo, San Ramon, Walnut Creek, Danville, and Moraga; Contra Costa County; and Contra Costa County Flood Control and Water Conservation District
San Mateo Countywide Water Pollution Prevention Program (SMCWPPP)	Cities and towns of Belmont, Brisbane, Burlingame, Daly City, East Palo Alto, Foster City, Half Moon Bay, Menlo Park, Millbrae, Pacifica, Redwood City, San Bruno, San Carlos, San Mateo, South San Francisco, Atherton, Colma, Hillsborough, Portola Valley, and Woodside; San Mateo County Flood Control District; and San Mateo County
Fairfield-Suisun Urban Runoff Management Program (FSURMP)	Cities of Fairfield and Suisun City
Vallejo Permittees	City of Vallejo and Vallejo Sanitation and Flood Control District

[1] The BASMAA programs supporting MRP Regional Projects include all MRP Permittees as well as the cities of Antioch, Brentwood, and Oakley which are not named as Permittees under the MRP but have voluntarily elected to participate in MRP-related regional activities.

2. Monitoring Protocols and Data Quality (C.8.b)

Provision C.8.b of the MRP and the Central Valley Permit requires water quality data collected by permittees to comply with and of be of a quality consistent with the State of California's SWAMP standards, set forth in the SWAMP QAPP and SOPs. RMC protocols and procedures were developed to assist permittees with meeting SWAMP data quality standards and to develop data management systems which allow for easy access of water quality monitoring data by permittees.

2.1. Standard Operating and Data Quality Assurance Procedures

For creek status monitoring, the RMC adapted existing SOPs and the QAPP developed by SWAMP to document the field procedures necessary to produce SWAMP-comparable, high quality data among RMC participants. The RMC creek status monitoring program QAPP and SOPs were updated to accommodate MRP 2.0 requirements in March 2016 (Version 3; BASMAA, 2016a and 2016b).

For POC monitoring, a draft SAP and QAPP were developed in 2016 to guide the monitoring efforts for each POC task. CCCWP's monitoring contractor implemented contracts with various laboratories for the analyses of all water and sediment samples.

2.2. Information Management System Development/Adaptation

For creek status monitoring, the RMC participants developed an Information Management System (IMS) to provide SWAMP-compatible storage and import/export of data for all RMC programs, with data formatted in a manner suitable for uploading to CEDEN.

For POC loads monitoring, BASMAA contracted with Dan Sterns to configure a design and maintain an IMS for management of POC data collected by the RMC programs. Local agencies conduct quality assurance review of the data collected by RMC programs, consistent with the QAPP for data collected. The IMS provides standardized data storage formats which allow RMC participants to share data among themselves and to submit data electronically to the SFBRWQCB and CVRWQCB.

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3. San Francisco Estuary Receiving Water Monitoring (C.8.c)

As described in MRP 2.0 provision C.8.c, permittees are required to financially contribute their fair-share on an annual basis toward implementing an estuary receiving water monitoring program which, at a minimum, is equivalent to the RMP. As agreed with the CVRWQCB, all CCCWP permittees (in Region 2 and Region 5) comply with this provision by making financial contributions to the San Francisco Bay Regional Monitoring Program for purposes of increased efficiencies Additionally, permittees actively participate in RMP committees and work groups through permittee and/or stormwater program representatives.

The RMP is a long-term monitoring program which is discharger funded and shares direction and participation by regulatory agencies and the regulated community, with the goal of assessing water quality in San Francisco Bay. The regulated community includes permittees, publicly owned treatment works, dredgers, and industrial dischargers. The RMP is intended to answer the following core management questions:

1. Are chemical concentrations in the estuary potentially at levels of concern and are associated impacts likely?
2. What are the concentrations and masses of contaminants in the estuary and its segments?
3. What are the sources, pathways, loadings, and processes leading to contaminant-related impacts in the estuary?
4. Have the concentrations, masses, and associated impacts of contaminants in the estuary increased or decreased?
5. What are the projected concentrations, masses, and associated impacts of contaminants in the estuary?

The RMP budget is generally broken into two major program elements: status and trends monitoring and pilot/special studies. The RMP publishes reports and study results on their website at www.sfei.org/rmp.

In WY 2017, a significant amount of staff time was spent overseeing and implementing Special Studies associated with the RMP's Small Tributary Loading Strategy (STLS). Pilot and Special Studies associated with the STLS are intended to fill data gaps associated with Pollutants of Concern (POCs) from small tributaries to the SF Bay. A summary report of these studies and data is presented in the Pollutants of Concern Monitoring Report: Water Year 2017 Sampling and Analysis (Appendix 4).

MRP Provision C.8.f. Pollutants of Concern Monitoring, Table 8.2 calls for conducting or causing to conduct a study that addresses relevant management information needs for emerging contaminants, at least alternative flame retardants. The special study must account for relevant CECs in stormwater and would address at least PFOS, PFAS, and alternative flame retardants being used to replace PBDEs. BASMAA representatives are currently helping to develop planning support for stormwater alternative flame retardants conceptual model through the RMP Emerging Contaminants Work Group to address this provision.

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4. Creek Status Monitoring (C.8.d)

MRP 2.0 provision C.8.d requires permittees to conduct creek status monitoring intended to answer the following management questions:

1. Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers, and tributaries?
2. Are conditions in local receiving waters supportive of or likely supportive of beneficial uses?

Creek status monitoring parameters, methods, occurrences, duration, and minimum number of sampling sites for each stormwater program are described in provision C.8.d of MRP 2.0 and provision C.8.c in the Central Valley Permit. Creek status monitoring coordinated through the RMC began in October 2011 and continues annually. Status and trends monitoring was conducted in non-tidally influenced, flowing water bodies (i.e., creeks, streams, and rivers).

4.1. Regional and Local Monitoring Designs

The RMC's regional monitoring strategy for creek status monitoring is described in *Creek Status and Long-Term Trends Monitoring Plan* (BASMAA, 2011). The monitoring methods follow the BASMAA RMC creek status and pesticides and toxicity monitoring program QAPP (Version 3; BASMAA, 2016a). In March 2016, SOPs for creek status and pesticide and toxicity monitoring were updated (Version 3, BASMAA, 2016b). The purpose of these SOPs is to provide RMC participants with a common basis for application of consistent monitoring protocols across jurisdictional boundaries. These protocols form part of the RMC's quality assurance program to help ensure validity of resulting data and comparability with SWAMP protocols. These SOPs complement the comprehensive RMC 2016 QAPP.

The creek status monitoring parameters required by MRP provisions C.8.d and C.8.g are divided into two types: those conducted under a regional probabilistic design, and those conducted under a local, targeted design. This distinction is shown in Table 3 for the required creek status monitoring parameters. The combination of these monitoring designs allows each individual RMC-participating program to assess the status of beneficial uses in local creeks within its program (jurisdictional) area, while also contributing data to answer management questions at the regional scale (e.g., differences between aquatic life condition in urban and non-urban creeks).

Creek status monitoring data were submitted by the CCCWP to the SFBRWQCB and CVRWQCB by March 31, 2018. The analysis of results from creek status monitoring conducted in WY 2017 is presented in Appendix 1 (the regional/probabilistic creek status monitoring report for WY 2017) and Appendix 2 (the local/targeted creek status monitoring report for WY 2017).

Table 3. Creek Status Monitoring Parameters Sampled in Compliance with MRP Provisions C.8.d. and C.8.g. as Either Regional/Probabilistic or Local/Targeted Parameters

Biological Response and Stressor Indicators	Monitoring Design	
	Regional/Probabilistic [1]	Local/Targeted [2]
Bioassessment, physical habitat assessment, CSCI	X	
Nutrients (and other water chemistry associated with bioassessment)	X	
Chlorine	X	
Water toxicity (wet and dry weather)	X	
Water chemistry (pesticides, wet weather) [3]	X	
Sediment toxicity	X	
Sediment chemistry	X	
General water quality (sonde data: temperature, dissolved oxygen, pH, specific conductance)		X
Temperature, continuous (HOBO data loggers)		X
Bacteria		X

1 For full report, see Appendix 1: Regional/Probabilistic Creek Status Monitoring Report, WY 2017

2 For full report, see Appendix 2: Local/Targeted Creek Status Monitoring Report, WY 2017

3 Per RMC decision, with Water Board staff concurrence, in accordance with MRP provision C.8.g.iii.(3), this monitoring will commence in WY 2018.

4.1.1. Regional/Probabilistic Monitoring

The regional/probabilistic creek status monitoring report (Appendix 1) documents the results of monitoring performed by CCCWP during WY 2017 under the regional/probabilistic monitoring design developed by the RMC. During WY 2017, 10 sites were monitored by the CCCWP for bioassessment, physical habitat, and related water chemistry parameters. Due to low California Stream Condition Index (CSCI) scores in WY 2016, one of the 10 bioassessment sites from that preceding water year was targeted to monitor for water and sediment toxicity and sediment chemistry.

RMC probabilistic monitoring sites are drawn from a sample frame consisting of a creek network geographic information system (GIS) data set within the RMC boundary[2] (BASMAA, 2011), including stream segments from all perennial and non-perennial creeks and rivers running through urban and non-urban areas within the portions of the five RMC participating counties within the SFBRWQCB boundary, and the eastern portion of Contra Costa County which drains to the CVRWQCB region. A map of the BASMAA RMC area, equivalent to the area covered by the regional/probabilistic design "sample frame", is shown in Figure 1. The sites selected from the regional/probabilistic design master sample draw and monitored in WY 2017 are shown graphically in Figure 2.

The creek status monitoring results are subject to potential follow-up actions, per MRP 2.0 provisions C.8.d. and C.8.g., if they meet certain specified threshold triggers. If monitoring results meet the requirements for follow-up actions, the results are compiled on a list for consideration as potential Stressor/Source Identification (SSID) projects per MRP 2.0 provision C.8.e. The results are compared to other regulatory standards, including Basin Plan water quality objectives, where available and applicable.

[2] Based on discussion during RMC meetings, with SFBRWQCB staff present, the sample frame was extended to include the portion of Eastern Contra Costa County that ultimately drains to San Francisco Bay to address parallel provisions in CCCWP's Central Valley Region Permit for Eastern Contra Costa County.

Figure 1. BASMAA Regional Monitoring Coalition Area, County Boundaries and Major Creeks

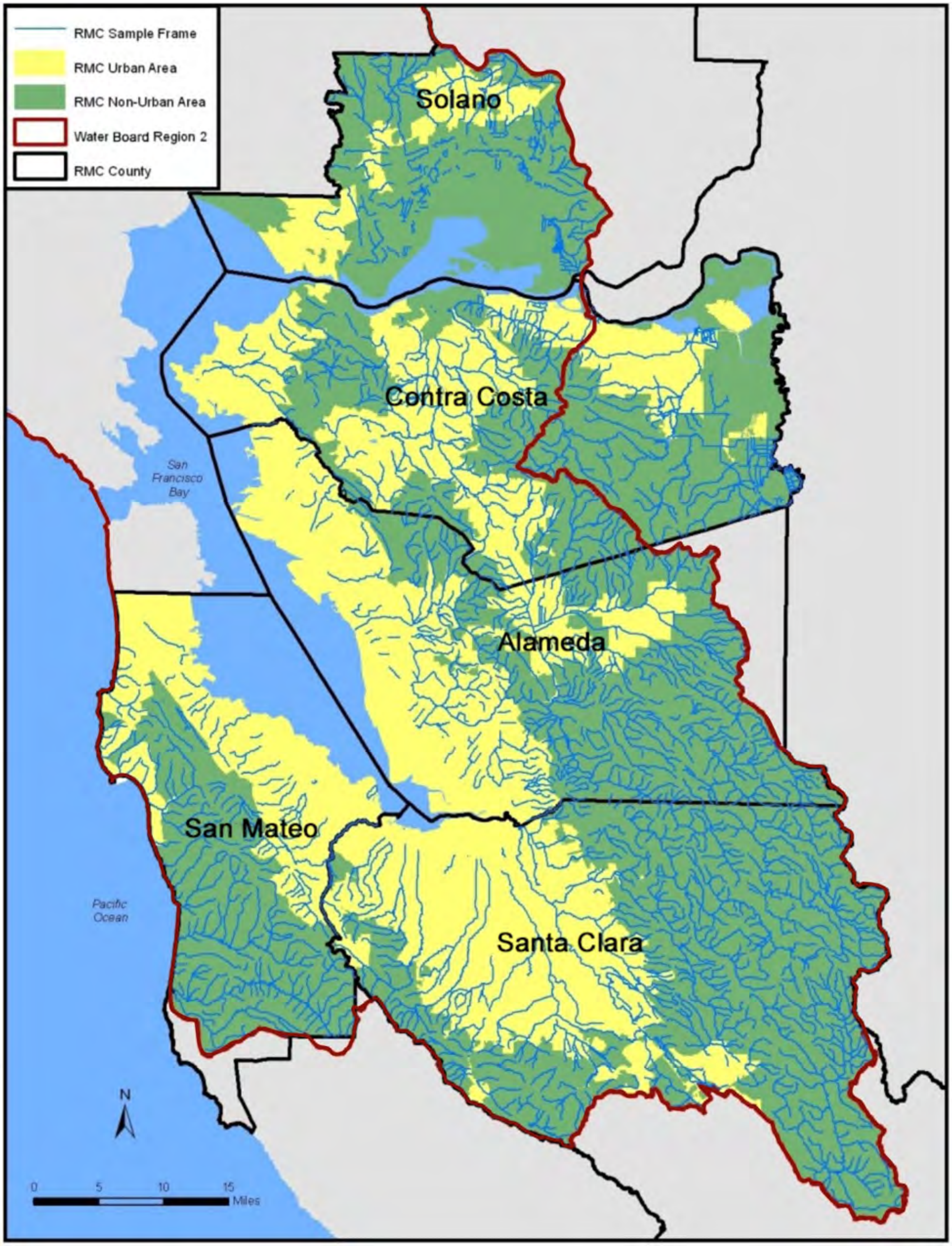
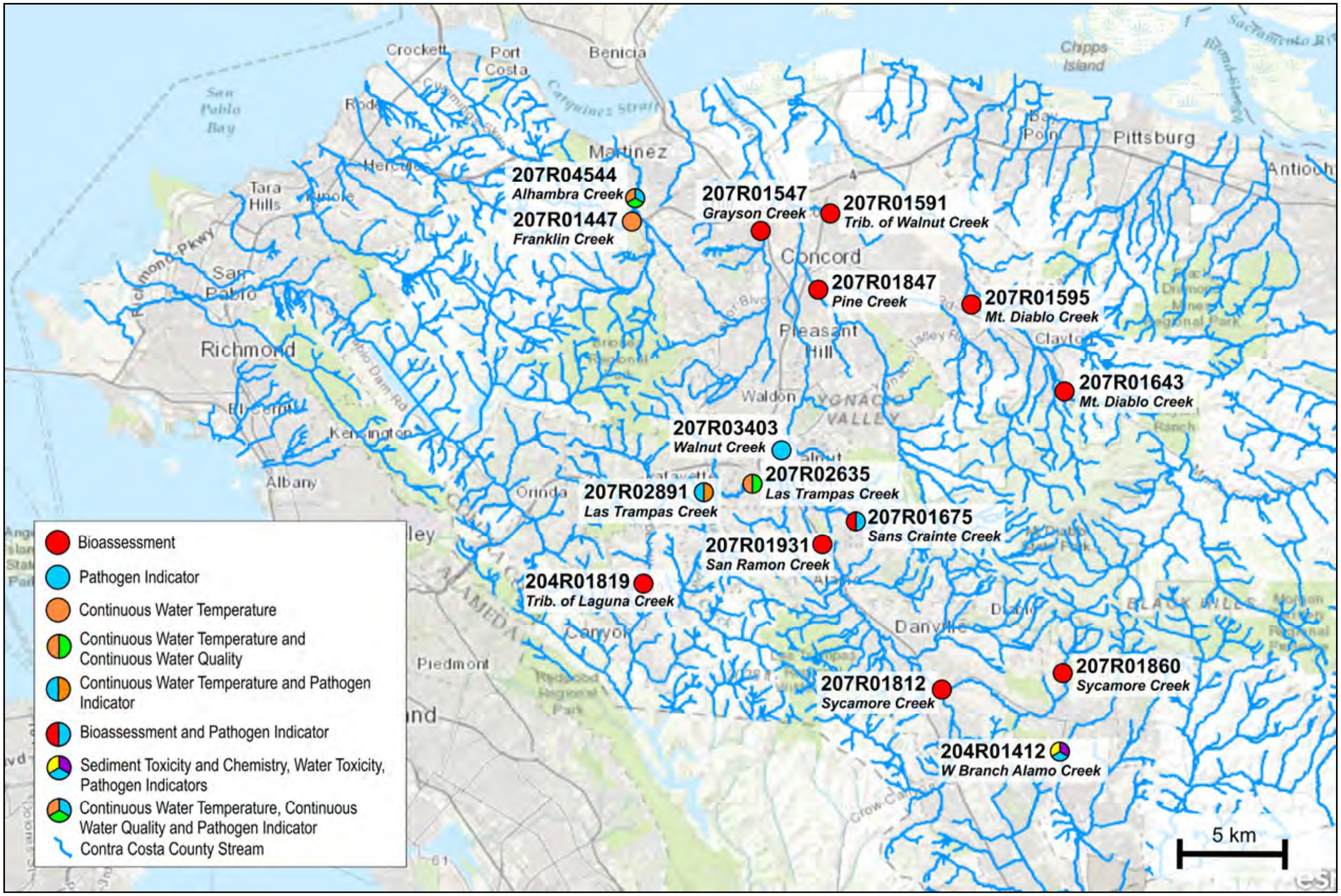


Figure 2. Contra Costa County Creek Status Sites Monitored in Water Year 2017



Note: Bioassessment sites are those selected from the RMC probabilistic monitoring design.

4.1.1.1 Bioassessments

In accordance with the RMC QAPP (BASMAA, 2016a), bioassessments were conducted during the spring index period (approximately April 15-July 15) and typically at a minimum of 30 days after any significant storm event (roughly defined as at least 0.5 inch of rainfall within a 24-hour period). Bioassessments were performed at 10 probabilistic sites in WY 2017.

Each bioassessment monitoring site consisted of an approximately 150-meter (m) stream reach divided into 11 equidistant transects placed perpendicular to the direction of flow. The sampling position within each transect alternated between 25, 50 and 75 percent distance of the wetted width of the stream (see SOP FS-1, BASMAA, 2016b).

Samples were collected and analyzed per SWAMP protocols for benthic macroinvertebrate (BMI) taxonomy, benthic algae taxonomy and related parameters (chlorophyll-*a*, pebble count algae information, and reach-wide algal percent cover, algal biomass as ash-free dry weight), water chemistry (nutrients and related parameters), and physical habitat assessment (per the full SWAMP protocol).

Benthic Macroinvertebrates

The California Stream Condition Index (CSCI) score is computed as the average of two other indices: O/E, the observed taxonomic diversity at the monitoring site divided by the taxonomic composition expected at a reference site with similar geographical characteristics, and the MMI, a multi-metric index incorporating several metrics reflective of BMI community attributes, such as measures of assemblage richness, composition, and diversity, as predicted for a site with similar physical characteristics. The six metrics selected for inclusion in the MMI calculations were taxonomic richness, number of shredder taxa, percent clinger taxa, percent Coleoptera taxa, percent EPT (Ephemeroptera, Plecopter and Trichoptera) taxa, and percent intolerant taxa. For consistency and comparison with the 2012 regional UCMR, subsequent UCMRs, and other RMC programs, the Southern California B-IBI score is also computed for condition assessment in this report.

Algae

Algae taxonomic data are evaluated through a variety of metrics and indices. Eleven diatom metrics, 11 soft algae metrics, and five algal IBIs were calculated following protocols developed from work in Southern California streams. IBI scoring ranges and values were provided by Dr. A. Elizabeth Fetscher. After each metric was scored, values were summed and then converted to a 100-point scale by multiplying the sum by the number of metrics (e.g., sum x (100/50) if five metrics included in the IBI).

Physical Habitat (PHab) Conditions

Physical habitat condition was assessed for the bioassessment monitoring sites using “mini-PHab” scores. Mini-PHab scores range from 0 to 60, representing a combined score of three physical habitat sub-categories (epifaunal substrate/cover, sediment deposition, and channel alteration), each of which can be scored on a range of 0 to 20 points. Higher PHab scores reflect higher quality habitat. Numerous additional PHab endpoints can also be calculated. Further analyses of various PHab endpoints are possible and will be considered in future reports, as the science is further developed.

CSCI Scores

California Stream Condition Index (CSCI) scores were calculated from the CCCWP bioassessment data in WY 2017. CSCI uses location-specific GIS data to compare the observed BMI taxonomic data to expected BMI assemblage characteristics from reference sites with similar geographical characteristics. Sites with a CSCI score lower than 0.795 are considered to represent degraded benthic habitats per the MRP. All ten bioassessment sites monitored during WY 2017 scored below the MRP CSCI threshold.

Nutrients and Conventional Analytes

Water samples were collected for nutrient and other conventional analyses using the standard grab sample collection method, as described in SOP FS-2 (BASMAA, 2016b), at all 10 bioassessment sites. Standard field parameters (temperature, DO, pH and specific conductance) were also measured in the field using a portable multi-meter and sonde.

Of the 12 water quality constituents monitored in association with the bioassessment monitoring, water quality standards or established thresholds are available only for ammonia (unionized form), chloride, and nitrate + nitrite – the latter for waters with MUN beneficial use only. There were no exceedances of those applicable criteria at any of the ten sites monitored in WY 2017.

4.1.1.2 Chlorine

Water samples were collected and analyzed for free and total chlorine in the field (using CHEMetrics test kits) during bioassessment monitoring. No water samples produced measurable levels of free or total chlorine (all results were 0.0).

4.1.2. Local/Targeted Monitoring

The local/targeted creek status monitoring report (Appendix 2) documents the results of targeted monitoring performed by CCCWP during WY 2017. Within Contra Costa County, targeted monitoring was conducted at:

- Four continuous water temperature monitoring locations
- Two general water quality monitoring locations
- Five pathogen indicator monitoring locations

Site locations for WY 2017 were identified using a targeted monitoring design based on the directed principle to address the following management questions:

- What is the range of general water quality measurements at targeted sites of interest?
- Do general water quality measurements indicate potential impacts to aquatic life?
- What are the pathogen indicator concentrations at creek sites where water contact recreation may occur?

During the first five years studied so far, winter seasons were very dry relative to average annual conditions. The last winter season broke this trend, producing above average rainfall, relative to annual conditions. Targeted monitoring data were evaluated against numeric water quality objectives (WQOs) or other applicable criteria, as described in MRP 2.0. None of the targeted monitoring locations sampled in WY 2017 were in the jurisdiction of the Central Valley Permit, so none of the Central Valley Permit thresholds apply. The results are summarized below:

Temperature

Numeric water quality objectives for temperature are defined in MRP 2.0 as follows: for all streams, 20 percent of instantaneous results shall not exceed 24 °C. For streams documented to support steelhead fisheries (i.e. steelhead streams), a maximum temperature of 17 °C is used as the applicable criterion to evaluate temperature data. Per MRP 2.0, if the temperature data is recorded by a HOBO® device, at most, one WAT can reach a threshold of 17 °C. For temperature recorded by sonde devices, all WAT must be below 17 °C.

At the four locations with continuously recorded temperature data from April until September, all four locations (Franklin Creek, Alhambra Creek and two sites at Las Trampas Creek) were classified as steelhead streams. Temperature was continuously monitored by sondes during two time periods (May and July-August of 2017) at Las Trampas Creek and Alhambra Creek. No location where water temperature was measured recorded a 20 percent instantaneous results exceedance of 24 °C. At locations classified as steelhead streams, there were exceedances of the 17 °C threshold in six of eight cases. These locations were Franklin Creek, both locations along Las Trampas Creek, and Alhambra Creek for the HOBO recorded data, and Las Trampas Creek and Alhambra Creek for the sonde recorded data during the August deployment. No exceedance occurred for the sonde recorded data during the May deployment at Las Trampas Creek or Alhambra Creek.

Dissolved Oxygen

WQOs for dissolved oxygen (DO) in non-tidal waters are applied as follows: for waters designated as steelhead habitat, less than 20 percent of instantaneous DO results may drop below 7.0 mg/L.

At those locations classified as steelhead streams, there were exceedances during the August deployment at both Las Trampas Creek and Alhambra Creek, where 40 percent and 100 percent of DO concentrations were measured below the threshold, respectively.

pH

WQOs for pH in surface waters are defined as follows: less than 20 percent of instantaneous pH results may fall outside the range of 6.5 to 8.5. This range was used to evaluate the pH data collected at all targeted locations over WY 2017.

During both monitoring periods, pH measurements at Las Trampas Creek and Alhambra Creek did not exceed stated WQOs.

Specific Conductance

WQOs for specific conductance in surface waters are applied as follows: less than 20 percent of instantaneous specific conductance results may exceed 2,000 µS/cm, or readings should not detect any spike in specific conductance with no obvious natural explanation.

During both monitoring periods, specific conductance measurements at Las Trampas Creek and Alhambra Creek did not exceed stated WQOs.

Pathogen Indicator Bacteria

Single sample maximum concentrations of 130 CFU/100 ml enterococci and 410 CFU/100 ml *E. coli* (EPA, 2012) were used as water contact recreation evaluation criteria for the purposes of this evaluation.

For enterococci, four out of five single sample concentrations (West Branch Alamo Creek, Sans Crainte Creek, Las Trampas Creek, and Alhambra Creek) exceeded the applicable threshold criteria. For *E. coli,* three of the five stations (Sans Crainte Creek, Las Trampas Creek, and Alhambra Creek) exceeded the single sample maximum concentration for water contact recreation criteria.

CCCWP will continue to conduct monitoring for local/targeted parameters in WY 2018.

4.1.3. Summary of MRP Trigger Exceedances

A summary of all MRP trigger exceedances for Regional/Probabilistic and Local/Targeted creek status monitoring during WY 2017 is included in Table 4.

All permit-related water quality threshold exceedances will be included in a compilation of water quality triggers for consideration by the RMC as potential SSID projects, and for other potential follow-up investigations and/or monitoring.

Table 4. CCCWP Threshold Exceedances for Water Year 2017

Creek	Index Period	Parameter	Criterion Exceedance
Franklin Creek	June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or 20 percent of instantaneous results > 24 °C
Las Trampas Creek (at Camino Posada Court)	May 3-May 9, 2017; May 17-May 23, 2017; May 31-June 6, 2017; June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or 20 percent of instantaneous results > 24 °C
Las Trampas Creek (at Camino Posada Court)	July 31-August 11, 2017	Continuous Water Temperature (sonde)	One WAT exceeds 17 °C or 20 percent of instantaneous results > 24 °C
Las Trampas Creek (at Camino Posada Court)	July 31-August 11, 2017	Continuous Water Quality – Dissolved Oxygen	20 percent of instantaneous results drop below 7.0 mg/L
Las Trampas Creek (at Reliez Station Road)	May 17-May 23, 2017; May 31-June 6, 2017; June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or 20 percent of instantaneous results > 24 °C
Alhambra Creek	May 31-June 6, 2017; June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or 20 percent of instantaneous results > 24 °C
Alhambra Creek	July 31-August 11, 2017	Continuous Water Temperature (sonde)	One WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Alhambra Creek	July 31-August 11, 2017	Continuous Water Quality - Dissolved Oxygen	20 percent of instantaneous results drop below 7.0 mg/L
West Branch Alamo Creek	July 24, 2017	Enterococci	Single grab sample exceeds USEPA criterion of 130 CFU/100ml
Sans Crainte Creek	July 24, 2017	Enterococci	Single grab sample exceeds USEPA criterion of 130 CFU/100ml
Las Trampas Creek (at Reliez Station Road)	July 24, 2017	Enterococci	Single grab sample exceeds USEPA criterion of 130 CFU/100ml
Alhambra Creek	July 24, 2017	Enterococci	Single grab sample exceeds USEPA criterion of 130 CFU/100ml
Sans Crainte Creek	July 24, 2017	*E. Coli*	Single grab sample exceeds USEPA criterion of 410 CFU/100ml
Las Trampas Creek (at Reliez Station Road)	July 24, 2017	*E. Coli*	Single grab sample exceeds USEPA criterion of 410 CFU/100ml
Alhambra Creek	July 24, 2017	*E. Coli*	Single grab sample exceeds USEPA criterion of 410 CFU/100ml
West Branch Alamo Creek	July 13, 2017	Sediment Chemistry: Cu TEC	TEC ratio > 1.0
West Branch Alamo Creek	July 13, 2017	Sediment Chemistry: Ni TEC	TEC ratio > 1.0
West Branch Alamo Creek	July 13, 2017	Sediment Chemistry: Zinc TEC	TEC ratio > 1.0
Tributary of Laguna Creek	June 1, 2017	BMI Taxonomy (CSCI Score)	CSCI < 0.795
Grayson Creek	May 31, 2017	BMI Taxonomy (CSCI Score)	CSCI < 0.795
Tributary of Walnut Creek	May 17, 2017	BMI Taxonomy (CSCI Score)	CSCI < 0.795
Mt. Diablo Creek	May 17, 2017	BMI Taxonomy (CSCI Score)	CSCI < 0.795
Mt. Diablo Creek	May 15, 2017	BMI Taxonomy (CSCI Score)	CSCI < 0.795
Sans Crainte Creek	May 15, 2017	BMI Taxonomy (CSCI Score)	CSCI < 0.795
Sycamore Creek	May 18, 2017	BMI Taxonomy (CSCI Score)	CSCI < 0.795
Pine Creek	May 30, 2017	BMI Taxonomy (CSCI Score)	CSCI < 0.795
Sycamore Creek	May 16, 2017	BMI Taxonomy (CSCI Score)	CSCI < 0.795
San Ramon Creek	June 15, 2017	BMI Taxonomy (CSCI Score)	CSCI < 0.795

WAT weekly average temperature
TEC threshold effect concentration
CSCI California Stream Condition Index

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5. Stressor/Source Identification Studies (C.8.e)

MRP 2.0 requires a minimum of eight new SSID projects for permittees who participate in a regional collaborative, with at least one project for toxicity. The process for identifying MRP 2.0 SSID projects includes the following elements:

- Annually update the trigger exceedance matrix template to accommodate MRP 2.0 thresholds (including pyrethroid TUs)
- RMC programs jointly consider the threshold trigger results and contemplate potential SSID Projects
- Eight SSID projects are required during the permit term, with the one required project estimated for CCCWP beginning by the third year of the permit term (i.e., WY 2018)

The threshold exceedances listed in Table 4 are combined with similar information from the other RMC Programs in a regional table listing threshold exceedances from WY 2016 and 2017 monitoring, to be considered for potential SSID Projects in conformance with MRP 2.0 requirements. The accumulated CCCWP MRP 2.0 data have produced several results with the potential to be considered SSID projects. For local/targeted parameters, the data trigger thresholds exceeded in WY 2016/2017 monitoring include temperature, DO, conductivity, and bacteria (*E. coli* and enterococci). For the regional/probabilistic parameters, the only notable thresholds triggered by WY 2016/2017 data involve sediment chemistry, specifically pyrethroid pesticide toxic unit equivalents (WY 2016 only), and all WY 2016 and 2017 bioassessment sites (CSCI below threshold). POC monitoring results also point to the potential for a project involving mercury and PCBs. The RMC has been discussing potential regional SSID projects as indicated by WY 2015-2017 data that trigger MRP 2.0 threshold exceedances. A summary of the BASMAA RMC SSID projects initially proposed for MRP 2.0 is attached as Appendix 3.

With agreement of the SFBRWQCB and CVRWQCB staff, CCCWP will be investigating the potential causes of fish kills observed in lower Marsh Creek as its MRP 2.0 SSID study. Over the past twelve years, nine fish kill occurrences were documented in lower Marsh Creek in the City of Brentwood. These events have been often associated with intermittent flows with various antecedent dry periods. The most recent event occurred in October 2017. The CVRWQCB has directed the City of Brentwood to develop a plan to conduct additional monitoring near the City's wastewater treatment plant (WWTP) and stormwater discharges to Marsh Creek. The storm event sampling shall occur during the first rain event and any other rain event of the water year forecasted for at least 0.10 inch in a twenty-four (24) hour period that is preceded by at least 30 days of dry weather.

In addition to potentially low in-stream DO levels, pesticide contaminants may have played a role in the fish kills. A conceptual model identifies data gaps that need to be addressed through monitoring. The conceptual model for Marsh Creek fish kills includes the assumption that low DO is the most common cause of fish kills, but also that there are other potential causative factors in Marsh Creek that are not exclusive of low DO. An investigation of the potential role of pyrethroid pesticides, daily oscillations of DO and pH, variations in temperature, storm events and episodic dry weather discharges will be conducted. Monitoring of stormwater and dry weather discharges will include flow or turbidity triggered sampling to capture samples from dry weather discharge events to characterize the types and concentrations of toxic pollutants, with an emphasis on pyrethroids and other pesticides used in the watershed. As part of developing this work plan, a more detailed analysis of the fish kill history will be developed that includes the timing of fish kills, along with antecedent weather and flow conditions. The daily variation of water quality downstream of the WWTP is a data gap that will be addressed through monitoring in this study.

The work plan for this SSID investigation is currently under development. The project planning takes into consideration related studies performed elsewhere within the San Francisco Bay Area, including prior SSID projects performed as part of MRP 1.0 compliance by the Santa Clara Valley Pollution Prevention Program in Guadalupe River (relating to fish kills and reports of low DO readings) and Coyote Creek (low DO readings), as well as monitoring data generated by CCCWP during both MRP 1.0 and MRP 2.0, involving pesticides and toxicity to aquatic species.

6. Pollutants of Concern Monitoring (C.8.f)

Pollutants of Concern (POC) monitoring is required by MRP 2.0 and the Central Valley Permit. Loads monitoring is intended to assess inputs of POCs to the bay from local tributaries and urban runoff, assess progress toward achieving WLAs for TMDLs, and help resolve uncertainties associated with loading estimates for these pollutants. There are five priority POC management information needs to be addressed though POC loads monitoring:

- Source identification
- Contributions to bay impairment
- Management action effectiveness
- Loads and status
- Trends

In October 2017, a POC monitoring report summarizing accomplishments in WY 2017 and the allocation of efforts for WY 2018 was submitted to the SFBRWQCB (CCCWP, 2017). That report fulfills provision C.8.h.iv of MRP 2.0 and describes monitoring goals, CCCWP's dual jurisdiction between the SFBRWQCB and CVRWQCB, lessons learned from prior years of permit implementation, and POC analytical results from currently identified source areas.

During WY 2017, the following monitoring activities were completed to increase CCCWP's understanding of the geographic distribution of PCBs and mercury within the county's urban landscape.

- Countywide street dirt sampling (Tier 1 approach) in areas targeted for historic industrial land uses and halo extent from known areas of elevated PCB concentrations

- Stormwater sampling (Tier 3 approach) in the Rumrill Boulevard and Chesley Avenue areas in the cities of San Pablo and Richmond adjacent to a suspected source property for PCBs and mercury to confirm if elevated concentrations are present in runoff

- Stormwater sampling for mercury and methylmercury in Marsh Creek during upper watershed discharge

Additionally, stormwater sampling for copper and nutrients was performed in lower Marsh Creek and lower Walnut Creek to satisfy specific permit requirements for monitoring of these POCs. Finally, BMP effectiveness monitoring for infiltration to native soil was performed at six bioretention BMPs in the City of Pittsburg. More sites will be monitored as opportunities arise.

All monitoring activities were performed in accordance with CCCWP's POC Sampling and Analysis Plan (SAP) and QAPP guidance documents (ADH and AMS, 2016a; ADH and AMS, 2016b). Results are presented in Appendix 4. Additional monitoring information, background and context, including a discussion of permit-driven goals, can be found in the CCCWP WY 2017 POCs monitoring report (CCCWP, 2017).

MRP 2.0 places an increased focus on finding watersheds, source areas, and source properties potentially more polluted and upstream from sensitive bay margin areas (high leverage). To support this focus, a stormwater characterization monitoring program was developed and implemented beginning in WY 2015 by the San Francisco Bay Regional Monitoring Program, through the Small Tributaries Loading Strategy, a subgroup of the Sources Pathways and Loadings Workgroup. This same design was implemented in the winter of WY 2017 at the following five locations: Kirker Creek (Pittsburg), East

Antioch Creek (Antioch), Little Bull Valley (Carquinez Shoreline, East Bay Parks), Refugio Creek (Hercules), and Rheem Creek at Giant Road (Richmond/San Pablo border). In addition, the RMP is piloting an effort and exploring the use of alternative, un-manned remote suspended sediment samplers. The UCMR summarizes the WY 2017 findings and provides a preliminary interpretation of data collected during WY 2017 (the detailed report is included as Appendix 5). The RMP's POC report is designed to be updated in subsequent years as more data are collected.

6.1. Sampling and Analysis Plan and Quality Assurance Project Plan

A Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP) were developed in WY 2016 to implement the new requirements of MRP 2.0 (ADH and AMS, 2016a and 2016b). The SAP's primary focus is to memorialize field sampling (procedures, documentation and methods) and analytical methods, which will be used to conduct analyses and testing in accordance with the MRP 2.0 provision C.8.f and C.8.g requirements. The 2016 SAP and QAPP will be updated as necessary to remain accurate with monitoring and analytical procedures.

7. Pesticides and Toxicity Monitoring (C.8.g)

As of MRP 2.0, pesticides and toxicity monitoring is a new section in the UCMR. During WY 2017, dry weather pesticides and toxicity monitoring was conducted at one site in Contra Costa County, West Branch Alamo Creek (204R01412), as summarized below. Per RMC decision, with Water Board staff concurrence, wet weather pesticide monitoring will commence in WY 2018. The full reporting of the pesticides and toxicity monitoring is included in Appendix 1, along with the rest of the regional/probabilistic creek status monitoring.

The RMC QAPP and SOPs were updated in WY 2016 to implement the new requirements of MRP 2.0 provision C.8.g (BASMAA, 2016a and 2016b).

7.1. Toxicity in Water Column – Dry Weather (C.8.g.i)

Water samples were collected on July 13, 2017 from one regional/probabilistic monitoring site (West Branch Alamo Creek, site 204R01412), and tested for toxicity to several different aquatic species, as required by MRP 2.0.

All test results were determined not to be toxic except one: the *Ceriodaphnia dubia* chronic effects assay for reproduction. The average reproduction for the Rimer Creek test samples was 22.0 neonates/female, compared to 30.2 neonates/female for the control samples. At 73 percent of the control result (27 percent effect), this test was not required to be repeated by the follow-up provisions of MRP provision C.8.g.iv. (toxicity test results which are less than 50 percent of the control).

The *Ceriodaphnia* chronic water sample test included one replicate that was determined to be a statistical outlier, but even when the outlier data point was included in the analysis, the result still was not less than 50 percent of the control (at 34 percent effect).

Water toxicity test results are shown in Appendix 1.

7.2. Toxicity, Pesticides and Other Pollutants in Sediment – Dry Weather (C.8.g.ii)

Sediment samples were collected on July 13, 2017 after water samples were collected at the same regional/probabilistic monitoring site sampled for water column toxicity (West Branch Alamo Creek, site 204R01412), and tested for acute toxicity (survival) to *Hyalella azteca* and *Chironomus dilutus*. The sample was not determined to be toxic to either of the two sediment test species. The sediment toxicity test results are shown in Appendix 1.

The sediment sample also was tested for a suite of potential sediment pollutants, as required by the MRP, and the results were compared to the trigger threshold levels specified for follow up in MRP provision C.8.g.iv. The complete sediment chemistry results are shown in Appendix 1.

Pyrethroid pesticides were again detected (five of seven analytes) in the sediment sample. Another common current-use pesticide, fipronil, was not detected, but all three of the fipronil degradates were detected.

Pyrethroid pesticide concentrations were compared to sediment concentrations known to cause toxicity, based on organic carbon-normalized pyrethroid concentrations, and used to compute toxic unit (TU) equivalents for each pyrethroid. The calculated TU sum for this sample was 0.255, indicating that the sample would not be toxic due to pyrethroid pesticides.

Three constituents exhibited results with a TEC value greater than 1.0 in the West Branch Alamo Creek sediment sample: copper, nickel and zinc. These three metals are among the most common urban stormwater pollutants. Nickel is a naturally occurring element throughout much of the San Francisco Bay area, and commonly occurs at elevated levels in creek status monitoring.

7.3. Sediment Triad Analysis

Stressor evaluation results for sites with data collected for sediment chemistry, sediment toxicity, and bioassessment parameters by CCCWP over the first five years of the RMC regional/probabilistic monitoring effort (WY 2012-2017) are summarized in Appendix 1.

Pyrethroid pesticide sediment concentrations appear to be potent predictors of sediment toxicity, as samples with calculated pyrethroid TU equivalents greater than 1.0 exhibited significant sediment toxicity. The samples with TU equivalents less than 1.0 did not exhibit sediment toxicity, based on the WY 2012-2017 results.

The current and previous regional/probabilistic reports have identified many potentially impacted sites that may deserve further evaluation and/or investigation to provide better understanding of the sources/ stressors that may be contributing to reduced water quality and lower biological condition at those sites.

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Appendix 1

Regional/Probabilistic Creek Status Monitoring Report

Water Year 2017

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CONTRA COSTA
CLEAN WATER
PROGRAM

Regional/Probabilistic Creek Status Monitoring Report Water Year 2017

(October 2016 – September 2017)

Submitted to the San Francisco Bay and Central Valley Regional Water Quality Control Boards in Compliance with NPDES Permit Provisions C.8.h.iii and C.8.g.iii

NPDES Permit Nos. CAS612008 and CAS083313

March 23, 2018

A Program of Contra Costa County, its Incorporated Cities and Towns, and the Contra Costa Flood Control & Water Conservation District

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This report is submitted by the participating agencies of the

CONTRA COSTA
CLEAN WATER
PROGRAM

Program Participants:

- Cities and Towns of: Antioch, Brentwood, Clayton, Concord, Danville (Town), El Cerrito, Hercules, Lafayette, Martinez, Moraga (Town), Oakley, Orinda, Pinole, Pittsburg, Pleasant Hill, Richmond, San Pablo, San Ramon and Walnut Creek
- Contra Costa County
- Contra Costa County Flood Control & Water Conservation District

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In addition to the Regional Monitoring Coalition participants, San Francisco Bay Regional Water Quality Control Board staff members Kevin Lunde and Jan O'Hara participated in the Regional Monitoring Coalition work group meetings, which contributed to the design and implementation of the Regional Monitoring Coalition Monitoring Plan. These staff members also provided input on the outline of the initial regional urban creeks status monitoring report and threshold trigger analyses conducted herein.

CCCWP staff, specifically Lucile Paquette, provided project supervision and review of draft documents. Alessandro Hnatt served as project manager for ADH Environmental, lead consultant to CCCWP. The staff of ADH Environmental also contributed to both the content and production of this report, with respect to data compilation and extraction, organization of metadata, graphics production, and analysis of the GIS and related data necessary to compute CSCI scores. Marco Sigala of Coastal Conservation and Research, Moss Landing, provided algae data analysis and interpretation, and assistance with preparation of watershed GIS information for computation of CSCI scores.

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List of Acronyms

ACCWP	Alameda Countywide Clean Water Program
ADH	ADH Environmental
AFDM	ash-free dry mass
A-IBI	algal index of biological integrity
ARC	Armand Ruby Consulting
Basin Plan	common term for the Regional Water Quality Control Plan
BASMAA	Bay Area Stormwater Management Agencies Association
B-IBI	benthic index of biological integrity
BMI	benthic macroinvertebrate
CCCWP	Contra Costa Clean Water Program
CCMAP	Contra Costa Monitoring and Assessment Program
CDFW	California Department of Fish and Wildlife
Central Valley Permit	East Contra Costa County Municipal NPDES Permit
cm	centimeter
CSCI	California Stream Condition Index
CU	clinical utility
CVRWQCB	Central Valley Regional Water Quality Control Board
DOC	dissolved organic carbon
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FSURMP	Fairfield-Suisun Urban Runoff Management Program
GIS	geographic information system
GRTS	Generalized Random Tessellated Stratified
IBI	Index of Biological Integrity
LC_{50}	lethal concentration to 50 percent of test organisms
m	meters
MCL	maximum contaminant level
MDL	method detection limit
MPC	Monitoring and Pollutants of Concern Committee
MRP	Municipal Regional Permit
MUN	municipal and domestic water supply
ND	not detected
NPDES	National Pollutant Discharge Elimination System
NT	non-target
PAH	polycyclic aromatic hydrocarbon
PEC	probable effect concentration
PHab	physical habitat assessment
PRM	pathogen-related mortality
PSA	perennial streams assessment
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RL	reporting limit
RMC	Regional Monitoring Coalition
RWB	reach-wide benthos
RWQCB	regional water quality control board
SCCWRP	Southern California Coastal Water Research Project
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program

SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SMC	Southern California Stormwater Monitoring Coalition
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
SOP	standard operating procedure
SSID	stress/source identification
SWAMP	Surface Water Ambient Monitoring Program
TEC	threshold effect concentration
TNS	target not sampled (or sampleable)
TOC	total organic carbon
TS	target sampled
TU	toxicity unit
U	unknown
UCMR	urban creeks monitoring report
Vallejo	City of Vallejo and Vallejo Sanitation and Flood Control District
WQO	water quality objective
WY	water year

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Preface

The Regional Monitoring Coalition (RMC) of the Bay Area Stormwater Management Agencies Association (BASMAA) developed a probabilistic design for regional characterization of selected creek status monitoring parameters. The following program participants make up the RMC:

- Alameda Countywide Clean Water Program (ACCWP)
- Contra Costa Clean Water Program (CCCWP)
- San Mateo Countywide Water Pollution Prevention Program (SMCWPPP)
- Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)
- Fairfield-Suisun Urban Runoff Management Program (FSURMP)
- City of Vallejo and Vallejo Sanitation and Flood Control District (Vallejo)

This report fulfills reporting requirements for the portion of the regional/probabilistic creek status monitoring data generated within Contra Costa County during water year 2017 (October 1, 2016-September 30, 2017) through the RMC's probabilistic design for certain parameters monitored, per provision C.8.c. This report is an appendix to the Contra Costa Clean Water Program's *Urban Creeks Monitoring Report, Water Year 2017* and complements similar reports submitted by each of the other participating RMC programs on behalf of their respective permittees.

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Executive Summary

This report documents the results of monitoring performed by CCCWP during water year (WY) 2017 (October 1, 2016-September 30, 2017) under the regional/probabilistic monitoring design developed by the RMC. This report is a component of the urban creeks monitoring report (UCMR) for WY 2017. Together with the creek status monitoring data reported in the *Local/Targeted Creek Status Monitoring Report, Water Year 2017* (ADH, 2018), this submittal fulfills reporting requirements for creek status monitoring specified in provisions C.8.d and C.8.g of the Municipal Regional Permit (MRP) for urban stormwater issued by the San Francisco Bay Regional Water Quality Control Board (SFRWQCB; Order No. R2-2015-0049) and the East Contra Costa County Municipal NPDES Permit (Central Valley Permit) issued by the Central Valley Regional Water Quality Control Board (CVRWQCB; Order No. R5-2010-0102).

Other creek status monitoring parameters were addressed using a targeted design, with regional coordination and common methodologies. The local/targeted parameters are reported in Appendix 2 of the CCCWP WY 2017 UCMR (ADH, 2018).

During WY 2017, ten sites were monitored by CCCWP under the regional/probabilistic design for bioassessment, physical habitat, and related water chemistry parameters. One other site (West Branch Alamo Creek, site 204R01412) was monitored for water and sediment toxicity and sediment chemistry.

The bioassessment and related data are used to develop a preliminary conditional assessment for the monitored sites, to be used in conjunction with the stressor assessment based on sediment chemistry and toxicity. The water and sediment chemistry and toxicity data are used to evaluate potential stressors which may affect aquatic habitat quality and beneficial uses.

The probabilistic design requires several years to produce sufficient data to develop a statistically robust characterization of regional creek conditions. BASMAA is conducting a regional project to prepare a report analyzing bioassessment monitoring data collected during a five-year period (2012-2016) by the Programs and will recommend potential changes to the monitoring program. The project also will develop a fact sheet that presents the report findings in a format accessible to a broad audience.

California Stream Condition Index (CSCI) scores were calculated from the CCCWP bioassessment data for the first time in WY 2016, and these calculations are included in the current year as well. The CSCI uses location-specific geographic information system (GIS) data to compare the observed benthic macroinvertebrate (BMI) taxonomic data to expected BMI assemblage characteristics from reference sites with similar geographical characteristics.

All calculated CSCI scores for the WY 2017 samples were below the MRP 2.0 threshold of 0.795, indicating degraded benthic biological communities at the ten sites monitored by CCCWP in WY 2017. Additional work will need to be completed with the CSCI scores in relation to this threshold to make a clearer assessment of relative biological conditions for these urban streams.

One instance of toxicity in the limited dry weather testing performed in WY 2017 occurred in the chronic *Ceriodaphnia dubia* test for the West Branch Alamo Creek sample. This result was consistent with the results obtained in limited testing performed in WY 2016, in which the Rimer Creek water sample also exhibited chronic toxicity to *C. dubia* but was inconsistent with previous years in which toxicity to *Hyalella azteca* was more common.

The principal potential stressors identified in the chemical analyses continue to be pyrethroid pesticides in sediments. Based on an analysis of the regional/probabilistic data collected by CCCWP during WY 2017, the stressor analysis is summarized as follows:

Physical Habitat Conditions

Limited analysis of PHab metrics did not produce any significant correlations with biological condition indicators for WY 2017 data.

Water Quality

Of 12 water quality parameters required in association with bioassessment monitoring, applicable water quality standards were only identified for ammonia, chloride, and nitrate + nitrite (for sites with MUN beneficial use only). None of the results generated at the ten sites monitored by CCCWP for those three parameters during WY 2017 exceeded the applicable water quality standard or threshold.

Water Toxicity

Toxicity testing was performed for four test species in water samples collected from West Branch Alamo Creek (site 204R01412) during one dry season sampling event in WY 2017. Only the *C. dubia* chronic (reproduction) water sample test was significantly toxic. This result did not meet the MRP threshold for follow-up testing.

Sediment Toxicity

The West Brach Alamo Creek sediment sample was not toxic to either of the test species (*H. azteca and C. dilutus*).

Sediment Chemistry

The pyrethroid pesticide bifenthrin and several other pesticides were found in the creek sediment sample, but the sum of pyrethroid pesticides did not exceed 1 TU.

Sediment Triad Analyses

Bioassessment, sediment toxicity, and sediment chemistry results were evaluated as the three lines of evidence used in the triad approach for assessing overall stream condition and added to the compiled results for water years 2012-2017. Good correlation is observed throughout that period in the triad analysis between pyrethroid concentrations (TU>1) and sediment toxicity.

The chemical stressors, particularly pesticides, may be contributing to the degraded biological conditions indicated by the low B-IBI scores in many of the monitored streams.

Efforts are currently underway by the RMC to evaluate data for selection of a new set of SSID projects for implementation during the current MRP term. CCCWP will continue to collaborate in this regional effort. If performed within a regional collaborative, eight SSID projects are required regionally per MRP 2.0. CCCWP will be required to perform one new SSID project during the MRP 2.0 permit term, per agreement within the RMC; this project will not necessarily involve toxicity. The current list of threshold triggers and potential SSID projects is included as Appendix 3 to the CCCWP WY 2017 UCMR.

The RMC programs, including CCCWP, are cooperating with SFBRWQCB and CEDEN staff to upload the historical (pre-MRP) bioassessment data into CEDEN. For CCCWP, this includes data generated by CCMAP monitoring in many stream reaches throughout Contra Costa County from 2001 to 2011.

CCCWP and the other RMC participants will continue to implement the regional/probabilistic bioassessment monitoring design in WY 2018, under the terms of MRP 2.0 (effective January 1, 2016).

Wet season toxicity and chemistry monitoring will commence in WY 2018, as required by MRP 2.0, Provision C.8.g.iii.

Candidate probabilistic sites previously classified with “unknown" sampling status in the RMC probabilistic site evaluation process may continue to be evaluated for potential sampling in WY 2018.

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1. Introduction

Contra Costa County lies within the jurisdictions of both the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB; Region 2) and the Central Valley Regional Water Quality Control Board (CVRWQCB; Region 5). Municipal stormwater discharges in Contra Costa County are regulated by the requirements of two National Pollutant Discharge Elimination System (NPDES) stormwater permits: Municipal Regional Permit (MRP) in Region 2 (Order No. R2-2015-0049[1]), and the East Contra Costa County Municipal NPDES Permit (Central Valley Permit) in Region 5 (Order No. R5-2010-0102[2]).

CCCWP conducted extensive bioassessment monitoring prior to MRP 1.0. Summaries of the findings can be found in *Preliminary Assessment of Aquatic Life Use Condition in Contra Costa Creeks, Summary of Benthic Macroinvertebrate Bioassessment Results (2001-2006)* (CCCWP, 2007), and *Contra Costa Monitoring and Assessment Program, Summary of Benthic Macroinvertebrate Bioassessment Results (2011)* (Ruby, 2012).

Prior to the reissuance of the MRP in 2015, the requirements of the two permits were effectively identical. With the reissued MRP, there are some differences between the permits, though in most respects the creek status monitoring and reporting requirements remain similar. Until the Central Valley Permit is reissued, the creek status monitoring and reporting requirements specified in the reissued MRP are considered the prevailing requirements. Sites in the Central Valley Region will be sampled as part of the RMC probabilistic design.

This report is a component of the UCMR for WY 2017, covering creek status monitoring conducted under a regional/probabilistic design. Together with the creek status monitoring data reported in the *Local/Targeted Creek Status Monitoring Report, Water Year 2017* (ADH, 2018), this submittal fulfills reporting requirements for creek status monitoring performed per the requirements of provisions C.8.d and C.8.g of the MRP, as well as complementary requirements in the Central Valley Permit.

The regional/probabilistic design was developed and implemented by the Regional Monitoring Coalition (RMC) of the Bay Area Stormwater Management Agencies Association (BASMAA). This monitoring design allows each RMC participating program to assess stream ecosystem conditions within its program area (e.g., county boundary), while contributing data to answer regional management questions about water quality and beneficial use conditions in the creeks of the San Francisco Bay Area.

The RMC was formed in early 2010 as a collaboration among several BASMAA members and the MRP permittees (Table 1.1) to implement the creek status monitoring requirements of the MRP through a regionally-coordinated effort.

The RMC Work Group is a subgroup of the BASMAA Monitoring and Pollutants of Concern Committee (MPC) which meets and communicates regularly to coordinate planning and implementation of

[1] The San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) adopted the reissued Municipal Regional Stormwater NPDES Permit (MRP, Order No. R2-2015-0049) to 76 cities, counties and flood control districts (i.e., permittees) in the Bay Area on November 19, 2015 (SFBRWQCB, 2015), effective January 1, 2016. The BASMAA programs supporting MRP regional projects include all MRP permittees, plus the eastern Contra Costa County cities of Antioch, Brentwood, and Oakley, which have voluntarily elected to participate in the RMC. The RMC regional monitoring design was expanded to include the eastern portion of eastern Contra Costa County which is within the Central Valley Region (Region 5) to assist CCCWP in fulfilling parallel provisions in the Central Valley Permit.

[2] The Central Valley Regional Water Quality Control Board (CVRWQCB) issued the East Contra Costa County Municipal NPDES Permit (Central Valley Permit, Order No. R5-2010-0102) on September 23, 2010 (CVRWQCB 2010).

monitoring-related activities. The RMC Work Group meetings are coordinated by a RMC coordinator funded by the participating county stormwater programs. This work group includes staff from the SFBRWQCB at two levels: those generally engaged with the MRP, as well as those working regionally with the State of California's Surface Water Ambient Monitoring Program (SWAMP). Through the RMC Work Group, the BASMAA RMC developed a quality assurance project plan (QAPP; BASMAA, 2016a), standard operating procedures (SOPs; BASMAA, 2016b), data management tools, and reporting templates and guidelines. Costs for these activities are shared among RMC members.

Table 1.1 Regional Monitoring Coalition Participants

Stormwater Programs	RMC Participants
Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)	Cities of Campbell, Cupertino, Los Altos, Milpitas, Monte Sereno, Mountain View, Palo Alto, San Jose, Santa Clara, Saratoga, Sunnyvale, Los Altos Hills, and Los Gatos; Santa Clara Valley Water District; and Santa Clara County
Alameda Countywide Clean Water Program (ACCWP)	Cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City; Alameda County; Alameda County Flood Control and Water Conservation District; and Zone 7 Water Agency
Contra Costa Clean Water Program (CCCWP)	Cities/Towns of Antioch, Brentwood, Clayton, Concord, El Cerrito, Hercules, Lafayette, Martinez, Oakley, Orinda, Pinole, Pittsburg, Pleasant Hill, Richmond, San Pablo, San Ramon, Walnut Creek, Danville, and Moraga; Contra Costa County; and Contra Costa County Flood Control and Water Conservation District
San Mateo Countywide Water Pollution Prevention Program (SMCWPPP)	Cities and towns of Belmont, Brisbane, Burlingame, Daly City, East Palo Alto, Foster City, Half Moon Bay, Menlo Park, Millbrae, Pacifica, Redwood City, San Bruno, San Carlos, San Mateo, South San Francisco, Atherton, Colma, Hillsborough, Portola Valley, and Woodside; San Mateo County Flood Control District; and San Mateo County
Fairfield-Suisun Urban Runoff Management Program (FSURMP)	Cities of Fairfield and Suisun City
Vallejo Permittees	City of Vallejo and Vallejo Sanitation and Flood Control District

The goals of the RMC are to:

- Assist RMC permittees in complying with requirements in MRP provision C.8 (water quality monitoring);
- Develop and implement regionally consistent creek monitoring approaches and designs in the San Francisco Bay Area through improved coordination among RMC participants and other agencies sharing common goals (e.g., regional water quality control boards, Regions 2 and 5, and SWAMP); and
- Stabilize the costs of creek monitoring by reducing duplication of effort and streamlining monitoring and reporting.

The RMC divided the creek status monitoring requirements required by MRP provisions C.8.d and C.8.g into those parameters which could reasonably be included within a regional/probabilistic design, and those which, for logistical and jurisdictional reasons, should be implemented locally using a targeted (non-probabilistic) design. The monitoring elements included in each category are specified in Table 1.2. Creek status monitoring data collected by CCCWP at local/targeted sites (not included in the regional/probabilistic design) are reported separately in Appendix 2 of the CCCWP WY 2017 UCMR (ADH, 2018).

The remainder of this report addresses study area and monitoring design (Section 2), data collection and analysis methods (Section 3), results and data interpretation (Section 4), and conclusions and next steps (Section 5). Additional information on other aspects of permit-required monitoring is found elsewhere in the CCCWP WY 2017 UCMR and its appendices.

Table 1.2 Creek Status Monitoring Parameters Sampled in Compliance with MRP Provisions C.8.d and C.8.g as Either Regional/Probabilistic or Local/Targeted Parameters

Bioassessment, physical habitat assessment, CSCI	X	
Nutrients (and other water chemistry associated with bioassessment)	X	
Chlorine	X	
Water toxicity (wet and dry weather)	X	
Water chemistry (pesticides, wet weather) [a]	X	
Sediment toxicity	X	
Sediment chemistry	X	
General water quality (sonde data: temperature, dissolved oxygen, pH, specific conductivity)		X
Temperature (HOBO data loggers)		X
Bacteria		X

a Per RMC decision, with Water Board staff concurrence and in accordance with MRP provision C.8.g.iii.(3), this monitoring will commence in WY 2018.

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2. Study Area and Monitoring Design

2.1 Regional Monitoring Coalition Area

For the purposes of the regional/probabilistic monitoring design, the study area is equal to the RMC area, encompassing the political boundaries of the five RMC participating counties, including the eastern portion of Contra Costa County which drains to the Central Valley region. A map of the BASMAA RMC area, equivalent to the area covered by the regional/probabilistic design sample frame, is shown in Figure 2.1.

2.2 Regional Monitoring Design

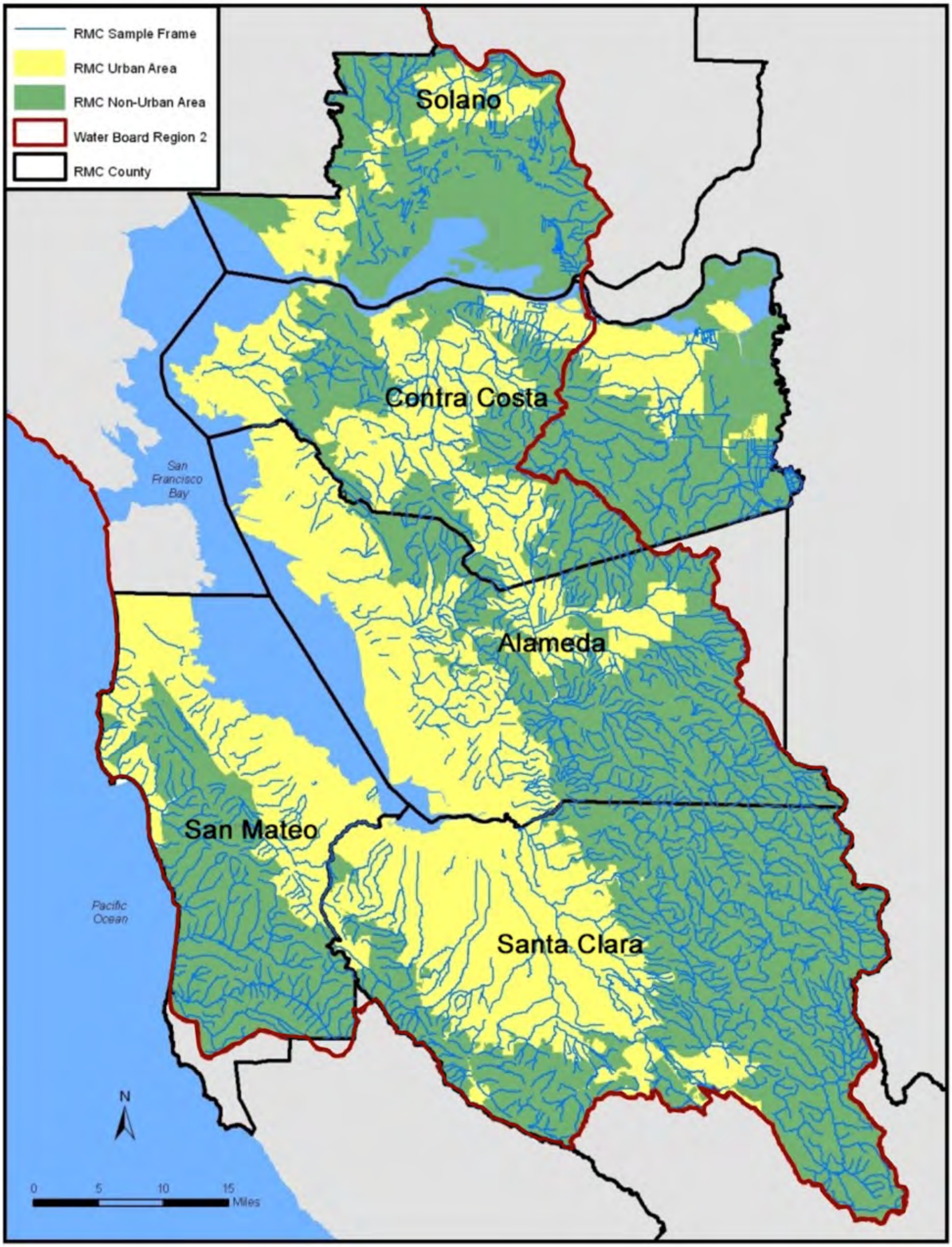
In 2011, the RMC developed a regional/probabilistic monitoring design to identify ambient conditions of creeks in the five main counties subject to the requirements of the MRP. The regional design was developed using the Generalized Random Tessellation Stratified (GRTS) approach developed by the U.S. Environmental Protection Agency (EPA) and Oregon State University (Stevens and Olson, 2004). The GRTS approach was implemented in California by several agencies, including the statewide perennial streams assessment (PSA) conducted by SWAMP (Ode et al., 2011) and the Southern California Stormwater Monitoring Coalition's regional monitoring (SMC, 2007). The RMC area is considered to define the sample frame and represent the sample universe.

2.2.1 Management Questions

The RMC regional monitoring probabilistic design was developed to address the following management questions:

- What is the condition of aquatic life in creeks in the RMC area; are water quality objectives met and are beneficial uses supported?
- What is the condition of aquatic life in the urbanized portion of the RMC area; are water quality objectives met and are beneficial uses supported?
- What is the condition of aquatic life in RMC participant counties; are water quality objectives met and are beneficial uses supported?
- To what extent does the condition of aquatic life in urban and non-urban creeks differ in the RMC area?
- To what extent does the condition of aquatic life in urban and non-urban creeks differ in each of the RMC participating counties?
- What are major stressors to aquatic life in the RMC area?
- What are major stressors to aquatic life in the urbanized portion of the RMC area?
- What are the long-term trends in water quality in creeks over time?

Figure 2.1 Map of BASMAA RMC Area, County Boundaries and Major Creeks



The regional design involves bioassessment monitoring to address the first set of questions regarding aquatic life condition. Assemblages of freshwater organisms are commonly used to assess the biological integrity of water bodies because they provide direct measures of ecological condition (Karr and Chu, 1999).

Benthic macroinvertebrates (BMIs) are an essential link in the aquatic food web, providing food for fish and consuming algae and aquatic vegetation (Karr and Chu, 1999). The presence and distribution of BMIs can vary across geographic locations based on elevation, creek gradient, and substrate (Barbour et al., 1999). These organisms are sensitive to disturbances in water and sediment chemistry, as well as physical habitat, both in the stream channel and along the riparian zone. Due to their relatively long life cycles (approximately one year) and limited migration, BMIs are particularly susceptible to site-specific stressors (Barbour et al., 1999). Algae also are increasingly used as indicators of water quality, as they form the autotrophic base of aquatic food webs and exhibit relatively short life cycles which respond quickly to chemical and physical changes. Diatoms are found to be particularly useful for interpreting some causes of environmental degradation (Hill et al., 2000); therefore, both BMI and algae taxonomic data are used in the aquatic life assessments.

Additional water quality parameters, including water and sediment toxicity testing and chemical analysis, along with physical habitat characteristics, are then used to assess potential stressors to aquatic life.

Table 2.1 shows conservative estimates of the expected cumulative progress toward establishing statistically representative sample sizes (estimated to be achieved at approximately n≥30) for each of the classified strata in the regional monitoring design, based on early planning efforts. As of WY 2016, four of the five RMC participating counties achieved the cumulative sample numbers required for such statistical analysis.

Table 2.1 Cumulative Numbers of Planned Bioassessment Samples Per Monitoring Year

Monitoring Year	Totals for RMC Area (Region-wide)		Santa Clara County		Alameda County		Contra Costa County		San Mateo County		Fairfield, Suisun City and Vallejo	
Land Use	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*
Year 1 (WY 2012)	48	22	16	6	16	6	8	4	8	4	0	2
Year 2 (WY 2013)	100	44	32	12	32	12	16	8	16	8	8	0
Year 3 (WY 2014)	156	66	48	18	48	18	24	12	24	12	12	6
Year 4 (WY 2015)	204	88	64	24	64	24	32	16	32	16	12	8
Year 5 (WY 2016)	256	110	80	30	80	30	40	20	40	20	16	10

Notes:

Shaded cells indicate when a minimum sample size (estimated to be n≥30) may be available to develop a statistically representative data set to address management questions related to condition of aquatic life for the strata included within the regional/probabilistic design.

Non-urban site tallies assume countywide programs will attempt to monitor an average of two non-urban sites annually in each RMC county in MRP 2.0.

2.2.2 Site Selection

Status and trends monitoring was conducted in non-tidally influenced, flowing water bodies (i.e., creeks, streams and rivers). The water bodies monitored were drawn from a master list which included all perennial and non-perennial creeks and rivers running through urban and non-urban areas within the portions of the RMC area. Sample sites were selected and attributed using the GRTS approach from a sample frame consisting of a creek network GIS data set within the RMC boundary (BASMAA, 2011), within five management units which represent the five participating RMC counties. The National Hydrography Dataset Plus (1:100,000) was selected as the creek network data layer to provide consistency with both the statewide PSA and the SMC, and the opportunity for future data coordination with these programs.

The RMC sample frame was classified by county and land use (i.e., urban and non-urban) to allow for comparisons within those strata. Urban areas were delineated by combining urban area boundaries and city boundaries defined by the U.S. Census Bureau (2000). Non-urban areas were defined as the remainder of the areas within the sample universe (RMC area). Based on discussion during RMC meetings, with SFBRWQCB staff present, RMC participants weight their sampling to ensure at least 80 percent of annually monitored sites are in urban areas and not more than 20 percent in non-urban areas. RMC participants coordinated with SWAMP/RWQCB staff by identifying additional non-urban sites from their respective counties for SWAMP monitoring. For Contra Costa County, SWAMP monitoring included non-urban bioassessment sites chosen from the probabilistic sample drawn in the Region 2 (San Francisco Bay) area of Contra Costa County, with the regional focus varying annually.

2.3 Monitoring Design Implementation

The number of probabilistic sites monitored annually in water years 2012 through 2017 by CCCWP are shown by land use category in Table 2.2. This tally includes non-urban sites monitored by SWAMP personnel.

Table 2.2 Number of Urban and Non-Urban Bioassessment Sites Sampled by CCCWP and SWAMP in Contra Costa County During Water Years 2012-2017

	Contra Costa County	
	Land Use	
Monitoring Year	Urban Sites	Non-Urban Sites [a]
WY 2012	8	2/2
WY 2013	10	0/3
WY 2014	10	0/1
WY 2015	10	0/1
WY 2016	10	0/0
WY 2017	10	0/0
Total	58	9

a Non-urban sites are shown as sampled by CCCWP/SWAMP for each year. The total represents combined non-urban sites.

3. Monitoring Methods

3.1 Site Evaluation

Sites identified in the regional sample draw were evaluated by each RMC participant in chronological order using a two-step process, consistent with Southern California Coastal Water Research Project (SCCWRP, 2012)[3]. Each site was evaluated to determine if it met the following RMC sampling location criteria:

- The location (latitude/longitude) provided for a site is located on or is within 300 meters (m) of a non-impounded receiving water body.
- The site is not tidally influenced.
- The site is wadable during the sampling index period.
- The site has sufficient flow during the sampling index period to support SOPs for biological and nutrient sampling.
- The site is physically accessible and can be entered safely at the time of sampling.
- The site may be physically accessed and sampled within a single day.
- Landowner(s) grants permission to access the site.[4]

In the first step, these criteria were evaluated to the extent possible using desktop analysis.

For sites which successfully passed the initial desktop analysis, site evaluations were completed during the second step via field reconnaissance visits. Based on the outcome of the site evaluations, sites were classified into one of four categories:

Target Sampleable (TS): sites meeting all seven criteria were classified as target sampleable (TS)

Target Non-Sampleable (TNS): sites meeting criteria 1 through 4, but not meeting at least one of criteria 5 through 7, were classified as target non-sampleable (TNS)

Non-Target (NT): sites not meeting at least one of criteria 1 through 4 were classified as non-target status and were not sampled

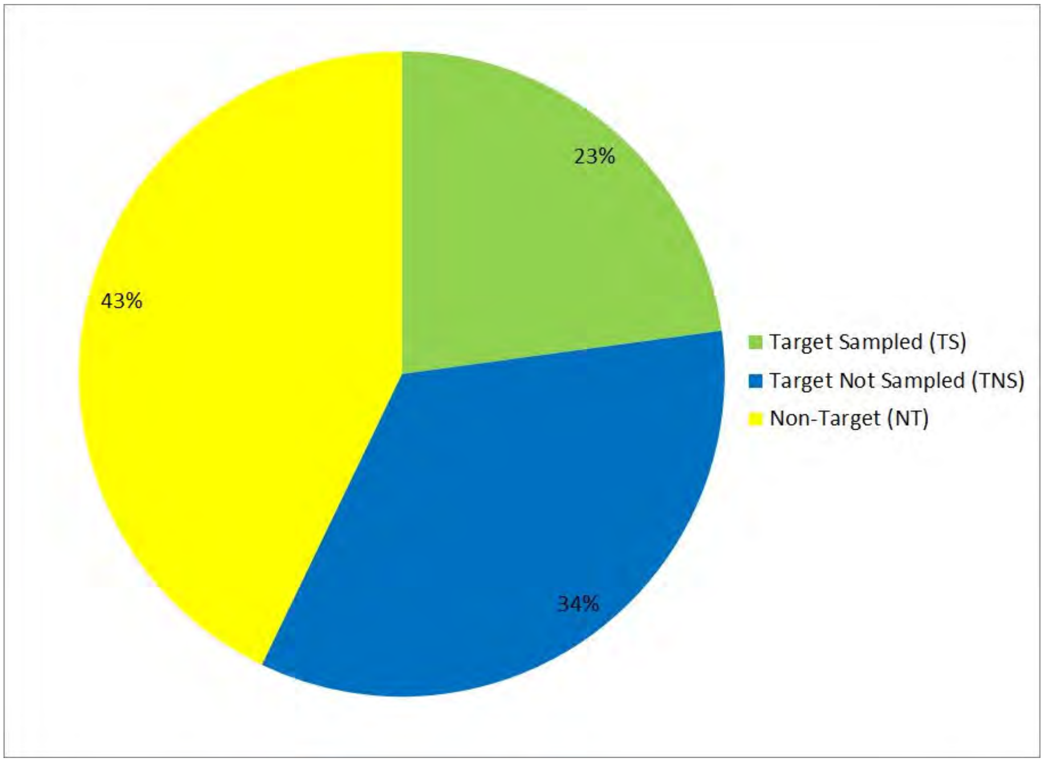
Unknown (U): sites were classified with unknown status and not sampled when it could be reasonably inferred, either via desktop analysis or a field visit, the site was a valid receiving water body and information for any of the seven criteria was unconfirmed.

The outcomes of these site evaluations for CCCWP sites for WY 2017 are illustrated in Figure 3.1. A relatively small fraction of sites evaluated each year are classified as target sampleable sites.

[3] Communication with managers for SMC and PSA will ensure the consistency of site evaluation protocols.

[4] If landowners did not respond to at least two attempts to contact them, either by written letter, e-mail or phone call, permission to access the respective site was effectively considered to be denied.

Figure 3.1 Results of CCCWP Site Evaluations for WY 2017



During the site evaluation field visits, flow status was recorded as one of five categories:

Wet Flowing: continuously wet or nearly so; flowing water

Wet Trickle: continuously wet or nearly so; very low flow; trickle less than 0.1 L/second

Majority Wet: discontinuously wet; greater than 25 percent by length of stream bed covered with water; isolated pools

Minority Wet: discontinuously wet; less than 25 percent of stream bed by length covered with water; isolated pools

No Water: no surface water present

Observations of flow status during pre-wet-weather, fall site reconnaissance events and during post-wet-weather, spring sampling were combined to classify sites as perennial or nonperennial as follows:

Perennial: fall flow status is either Wet Flowing or Wet Trickle, and spring flow is sufficient to sample

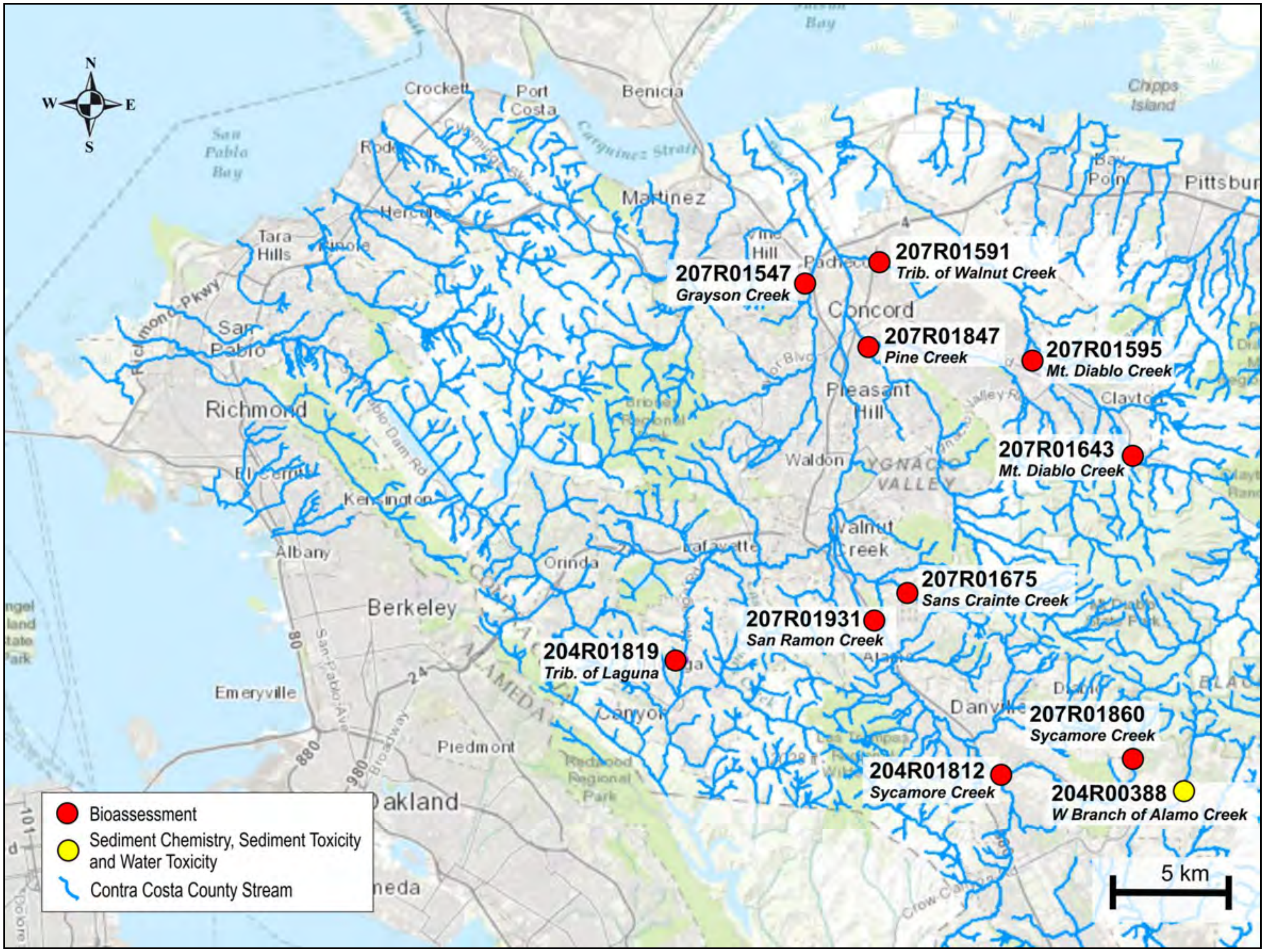
Non-Perennial: fall flow status is Majority Wet, Minority Wet, or No Water, and spring flow is sufficient to sample

The probabilistic sites selected for monitoring in WY 2017, following site evaluation, are shown graphically in Figure 3.2 as the bioassessment sites, and are listed with additional site information in Table 3.1. As indicated in Table 3.1, the selected site was West Branch Alamo Creek (204R01412) for dry weather water toxicity, sediment toxicity and sediment chemistry testing, which was a probabilistic/ bioassessment site during WY 2016 monitoring.

Table 3.1 Site Locations, Monitoring Parameters and Dates Sampled at CCCWP Sites from the RMC Probabilistic Monitoring Design in WY 2017

Site ID	Creek Name	Land Use	Latitude	Longitude	Bioassessment, PHab, Chlorine, Nutrients	Water Toxicity (Dry Weather)	Sediment Toxicity and Chemistry (Dry Weather)
204R01819	Tributary of Laguna Creek	Urban	37.85246	-122.12644	06/01/17		
207R01547	Grayson Creek	Urban	37.98729	-122.06967	05/31/17		
207R01591	Tributary of Walnut Creek	Urban	37.99442	-122.03566	05/17/17		
207R01595	Mt. Diablo Creek	Urban	37.95949	-121.96674	05/17/17		
207R01643	Mt. Diablo Creek	Urban	37.92581	-121.92104	05/15/17		
207R01675	Sans Crainte Creek	Urban	37.87660	-122.02369	05/15/17		
207R01812	Sycamore Creek	Urban	37.81161	-121.98097	05/18/17		
207R01847	Pine Creek	Urban	37.96457	-122.04116	05/30/17		
207R01860	Sycamore Creek	Urban	37.81677	-121.92161	05/16/17		
207R01931	San Ramon Creek	Urban	37.86655	-122.03974	06/15/17		
204R01412	West Branch Alamo Creek	Urban	37.78499	-121.92294		07/13/17	07/13/17

Figure 3.2 Contra Costa County Creek Status Sites Monitored in WY 2017



Note: Bioassessment sites are those selected from the RMC Probabilistic Monitoring Design.

3.2 Field Sampling and Data Collection Methods

Field data and samples were collected in accordance with existing SWAMP-comparable methods and procedures, as described in the RMC QAPP (BASMAA, 2016a) and the associated SOPs (BASMAA, 2016b). The SOPs were developed using a standard format describing health and safety cautions and considerations, relevant training, site selection, and sampling methods/procedures. Sampling methods/ procedures include pre-fieldwork mobilization activities to prepare equipment, sample collection, and demobilization activities to preserve and transport samples, as well as to avoid transporting invasive species between creeks. The SOPs relevant to the monitoring discussed in this report are listed in Table 3.2.

Procedures for sample container size and type, preservative type, and associated holding times for each regional/probabilistic analyte are described in RMC SOP FS-9 (BASMAA, 2016b). Procedures for completion of field data sheets are provided in RMC SOP FS-10, and procedures for sample bottle labeling are described in RMC SOP FS-11 (BASMAA, 2016b).

Table 3.2 RMC Standard Operating Procedures Pertaining to Regional Creek Status Monitoring

SOP	Procedure
FS-1	BMI and algae bioassessments and physical habitat assessments
FS-2	Water quality sampling for chemical analysis, pathogen indicators, and toxicity testing
FS-3	Field measurements, manual
FS-6	Collection of bedded sediment samples
FS-7	Field equipment cleaning procedures
FS-8	Field equipment decontamination procedures
FS-9	Sample container, handling, and chain-of-custody procedures
FS-10	Completion and processing of field data sheets
FS-11	Site and sample naming convention
FS-12	Ambient creek status monitoring site evaluation
FS-13	QA/QC data review

3.2.1 Bioassessments

In accordance with the RMC QAPP (BASMAA, 2016a), bioassessments were conducted during the spring index period (approximately April 15 to July 15) and at a minimum of 30 days after any significant storm (roughly defined as at least 0.5 inch of rainfall within a 24-hour period).

Each bioassessment monitoring site consisted of an approximately 150-meter stream reach divided into 11 equidistant transects placed perpendicular to the direction of flow. The sampling position within each transect alternated between 25, 50 and 75 percent distance of the wetted width of the stream (see SOP FS-1, BASMAA, 2016b).

3.2.1.1 Benthic Macroinvertebrates (BMI)

BMIs were collected via kick net sampling using the reach-wide benthos (RWB) method described in RMC SOP FS-1 (BASMAA, 2016b), based on the SWAMP bioassessment procedures (Ode et al., 2016a and 2016b). Samples were collected from a 1 square foot area approximately 1 meter downstream of each transect. The benthos was disturbed by manually rubbing areas of coarse substrate, followed by disturbing the upper layers of finer substrate to a depth of 4 to 6 inches to dislodge any remaining invertebrates into the net. Slack water habitat procedures were used at transects with deep and/or slow-moving water. Material collected from the 11 subsamples was composited in the field by transferring the entire sample into one to two 1,000 mL wide-mouth jar(s), and the samples were preserved with 95 percent ethanol.

3.2.1.2 Algae

Filamentous algae and diatoms also were collected using the RWB method described in SOP FS-1 (BASMAA, 2016b), based on the SWAMP bioassessment procedures (Ode et al., 2016a and 2016b). Algae samples were collected synoptically with BMI samples. The sampling position within each transect was the same as used for BMI sampling, except algae samples were collected 6 inches upstream of the BMI sampling position and following BMI collection from that location. The algae were collected using a range of methods and equipment, depending on the substrate occurring at the site (e.g., erosional, depositional, large and/or immobile) per RMC SOP FS-1. Erosional substrates included any material (substrate or organics) small enough to be removed from the stream bed, but large enough to isolate an area equal to a rubber delimiter (12.6 cm^2 in area).

When a sample location along a transect was too deep to sample, a more suitable location was selected, either on the same transect or from one further upstream. Algae samples were collected at each transect prior to moving on to the next transect. Sample material (substrate and water) from all 11 transects was combined in a sample bucket, agitated, and a suspended algae sample was then poured into a 500 mL cylinder, creating a composite sample for the site. A 45 mL subsample was taken from the algae composite sample and combined with 5 mL glutaraldehyde into a 50 mL sample tube for taxonomic identification of soft algae. Similarly, a 40 mL subsample was taken from the algae composite sample and combined with 10 mL of 10 percent formalin into a 50 mL sample tube for taxonomic identification of diatoms.

The algae composite sample also was used for collection of chlorophyll-*a* and ash-free dry mass (AFDM) samples following methods described in Fetscher et al. (2009). For the chlorophyll-*a* sample, 25 mL of the algae composite volume was removed and run through a glass fiber filter (47 mm, 0.7 µm pore size) using a filtering tower apparatus in the field. The AFDM sample was collected using a similar process which employs pre-combusted filters. Both filter samples were placed in Whirl-Pak® bags, covered in aluminum foil, and immediately placed on ice for transport to the analytical laboratory.

3.2.1.3 Physical Habitat (PHab)

Physical habitat (PHab) assessments were conducted during each BMI bioassessment monitoring event using the SWAMP PHab protocols (Ode et al., 2016a and 2016b) and RMC SOP FS-1 (BASMAA, 2016b). PHab data were collected at each of the 11 transects and 10 additional inter-transects (located between each main transect) by implementing the “Full” SWAMP level of effort (as prescribed in the MRP). At algae sampling locations, additional assessment of the presence of micro- and macroalgae was conducted during the pebble counts. In addition, water velocities were measured per SWAMP protocols at a single location in the sample reach (when possible).

3.2.2 Physicochemical Measurements

Dissolved oxygen, temperature, conductivity, and pH were measured during bioassessment monitoring using a multi-parameter probe (see SOP FS-3, BASMAA, 2016b). Dissolved oxygen, specific conductivity, water temperature, and pH measurements were made either by direct submersion of the instrument probe into the sample stream or by collection and immediate analysis of grab sample in the field. Water quality measurements were taken approximately 0.1m below the water surface at locations of the stream appearing to be completely mixed, ideally at the centroid of the stream. Measurements should occur upstream of sampling personnel and equipment and upstream of areas where bed sediments have been disturbed or prior to such bed disturbance.

3.2.3 Chlorine

Water samples were collected and analyzed for free and total chlorine using CHEMetrics test kits (K-2511 for low range and K-2504 for high range). Chlorine measurements in water were conducted during bioassessment monitoring and again during dry season monitoring for sediment chemistry, sediment toxicity, and water toxicity.

3.2.4 Nutrients and Conventional Analytes (Water Chemistry)

Water samples were collected for nutrient analyses using the standard grab sample collection method, as described in SOP FS-2 (BASMAA, 2016b) and associated with bioassessment monitoring. Sample containers were rinsed, as appropriate, using ambient water and filled and recapped below water surface whenever possible. An intermediate container was used to collect water for all sample containers with preservative added in advance by the laboratory. Sample container size and type, preservative type, and associated holding times for each analyte are described in Table 1 of FS-9 (BASMAA, 2016b). Syringe filtration method was used to collect samples for analyses of dissolved orthophosphate and dissolved organic carbon. All sample containers were labeled and stored on ice for transport to the analytical laboratory, except for analysis of AFDM and chlorophyll-*a* samples, which were field-frozen on dry ice by sampling teams, where appropriate.

3.2.5 Water Toxicity

Samples were collected using the standard grab sample collection method described above, filling the required number of labeled 2.25-liter amber glass bottles with ambient water, putting them on ice to cool to 4 °C ± 2 °C, and delivered to the laboratory within the required hold time. The laboratory was notified of the impending sample delivery to ensure meeting the 24-hour sample delivery time requirement. Procedures used for sample collection and transport are described in SOP FS-2 (BASMAA, 2016b).

3.2.6 Sediment Chemistry and Sediment Toxicity

In the case where sediment samples and water samples and measurements were collected at the same event, sediment samples were collected after water samples were collected. Before conducting sampling, field personnel surveyed the proposed sampling area to identify appropriate fine-sediment depositional areas to avoid disturbing possible sediment collection sub-sites. Personnel carefully entered the stream and began sampling at the closest appropriate reach, continuing upstream. Sediment samples were collected from the top 2 cm of sediment in a compositing container, thoroughly homogenized, and then aliquoted into separate jars for chemical and toxicological analysis using standard clean sampling techniques (see SOP FS-6, BASMAA, 2016b). Sample jars were submitted to the respective laboratories per SOP FS-9 (BASMAA, 2016b).

3.3 Laboratory Analysis Methods

RMC participants agreed to use the same set of analytical laboratories for regional/probabilistic parameters, developed standards for contracting with the labs, and coordinated quality assurance issues. All samples collected by RMC participants sent to laboratories for analysis were analyzed and reported per SWAMP-comparable methods, as described in the RMC QAPP (BASMAA, 2016a). The following analytical laboratory contractors were used for chemical and toxicological analysis:

BioAssessment Services, Inc. – BMI taxonomic identification

The laboratory performed taxonomic identification nominally on a minimum of 600 BMI individuals for each sample, per standard taxonomic effort Level 1, as established by the Southwest Association of Freshwater Invertebrate Taxonomists, with additional identification of chironomids to subfamily/tribe level (corresponding to a Level 1a STE).

EcoAnalysts, Inc. – Algae taxonomic identification

Samples were processed in the laboratory following draft SWAMP protocols to provide count (diatom and soft algae), biovolume (soft algae), and presence (diatom and soft algae) data. Laboratory processing included identification and enumeration of 300 natural units of soft algae and 600 diatom valves to the lowest practical taxonomic level. Diatom and soft algae identifications were not fully harmonized with the California Algae and Diatom Taxonomic Working Group’s Master Taxa List, and 12 taxa were not included in the data analysis.

Caltest Analytical Laboratory, Inc. – Water chemistry (nutrients, etc.), sediment chemistry, chlorophyll-a, AFDM

Upon receipt at the laboratory, samples were immediately logged and preserved as necessary. EPA-approved testing protocols were then applied for analysis of water and sediment samples.

Pacific EcoRisk, Inc. – Water and sediment toxicity

Testing of water and sediment samples was performed per species-specific protocols published by EPA.

3.4 Data Analysis

Only data collected by CCCWP during WY 2017 for regional/probabilistic parameters are presented and analyzed in this report. This includes data collected during bioassessment monitoring, including BMI and algae taxonomy, water chemistry, and physical habitat evaluations at 10 sites, as well as water and sediment toxicity and sediment chemistry data from one of those 10 sites. The bioassessment data are used to evaluate stream conditions, and the associated physical, chemical and toxicity testing data are then analyzed to identify potential stressors which may impact water quality and biological conditions. As the cumulative RMC sample sizes increase through monitoring conducted in future years, it will be possible to develop a statistically representative data set for the RMC region to address management questions related to condition of aquatic life.

Creek status monitoring data generated by CCCWP for local/targeted parameters (not included in the probabilistic design), per MRP provision C.8.d, are reported in the *Local/Targeted Creek Status Monitoring Report*, found in Appendix 2 of the CCCWP WY 2017 UCMR (ADH, 2018).

The creek status monitoring results are subject to potential follow-up actions, per MRP 2.0

provisions C.8.d and C.8.g, if they meet certain specified threshold triggers, as shown in Table 3.3 for the regional/ probabilistic parameters. If monitoring results meet the requirements for follow-up actions as shown in Table 3.3, the results are compiled on a list for consideration as potential SSID projects, per MRP provision C.8.e, as addressed in Appendix 3 of the CCCWP WY 2017 UCMR (ADH, 2018).

As part of the stressor assessment for this report, water and sediment chemistry and toxicity data generated during WY 2017 also were analyzed and evaluated against these threshold triggers to identify potential stressors which might contribute to degraded or diminished biological conditions.

In addition to those threshold triggers for potential SSID projects, the results are compared to other regulatory standards, including Basin Plan water quality objectives, where available and applicable.

Table 3.3 Requirements for Follow-up for Regional/Probabilistic Creek Status Monitoring Results per MRP Provisions C.8.d and C.8.g

Constituent	Threshold Trigger Level	MRP 2 .0 Provision	Provision Text
CSCI Score	< 0.795 (plus see provision text =>)	C.8.d.i.(8)	Sites scoring less than 0.795 per CSCI are appropriate for an SSID project, as defined in provision C.8.e. Such a score indicates a substantially degraded biological community relative to reference conditions. Sites where there is a substantial difference in CSCI score observed at a location relative to upstream or downstream sites are also appropriate for an SSID project. If many samples show a degraded biological condition, sites where water quality is most likely to cause and contribute to this degradation may be prioritized by the permittee for an SSID project.
Chlorine	> 0.1 mg/L	C.8.d.ii.(4)	The permittees shall immediately resample if the chlorine concentration is greater than 0.1 mg/L. If the resample is still greater than 0.1 mg/L, then permittees shall report the observation to the appropriate permittee central contact point for illicit discharges, so the illicit discharge staff can investigate and abate the associated discharge in accordance with provision C.5.e (Spill and Dumping Complaint Response Program).
Toxicity	TST "fail" on initial and follow-up sample test; both results have > 50% effect	C.8.g.iv	The permittees shall identify a site as a candidate SSID project when analytical results indicate any of the following: (1) a toxicity test of growth, reproduction, or survival of any test organism is reported as “fail” in both the initial sampling, and (2) a second, follow up sampling, and both have ≥ 50 percent effect. Note: Applies to dry and wet weather, water column and sediment tests.
Pesticides (Water)[a]	> Basin Plan WQO	C.8.g.iv	The permittees shall identify a site as a candidate SSID project when analytical results indicate a pollutant is present at a concentration exceeding its water quality objective in the Basin Plan.
Pesticides and Other Pollutants (Sediment)	Result exceeds PCE or TCE (per MacDonald et al., 2000)	C.8.g.iv	The permittees shall identify a site as a candidate SSID project when analytical results indicate any of the following: (1) A pollutant is present at a concentration exceeding its water quality objective in the Basin Plan; (2) for pollutants without WQOs, results exceed PEC or TEC.

Note: Per MRP provision C.8.d. and C.8.g., these are the data thresholds which trigger listings as candidate SSID projects, per MRP provision C.8.e.

a Per RMC decision, with Water Board staff concurrence, in accordance with MRP provision C.8.g.iii.(3), this monitoring will commence in WY 2018.

TEC threshold effects concentrations

PEC probable effects concentrations

3.4.1 Biological Data

The biological condition of each probabilistic site monitored by CCCWP in WY 2017 was evaluated principally through analysis of BMI and algal taxonomic metrics, and calculation of associated index of biological integrity (IBI) scores. An IBI is an analytical tool involving calculation of a site condition score based on a compendium of biological metrics.

3.4.1.1 Benthic Macroinvertebrate Data Analysis

Under MRP 2.0, the BMI taxonomic data are evaluated principally through calculation of the CSCI, a recently-developed bioassessment index (Rehn et al., 2015; Rehn, 2016; Mazor et al., 2016). The CSCI scores evaluate stream health based on comparison of the observed BMI taxonomy (as reported by the lab) versus the expected BMI community characteristics that would, in theory, be present in a reference stream with similar geographic characteristics as the monitored stream, based on a specific set of watershed parameters.

The CSCI score is computed as the average of two other indices: O/E, the observed taxonomic diversity at the monitoring site divided by the taxonomic composition expected at a reference site with similar geographical characteristics, and MMI, a multi-metric index incorporating several metrics reflective of BMI community attributes (such as measures of assemblage richness, composition, and diversity), as predicted for a site with similar physical characteristics. The six metrics selected for inclusion in the MMI calculations were taxonomic richness, number of shredder taxa, percent clinger taxa, percent Coleoptera taxa, percent EPT (Ephemeroptera, Plecopter, and Trichoptera) taxa, and percent intolerant taxa (Rehn et al., 2015; Rehn, 2016).

CSCI scores run from a minimum of 0 (indicating no correspondence to modeled reference site conditions) to a maximum of 1 (perfect correspondence with modeled reference site conditions). A CSCI score below 0.795 indicates biological degradation and a potential candidate site for an SSID project, per MRP 2.0. This index produces conservative values relative to urban creeks.

Prior to the adoption of the first MRP, work was initiated on a San Francisco Bay Region B-IBI in a collaborative effort by BASMAA participants and others, and the results were provisionally tested in Contra Costa (CCCWP, 2007) and Santa Clara (SCVURPPP, 2007) Counties. The Contra Costa County version of the Bay Area B-IBI was subsequently used in analysis and reporting of BMI data over the course of several years for the annual Contra Costa Monitoring and Assessment Program (CCMAP) bioassessment monitoring (see summary, Ruby, 2012). Calculation of the preliminary Contra Costa B-IBI is also presented for CCCWP's BMI data in this report, to allow for comparisons with the historical CCMAP data set. For consistency and comparison with the 2012 regional UCMR, subsequent UCMRs, and other RMC programs, the Southern California B-IBI score (per Ode et al., 2005) is also computed for condition assessment in this report.

3.4.1.2 Algae Data Analysis

Algae taxonomic data are evaluated through a variety of metrics and indices. MRP 2.0 does not specify threshold trigger levels for algae data. Eleven diatom metrics, 11 soft algae metrics, and five algal IBIs (A-IBI; D18, H20, H21, H23 and S2) were calculated for this report following protocols developed from work in Southern California streams (Fetscher et al., 2014). These A-IBIs were not tested for Bay Area waters; however, because the Southern California A-IBI D18 (per Fetscher et al., 2014) relies only on diatoms and is thought to be more transferable to other areas of the state (Marco Sigala, personal communication), it was determined the D-18 A-IBI could be used provisionally for assessment of stream conditions for this report.

Diatom and soft algae metrics fall into five categories:

Tolerance/Sensitivity: association with specific water-quality constituents like nutrients; tolerance to low dissolved oxygen; tolerance to high-ionic-strength/saline waters

Autoecological Guild: nitrogen fixers; saprobic/heterotrophic taxa

Morphological Guild: sedimentation indicators; motility

Taxonomic Groups: Chlorophyta, Rhodophyta, Zygnemataceae, heterocystous cyanobacteria

Relationship to Reference sites

IBI scoring ranges and values were provided by Dr. A. Elizabeth Fetscher (Marco Sigala, personal communication). After each metric was scored, values were summed and then converted to a 100-point scale by multiplying the sum by the number of metrics (e.g., sum x [100/50] if five metrics included in the IBI).

3.4.2 Physical Habitat Condition

Physical habitat condition was assessed for the bioassessment monitoring sites using “mini-PHab” scores. Mini-PHab scores range from 0 to 60, representing a combined score of three physical habitat sub-categories (epifaunal substrate/cover, sediment deposition, and channel alteration), each of which can be scored on a range of 0 to 20 points. Higher PHab scores reflect higher quality habitat. Numerous additional PHab endpoints can also be calculated. Further analyses of various PHab endpoints are possible and will be considered in future reports, as the science becomes further developed.

3.4.3 Water and Sediment Chemistry and Toxicity

As part of the stressor assessment for this report, water and sediment chemistry and toxicity data generated during WY 2017 were analyzed and evaluated to identify potential stressors that may contribute to degraded or diminished biological conditions. The threshold triggers for chlorine and toxicity were modified slightly in MRP 2.0, as shown in Table 3.3, but the evaluative approach is like that used in MRP 1.0. Water chemistry results were evaluated with respect to applicable water quality objectives, where feasible.

For sediment chemistry trigger criteria, threshold effects concentrations (TECs) and probable effects concentrations (PECs) are as defined in MacDonald et al. (2000). For each constituent for which there is a published TEC or PEC value, the ratio of the measured concentration to the respective TEC or PEC value was computed as the TEC or PEC quotient, respectively. All results where a TEC quotient was equal to or greater than 1.0 were identified. For each site, the mean PEC quotient was then computed, and any sites where mean PEC quotient was equal to or greater than 0.5 were identified.

Pyrethroids toxic unit equivalents (TUs) were computed for pyrethroid pesticides in sediment, based on available literature LC_{50} values (LC_{50} is the concentration of a chemical which is lethal on average to 50 percent of test organisms). Because organic carbon mitigates the toxicity of pyrethroid pesticides in sediments, the LC_{50} values were derived based on organic carbon-normalized pyrethroid concentrations. Therefore, the RMC pyrethroid concentrations reported by the lab also were divided by the measured total organic carbon (TOC) concentration at each site (as a percentage), and the TOC-normalized concentrations were then used to compute TU equivalents for each pyrethroid. For each site, the TU equivalents for the individual pyrethroids were summed, and sites where the summed TU was equal to or greater than 1.0 were identified.

3.5 Quality Assurance/Quality Control

Data quality assurance and quality control (QA/QC) procedures are described in detail in the BASMAA RMC QAPP (BASMAA, 2016a) and in RMC SOP FS13, QA/QC Data Review (BASMAA, 2016b).

Data quality objectives (DQOs) were established to ensure the data collected were of sufficient quality for the intended use. DQOs include both quantitative and qualitative assessment of the acceptability of data. The qualitative goals include representativeness and comparability. The quantitative goals include completeness, sensitivity (detection and quantitation limits), precision, accuracy, and contamination. To ensure consistent and comparable field techniques, pre-monitoring field training and *in situ* field assessments were conducted.

Data were collected per the procedures described in the relevant SOPs (BASMAA, 2016b), including appropriate documentation of data sheets and samples, and sample handling and custody. Laboratories providing analytical support to the RMC were selected based on demonstrated capability to adhere to specified protocols.

All data were thoroughly reviewed by the programs responsible for collecting them, for conformance with QAPP requirements, and review of field procedures for compliance with the methods specified in the relevant SOPs. Data review was performed per protocols defined in RMC SOP FS13, QA/QC Data Review (BASMAA, 2016b). Data quality was assessed, and qualifiers were assigned, as necessary, in accordance with SWAMP requirements.

4. Results and Discussion

4.1 Statement of Data Quality

The RMC established a set of guidance and tools to help ensure data quality and consistency implemented through the collaborating programs. Additionally, the RMC participants continue to meet and coordinate on an ongoing basis to plan and coordinate monitoring, data management, and reporting activities, among others.

A comprehensive QA/QC program was implemented by each of the RMC programs, each of which is solely responsible for the quality of the data submitted on its behalf, covering all aspects of the regional/probabilistic monitoring. In general, QA/QC procedures were implemented as specified in the RMC QAPP (BASMAA, 2016a), and monitoring was performed per protocols specified in the RMC SOPs (BASMAA, 2016b) and in conformity with SWAMP protocols. QA/QC issues noted by the laboratories and/or RMC field crews are summarized below.

4.1.1 Bioassessment

Duplicate BMI samples were collected at Sycamore Creek (207R01860). The CSCI scores produced for this duplicate set produced a relative percent difference of 16 percent, which is considered an acceptable level of variation between duplicate sets of taxonomic data.

4.1.2 Sediment Chemistry

No significant issues were reported with the data.

4.1.3 Water Chemistry

No significant issues were reported.

4.1.4 Sediment Toxicity

No significant issues were reported.

4.1.5 Water Toxicity

The *Ceriodaphnia* chronic water sample test included one replicate that was determined to be a statistical outlier. No other significant issues were reported.

Pathogen-related mortality (PRM) was not observed in any samples tested for WY 2017.

4.2 Biological Condition Assessment

Biological condition assessment addresses the RMC's core management question: what is the condition of aquatic life in creeks in the RMC area and are aquatic life beneficial uses supported? The designated beneficial uses listed in the San Francisco Bay Region Basin Plan (SFBRWQCB, 2015) for RMC creeks sampled by CCCWP in WY 2017 are shown in Table 4.1.

Future reports will provide additional analysis at the countywide program and regional levels, as well as comparisons between urban and non-urban land use sites.

Table 4.1 Designated Beneficial Uses Listed in the San Francisco Bay Region Basin Plan (SFBRWQCB, 2015) for CCCWP Bioassessment Sites Monitored in WY 2017

		Human Consumptive Uses							Aquatic Life Uses										Recreational Uses		
Site ID	Water Body	AGR	MUN	FRSH	GWR	IND	PROC	COMM	SHELL	COLD	EST	MAR	MIGR	RARE	SPWN	WARM	WILD	REC-1	REC-2	NAV
204R01819	Tributary of Laguna Creek[a]			E						E					E	E	E	E	E	
207R01547	Grayson Creek									E			E	E		E	E	E	E	
207R01591	Tributary of Walnut Creek									E			E	E	E	E	E	E	E	
207R01595	Mt. Diablo Creek									E			E	E	E	E	E	E	E	
207R01643	Mt. Diablo Creek									E			E	E	E	E	E	E	E	
207R01675	Sans Crainte Creek									E			E		E	E	E	P	P	
207R01812	Sycamore Creek[b]															E	E	E	E	
207R01847	Pine Creek									E			E	E	E	E	E	E	E	
207R01860	Sycamore Creek[b]															E	E	E	E	
207R01931	San Ramon Creek															E	E	E	E	

Note: Per Basin Plan Ch. 2 (SFBRWQCB, 2015), beneficial uses for freshwater creeks include municipal and domestic supply (MUN), agricultural supply (AGR), industrial process supply (PRO), groundwater recharge (GWR), water contact recreation (REC1), noncontact water recreation (REC2), wildlife habitat (WILD), cold freshwater habitat (COLD), warm freshwater habitat (WARM), fish migration (MIGR), and fish spawning (SPWN). The San Francisco Bay Estuary supports estuarine habitat (EST), industrial service supply (IND), and navigation (NAV) in addition to all the uses supported by streams. Coastal waters' beneficial uses include water contact recreation (REC1); noncontact water recreation (REC2); industrial service supply (IND); navigation (NAV); marine habitat (MAR); shellfish harvesting (SHELL); ocean, commercial and sport fishing (COMM); and preservation of rare and endangered species (RARE).

a Tributary to Moraga Creek; Moraga Creek beneficial use data used

b Tributary to San Ramon Creek; San Ramon Creek beneficial use data used

E existing beneficial use

P potential beneficial use

4.2.1 Benthic Macroinvertebrate Metrics

BMI taxonomic metrics are shown in Table 4.2 for the CCCWP creek status sites monitored in the spring index period of WY 2017. For consistency with the 2012 regional UCMR, subsequent UCMRs, and other RMC programs, the SoCal B-IBI score is included in the condition assessment analysis in this report. The preliminary Contra Costa B-IBI also is reported for purposes of comparison with the extensive historical database of bioassessment data produced by CCCWP during 2001-2011, as well as recent UCMRs. The condition category based on the Contra Costa B-IBI score is also shown for each bioassessment site at the bottom of Table 4.2.

Table 4.2 Benthic Macroinvertebrate Metrics for CCCWP Bioassessment Sites Monitored in WY 2017

Metrics	CCCWP Bioassessment Sampling Sites Spring 2017									
	204R01819	207R01547	207R01591	207R01595	207R01643	207R01675	207R01812	207R01847	207R01860	207R01931
	Tributary of Laguna Creek	Grayson Creek	Tributary of Walnut Creek	Mt. Diablo Creek	Mt. Diablo Creek	Sans Crainte Creek	Sycamore Creek	Pine Creek	Sycamore Creek	San Ramon Creek
Richness										
Taxonomic	30	18	15	17	23	18	17	22	14	25
EPT	4	1	1	2	3	2	3	4	1	7
Ephemeroptera	1	1	1	1	2	1	1	3	1	4
Plecoptera	1	0	0	0	0	0	0	0	0	0
Trichoptera	2	0	0	1	1	1	2	1	0	3
Coleoptera	3	0	1	1	3	0	0	2	1	0
Predator	13	5	4	5	10	6	3	6	4	8
Diptera	13	6	4	7	10	6	6	8	9	10
Composition										
EPT Index (%)	17	0.5	7.3	32	4.9	4.1	7.3	27	2.6	47
Sensitive EPT Index (%)	9.8	0.0	0.0	0.2	0.0	0.0	0.5	0.0	0.0	0.8
Shannon Diversity	2.22	1.77	1.99	1.73	1.79	2.25	1.73	2.56	1.30	2.34
Dominant Taxon (%)	22	41	29	32	39	21	53	19	59	26
Non-insect Taxa (%)	27	39	47	41	22	39	35	32	21	24
Tolerance										
Tolerance Value	5.2	7.7	5.9	5.8	5.8	6.1	6.1	6.0	5.8	5.8
Intolerant Organisms (%)	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.8
Intolerant Taxa (%)	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	4.0
Tolerant Organisms (%)	1.4	86	16	18	8.7	21	12	26	0.5	20
Tolerant Taxa (%)	23	61	47	35	26	39	41	41	14	28
Functional Feeding Groups:										
Collector-Gatherers (%)	59	21	59	66	57	55	86	80	40	61
Collector-Filterers (%)	20	0.0	29	15	39	33	0.8	5.1	59	9.0
Scrapers (%)	0.2	49	11	17	0.5	1.9	3.2	3.9	0.0	14

Table 4.2 Benthic Macroinvertebrate Metrics for CCCWP Bioassessment Sites Monitored in WY 2017

Metrics	CCCWP Bioassessment Sampling Sites Spring 2017									
	204R01819	207R01547	207R01591	207R01595	207R01643	207R01675	207R01812	207R01847	207R01860	207R01931
	Tributary of Laguna Creek	Grayson Creek	Tributary of Walnut Creek	Mt. Diablo Creek	Mt. Diablo Creek	Sans Crainte Creek	Sycamore Creek	Pine Creek	Sycamore Creek	San Ramon Creek
Predators (%)	9.0	30.2	1.0	1.5	2.3	9.6	7.6	8.6	1.5	9.8
Shredders (%)	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other (%)	1.9	0.0	0.0	0.2	0.3	0.6	2.1	2.3	0.2	6.7
Estimated Abundance										
Composite Sample (11 ft^2)	1,812	7,808	3,047	2,416	1,766	4,253	4,245	9,808	2,336	4,160
#/ft^2	165	710	277	220	161	387	386	892	212	378
#/m^2	1,760	7,581	2,958	2,346	1,714	4,129	4,121	9,522	2,268	4,039
Supplemental Metrics										
Collectors (%)	79	21	88	82	97	88	87	85	98	70
Non-Gastropoda Scrapers (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Shredder Taxa (%)	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diptera Taxa[a]	79	21	88	82	97	88	87	85	98	70
IBI Scores										
SoCal B-IBI Score	50	20	9	17	31	13	10	23	26	37
CC B-IBI Score	41	32	20	30	34	29	28	34	25	43
CC B-IBI Category	Good	Fair	Marginal	Fair	Fair	Fair	Fair	Fair	Fair	Very Good

Note: Metrics are calculated from standard classifications, based on level I standard taxonomic effort, except Chironomids, which are identified to subfamily/ tribe. Standard taxonomic effort source: Southwest Association of Freshwater Invertebrate Taxonomists (http://www.waterboards.ca.gov/swamp/docs/safit/ste_list.pdf).

a Calculated based on Chironomids identified to family level.

CSCI scores were computed from the BMI taxonomy data and site-specific watershed characteristics for each bioassessment monitoring site. The CSCI score is computed as the average of the observed-to-expected score (O/E; the observed taxonomic diversity at the monitoring site divided by the taxonomic composition expected at a reference site with similar geographical characteristics), and the MMI score (a multi-metric index incorporating several metrics reflective of BMI community attributes, such as measures of assemblage richness, composition, and diversity, as predicted for a site with similar physical characteristics). CSCI scores run from a minimum of 0 (indicating no correspondence to modeled reference site conditions) to a maximum of 1 (perfect correspondence with modeled reference site conditions). Per MRP 2.0, a CSCI score of less than 0.795 is degraded, and should be evaluated for consideration as a possible SSID study location.

The essential results of the CSCI calculations are presented in Table 4.3. As shown in Table 4.3, every CCCWP bioassessment site monitored in WY 2017 produced a CSCI score below the MRP 2.0 threshold of 0.795, indicating a degraded biological community relative to reference conditions. These sites will consequently be listed as potential candidates for SSID studies.

Table 4.3 Results of CSCI Calculations for WY 2017 CCCWP Bioassessment Sites

Station Code	Water Body	Sample Date	BMI Count	O/E	MMI	CSCI
204R01819	Tributary of Laguna Creek	06/01/17	623	0.643	0.498	0.571
207R01547	Grayson Creek	05/31/17	610	0.393	0.171	0.282
207R01591	Tributary of Walnut Creek	05/17/17	603	0.587	0.291	0.439
207R01595	Mt. Diablo Creek	05/17/17	604	0.550	0.278	0.414
207R01643	Mt. Diablo Creek	05/15/17	618	0.572	0.392	0.482
207R01675	Sans Crainte Creek	05/15/17	638	0.570	0.228	0.399
207R01812	Sycamore Creek	05/18/17	619	0.461	0.345	0.403
207R01847	Pine Creek	05/30/17	613	0.726	0.444	0.585
207R01860	Sycamore Creek	05/16/17	657	0.474	0.259	0.367
207R01931	San Ramon Creek	06/15/17	624	0.807	0.444	0.626

Note: CSCI scores less than 0.795 indicate a substantially degraded biological community relative to reference conditions, and such sites are candidates for SSID projects.

The WY 2017 CSCI scores ranged from a low of 0.282 at Grayson Creek (207R01547) to a high of 0.626 at San Ramon Creek (207R01931). Seven sites had scores less than 0.5.

4.2.2 Algae Metrics

The five calculated A-IBI scores are shown in summary in Table 4.4 for each bioassessment site monitored in WY 2017, with the highest and lowest scores highlighted for each of the IBIs. A discussion of the results for each of the five IBIs follows.

Soft algae and diatom taxonomy samples were collected at 10 sites in Contra Costa county in calendar year 2017 as part of the San Francisco RMC program. Samples were collected following the SWAMP Bioassessment Wadable Streams Protocol (Ode et al., 2016). Samples were processed in the laboratory by EcoAnalysts following draft SWAMP protocols to provide count (diatom and soft algae), biovolume (soft algae), and “presence” (diatom and soft algae) data. Diatom and soft algae identifications were not fully harmonized with the California Algae and Diatom Taxonomic Working Group's Master Taxa List, but all FinalIDs matched existing values and were included in the calculations.

Eleven diatom metrics, 11 soft algae metrics, and five IBIs (D18, H20, H21, H23 and S2) were calculated following work performed on Southern California streams (Fetscher et al., 2014). Diatom and soft algae metrics fall into five categories:

Tolerance/Sensitivity: association with specific water-quality constituents like nutrients; tolerance to low dissolved oxygen; tolerance to high-ionic-strength/saline waters

Autoecological Guild: nitrogen fixers; saprobic/heterotrophic taxa

Morphological Guild: sedimentation indicators; motility

Taxonomic Groups: Chlorophyta, Rhodophyta, Zygnemataceae, heterocystous cyanobacteria

Relationship to Reference sites

IBI scoring ranges and values were provided by Dr. A. Elizabeth Fetscher (personal communication). After each metric was scored, values were summed and then converted to a 100-point scale by multiplying the sum by the number of metrics (e.g., sum x [100/50] if five metrics included in the IBI).

The average D18 diatom IBI score across all 10 Contra Costa sites was 53 (Table 4.5). In comparison, the average D18 scores across samples collected in 2012 through 2016 was 38, indicating higher overall health of the diatom community in the 2017 sites. The highest score (92) occurred at site 207R01547 (Grayson Creek) while site 207R01931 (San Ramon Creek) had the lowest score at 6. Most sites had scores between 42 and 74. Higher scores tended to be associated with a lower proportion of haplobiontic species, nitrogen heterotrophic species, and sediment tolerant, highly motile species but higher proportion of species requiring >50 percent dissolved oxygen saturation (Tables 4.5 and 4.6). Eight of 10 sites scored very low (metric score of 1) for the proportion of diatom species that are indicative of low total phosphorous levels, suggesting phosphorous is not a limiting factor in these streams, and that phosphorous may be elevated at those sites. *Cocconeis spp* and *Planothidium frequentissimum* were the dominant diatom species found at eight of 10 sites, although *Achnanthidium minutissimum* was the dominant diatom species (78 percent) at site 207R01547. *Cyclotella meneghiniana* was the dominant diatom (32.8 percent) at the lowest scoring site (207R01931), but *Cocconeis spp* and *Planothidium frequentissimum* were ranked 2 to 4 behind it. Fetscher et al. (2014) found the diatom IBI (D18) to be responsive to stream order, watershed area, and percent fines, so these values could also play a role in IBI scores.

The soft algae S2 IBI had an average score of 7.7 compared to the average score of 33.7 in years 2014 through 2016 (Table 4.7). The highest score (35) occurred at site 207R01812 (Sycamore Creek) while seven sites scored 7 or lower, including four sites with a 0 score. Site 207R01812 scored higher because it had a higher proportion of low TP indicators (33 percent) and fewer soft algae species belonging to the green algae CRUS (*Cladophora glomerata*, *Rhizoclonium hieroglyphicum*, *Ulva flexuosa*, and *Stigeoclonium spp*; see Tables 4.7 and 4.8). In contrast, the sites with lower scores were dominated by taxa belonging to CRUS, indicative of high copper and DOC concentrations, characteristic of non-reference conditions, and no ZHR (*Zygnemataceae*, heterocystous cyanobacteria, Rhodophyta) taxa. This result is a little deceiving because SWAMP has not updated the Algae Attribute list since March 2013 and some FinalIDs (e.g., *Heteroleibleinia* or *Leptolyngbya*) have not been assigned trait characteristics for copper or DOC, so they are not included in the calculations. Nine of 10 sites had zero species that are indicative of low total phosphorous concentrations. The biovolume at nine sites was dominated by

Cladophera glomerate, while species richness was dominated by *Heteroleibleinia* or *Leptolyngbya* at seven sites (three sites did not have algae in the count samples). Fetscher et al. (2014) found soft algae IBIs were most responsive (negatively) to canopy cover and slope.

The hybrid IBIs (H20, H21 and H23), consisting of both soft algae and diatom metrics, produced similar results in determining the highest (Grayson Creek, site 207R01547) and lowest (San Ramon Creek, site 207R01931) scores among the 10 sites (Tables 4.9, 4.10 and 4.11). However, the average IBI score varied slightly among the three IBIs (H20 = 35.3, H21 = 39, and H23 = 36.3), which could reflect H21's inclusion of only two soft algae metrics compared to H20 and H23, which include three soft algae metrics. The main differences in the H20 IBI scores were due to the proportion of haplobiontic diatoms, diatoms indicative of low TN, highly motile diatoms, heterotroph diatoms, and diatoms requiring >50 percent dissolved oxygen saturation. H21 IBI scores were driven by the biomass proportion of Chlorophyta soft algae taxonomic groups and the proportion of haplobiontic, heterotroph, low TP, and sediment tolerant, highly motile diatoms. The proportion of ZHR and CRUS soft algae species affected the differences in H23 IBI scores, as well as the proportion of haplobiontic, low TP, and sediment tolerant, highly motile diatoms. Fetscher et al. (2014) designated H20 as the overall top-performing IBI for Southern California streams, although differences with H23 were not pronounced.

Overall, site 207R01547 (Grayson Creek) had the highest score across four of the five IBIs (D18, H20, H21 and H23), while site 207R01812 (Sycamore Creek) had the highest score for the S2 IBI. Site 207R01931 (San Ramon Creek) had the lowest score for four of the five IBIs (D18, H20, H21 and H23), while four sites had the lowest score (0) for the S2 IBI. The proportion of diatom and algae species that are indicative of low TP concentrations was very low (metric scores of 1 or 0 at 8 of 10 sites for diatoms and 9 of 10 sites for soft algae), suggesting potentially elevated levels of phosphorous at those sites. The presence of haplobiontic and sediment tolerant, highly motile diatom species affected scores across IBIs, suggesting the importance of low ionic strength/salinities and sediment qualities for a stronger diatom community. Soft algae scores were affected by the proportion of taxonomic groups and lack of species found within sites indicating an impacted community for all sites. An external audit of the field crews can also be performed to ensure collection protocols are followed correctly. The proportion of algae indicative of high copper and DOC concentrations also affected the results, but this could be due in part to the lack of assigned traits rather than an environmental signal.

Notes for abbreviations used in Tables 4.4-4.11:

- D18= diatom IBI #18
- S2 = soft algae IBI #2
- H20 = hybrid algae IBI #20
- H21 = hybrid algae IBI #21
- H22 = hybrid algae IBI #22
- (d) = diatom
- (s) = soft algae, further defines as:
    - (sp) = species counts
    - (b) = biovolume
    - (m) = mean of the species results

Table 4.4 Algal-IBI Scores for the Diatom (D18), Soft Algae (S2) and Hybrid (H20, H21, H23) Indices for Contra Costa Stations Sampled in 2017

Station Code	Water Body	Sample Date	D18 A-IBI Score	S2 A-IBI Score	H20 A-IBI Score	H21 A-IBI Score	H23 A-IBI Score
204R01819	Tributary of Laguna Creek	06/01/17	64	0	40	46	40
207R01547	Grayson Creek	05/31/17	92	0	58	66	58
207R01591	Trib. of Walnut Creek	05/17/17	42	13	29	30	31
207R01595	Mt. Diablo Creek	05/17/17	74	0	46	53	46
207R01643	Mt. Diablo Creek	05/15/17	62	17	39	59	51
207R01675	Sans Crainte Creek	05/15/17	60	0	38	43	38
207R01812	Sycamore Creek	05/18/17	30	35	32	21	28
207R01847	Pine Creek	05/30/17	34	3	24	24	22
207R01860	Sycamore Creek	05/16/17	62	2	38	44	40
207R01931	San Ramon Creek	06/15/17	6	7	9	4	9
		Average	53	8	35	39	36

Note: High scores for each of the five algal IBIs are highlighted in green. Low scores are highlighted in gray, except for S2 IBI, which had a four-way tie at 0.

Table 4.5 Diatom IBI (D18) and Individual Metric Scores for Contra Costa Stations Sampled in 2017

Station Code	Water Body	Sample Date	D18 IBI Score	Proportion Haplobiontic (d) Score	Proportion Low TP Indicators (d) Score	Proportion N Heterotrophs (d) Score	Proportion Requiring >50% DO Saturation (d) Score	Proportion Sediment Tolerant (Highly Motile) (d) Score
204R01819	Tributary of Laguna Creek	06/01/17	64	7	1	7	9	8
207R01547	Grayson Creek	05/31/17	92	9	10	9	9	9
207R01591	Tributary of Walnut Creek	05/17/17	42	4	1	5	6	5
207R01595	Mt. Diablo Creek	05/17/17	74	9	1	9	9	9
207R01643	Mt. Diablo Creek	05/15/17	62	7	1	8	7	8
207R01675	Sans Crainte Creek	05/15/17	60	8	1	8	7	6
207R01812	Sycamore Creek	05/18/17	30	0	1	5	4	5
207R01847	Pine Creek	05/30/17	34	4	3	3	5	2
207R01860	Sycamore Creek	05/16/17	62	6	1	9	9	6
207R01931	San Ramon Creek	06/15/17	6	0	1	0	0	2

Note: Metric scores were assigned based on metric results, as shown in Table 4.6, using scoring ranges and values provided by Dr. A. Elizabeth Fetscher (personal communication). The overall IBI score was calculated by converting the sum of individual scores to a 100-point scale by summing the scores and multiplying by the number of metrics (sum x [100/50]).

Table 4.6 Diatom Metric Results for Contra Costa Stations Samples in 2017

Station Code	Sample Date	Proportion A Minutissimum (d)	Proportion Haplobiontic (d)	Proportion Highly Motile (d)	Proportion Low TN Indicators (d)	Proportion Low TP Indicators (d)	Proportion N Heterotrophs (d)	Proportion oligo- & beta Mesosaprobic (d)	Proportion poly- & eutrophic (d)	Proportion Requiring >50% DO Saturation (d)	Proportion Requiring Nearly 100% DO Saturation (d)	Proportion Sediment Tolerant (Highly Motile) (d)
204R01819	06/01/17	0.008	0.143	0.108	0.037	0.037	0.149	0.719	0.977	0.96	0.014	0.111
207R01547	05/31/17	0.78	0.044	0.03	0.866	0.89	0.027	0.964	0.121	0.99	0.872	0.03
207R01591	05/17/17	0.005	0.339	0.219	0.031	0.038	0.223	0.556	0.948	0.843	0.009	0.247
207R01595	05/17/17	0.022	0.048	0.028	0.029	0.029	0.034	0.889	0.945	0.991	0.03	0.028
207R01643	05/15/17	0.002	0.172	0.112	0.055	0.062	0.07	0.699	0.882	0.88	0.009	0.112
207R01675	05/15/17	0.002	0.114	0.207	0.027	0.028	0.092	0.738	0.821	0.904	0.02	0.207
207R01812	05/18/17	0.002	0.755	0.08	0.009	0.034	0.225	0.591	0.976	0.77	0.004	0.242
207R01847	05/30/17	0.047	0.329	0.294	0.18	0.192	0.341	0.588	0.894	0.808	0.094	0.401
207R01860	05/16/17	0	0.208	0.182	0.002	0.028	0.049	0.861	0.904	0.977	0.002	0.182
207R01931	06/15/17	0.008	0.56	0.101	0.02	0.022	0.514	0.48	0.965	0.521	0.011	0.429

Note: All calculations based on count data; proportions are individual counts/total count for each sample

Table 4.7 Soft Algae IBI (S2) and Individual Metric Scores for Contra Costa Stations Samples in 2017

Station Code	Water Body	Sample Date	S2 IBI Score	Proportion High Cu Indicators (s, sp) Score	Proportion High DOC Indicators (s, sp) Score	Proportion Low TP Indicators (s, sp) Score	Proportion Non-Reference Indicators (s, sp) Score	Proportion Green Algae Belonging to CRUS (s, b) Score	Proportion ZHR (s, m) Score
204R01819	Tributary of Laguna Creek	06/01/17	0	0	0	0	0	0	0
207R01547	Grayson Creek	05/31/17	0	0	0	0	0	0	0
207R01591	Tributary of Walnut Creek	05/17/17	13	1	1	0	3	0	3
207R01595	Mt. Diablo Creek	05/17/17	0	0	0	0	0	0	0
207R01643	Mt. Diablo Creek	05/15/17	17	0	0	0	0	10	0
207R01675	Sans Crainte Creek	05/15/17	0	0	0	0	0	0	0
207R01812	Sycamore Creek	05/18/17	35	1	1	10	3	4	2
207R01847	Pine Creek	05/30/17	3	1	1	0	0	0	0
207R01860	Sycamore Creek	05/16/17	2	0	0	0	0	1	0
207R01931	San Ramon Creek	06/15/17	7	0	4	0	0	0	0

Note: The overall IBI score was calculated by converting the sum of individual scores to a 100-point scale by summing the scores and multiplying by the number of metrics (sum x [100/60]).

Table 4.8 Soft Algae Metric Results for Contra Costa Stations Samples in 2017

Station Code	Sample Date	Proportion High Cu Indicators (s, sp)	Proportion High DOC Indicators (s, sp)	Proportion Low TP Indicators (s, sp)	Proportion Non-Reference Indicators (s, sp)	Proportion ZHR (s, sp)	Proportion Chlorophyta (s, b)	Proportion High DOC Indicators (s, b)	Proportion Non-Reference Indicators (s, b)	Proportion Green Algae Belonging to CRUS (s, b)	Proportion ZHR (s, b)	Proportion ZHR (s, m)
204R01819	06/01/17	1	1	0	1	0	0.006	1	1	1	0	0
207R01547	05/31/17	0.4	0.8	0	0.8	0	0	1	1	1	0	0
207R01591	05/17/17	0.333	0.667	0	0.333	0.333	0.5	1	1	1	0	0.167
207R01595	05/17/17	1	1	0	1	0	0	1	1	1	0	0
207R01643	05/15/17	1	1	0	1	0	1	0	0	0	0	0
207R01675	05/15/17	1	1	0	1	0	1	1	1	1	0	0
207R01812	05/18/17	0.333	0.667	0.333	0.333	0.2	0.905	1	1	0.6	0	0.1
207R01847	05/30/17	0.333	0.667	0	0.667	0	0	1	1	1	0	0
207R01860	05/16/17	1	1	0	1	0	0.103	1	1	0.999	0	0
207R01931	06/15/17	0.667	0.5	0	0.5	0	1	1	1	1	0	0

Note: Calculations based on either species counts (sp) or biovolume (b); proportion ZHR (s, m) was based on the mean of the species and biovolume results.

Table 4.9 Hybrid (diatom and soft algae) IBI (H20) and Individual Metric Scores for Contra Costa Stations Samples in 2017

Station Code	Water Body	Sample Date	H20 IBI Score	Proportion Haplobiontic (d) Score	Proportion High Cu Indicators (s, sp) Score	Proportion High DOC Indicators (s, sp) Score	Proportion Low TN Indicators (d) Score	Proportion Low TP Indicators (s, sp) Score	Proportion N Heterotrophs (d) Score	Proportion Requiring >50% DO Saturation (d) Score	Proportion Sediment Tolerant (Highly Motile) (d) Score
204R01819	Tributary of Laguna Creek	06/01/17	40	7	0	0	1	0	7	9	8
207R01547	Grayson Creek	05/31/17	58	9	0	0	10	0	9	9	9
207R01591	Tributary of Walnut Creek	05/17/17	29	4	1	1	1	0	5	6	5
207R01595	Mt. Diablo Creek	05/17/17	46	9	0	0	1	0	9	9	9
207R01643	Mt. Diablo Creek	05/15/17	39	7	0	0	1	0	8	7	8
207R01675	Sans Crainte Creek	05/15/17	38	8	0	0	1	0	8	7	6
207R01812	Sycamore Creek	05/18/17	32	0	1	1	0	10	5	4	5
207R01847	Pine Creek	05/30/17	24	4	1	1	3	0	3	5	2
207R01860	Sycamore Creek	05/16/17	38	6	0	0	0	0	9	9	6
207R01931	San Ramon Creek	06/15/17	9	0	0	4	1	0	0	0	2

Note: The overall IBI score was calculated by converting the sum of individual scores to a 100-point scale by summing the scores and multiplying by the number of metrics (sum x [100/80]).

Table 4.10 Hybrid (diatom and soft algae) IBI (H21) and Individual Metric Scores for Contra Costa Stations Sampled in 2017

Station Code	Water Body	Sample Date	H21 IBI Score	Proportion Chlorophyta (s, b) Score	Proportion Haplobiontic (d) Score	Proportion Low TP Indicators (d) Score	Proportion N Heterotrophs (d) Score	Proportion Requiring >50% DO Saturation (d) Score	Proportion Sediment Tolerant (Highly Motile) (d) Score	Proportion ZHR (s, b) Score
204R01819	Tributary of Laguna Creek	06/01/17	46	0	7	1	7	9	8	0
207R01547	Grayson Creek	05/31/17	66	0	9	10	9	9	9	0
207R01591	Tributary of Walnut Creek	05/17/17	30	0	4	1	5	6	5	0
207R01595	Mt. Diablo Creek	05/17/17	53	0	9	1	9	9	9	0
207R01643	Mt. Diablo Creek	05/15/17	59	10	7	1	8	7	8	0
207R01675	Sans Crainte Creek	05/15/17	43	0	8	1	8	7	6	0
207R01812	Sycamore Creek	05/18/17	21	0	0	1	5	4	5	0
207R01847	Pine Creek	05/30/17	24	0	4	3	3	5	2	0
207R01860	Sycamore Creek	05/16/17	44	0	6	1	9	9	6	0
207R01931	San Ramon Creek	06/15/17	4	0	0	1	0	0	2	0

Note: The overall IBI score was calculated by converting the sum of individual scores to a 100-point scale by summing the scores and multiplying by the number of metrics [sum x (100/70]

Table 4.11 Hybrid (diatom and soft algae) IBI (H23) and Individual Metric Scores for Contra Costa Stations Sampled in 2017

Station Code	Water Body	Sample Date	H23 IBI Score	Proportion Haplobiontic (d) Score	Proportion High DOC Indicators (s, sp) Score	Proportion Low TP Indicators (d) Score	Proportion N Heterotrophs (d) Score	Proportion Green Algae Belonging to CRUS (s, b) Score	Proportion Requiring >50% DO Saturation (d) Score	Proportion Sediment Tolerant (Highly Motile) (d) Score	Proportion ZHR (s, m) Score
204R01819	Tributary of Laguna Creek	06/01/17	40	7	0	1	7	0	9	8	0
207R01547	Grayson Creek	05/31/17	58	9	0	10	9	0	9	9	0
207R01591	Tributary of Walnut Creek	05/17/17	31	4	1	1	5	0	6	5	3
207R01595	Mt. Diablo Creek	05/17/17	46	9	0	1	9	0	9	9	0
207R01643	Mt. Diablo Creek	05/15/17	51	7	0	1	8	10	7	8	0
207R01675	Sans Crainte Creek	05/15/17	38	8	0	1	8	0	7	6	0
207R01812	Sycamore Creek	05/18/17	28	0	1	1	5	4	4	5	2
207R01847	Pine Creek	05/30/17	22	4	1	3	3	0	5	2	0
207R01860	Sycamore Creek	05/16/17	40	6	0	1	9	1	9	6	0
207R01931	San Ramon Creek	06/15/17	9	0	4	1	0	0	0	2	0

Note: The overall IBI score was calculated by converting the sum of individual scores to a 100-point scale by summing the scores and multiplying by the number of metrics (sum x [100/80]).

4.3 Stressor Assessment

This section addresses the question: what are the major stressors to aquatic life in the RMC area? The biological, physical, chemical, and toxicity testing data produced by CCCWP during WY 2017 were compiled, evaluated, and analyzed against the threshold trigger criteria shown in Table 3.3. When the data analysis indicated the associated trigger criteria were exceeded, those sites and results were identified as potentially warranting further investigation.

When interpreting analytical chemistry results, it is important to account for laboratory data reported as either below method detection limits (MDLs) or between detection and reporting limits (RLs). Dealing with data in this range of the analytical spectrum introduces some level of uncertainty, especially when attempting to generate summary statistics for a data set. In the following compilation of statistics for analytical chemistry, in some cases non-detect data (ND) were substituted with a concentration equal to half of the respective MDL, as reported by the laboratory.

4.3.1 Physical Habitat Parameters

The metrics included in calculation of the mini-PHab scores are summarized in Table 4.12 for bioassessment sites monitored in WY 2017. The two Mt. Diablo Creek sites had the highest mini-PHab scores, while the Pine Creek site (207R01847) had the lowest mini-PHab score.

Table 4.12 Physical Habitat Metrics and Scores for CCCWP Bioassessment Sites Monitored in WY 2017

Site Code	Creek Name	Sample Date	Epifaunal Substrate	Sediment Deposition	Channel Alteration	Mini-PHab Score
204R01819	Tributary of Laguna Creek	06/01/17	10	9	11	30
207R01547	Grayson Creek	05/31/17	7	12	10	29
207R01591	Tributary of Walnut Creek	05/17/17	5	9	17	31
207R01595	Mt. Diablo Creek	05/17/17	18	15	14	47
207R01643	Mt. Diablo Creek	05/15/17	15	13	17	45
207R01675	Sans Crainte Creek	05/15/17	17	12	14	43
207R01812	Sycamore Creek	05/18/17	7	10	6	23
207R01847	Pine Creek	05/30/17	2	4	1	7
207R01860	Sycamore Creek	05/16/17	12	13	16	41
207R01931	San Ramon Creek	06/15/17	10	11	12	33

The principal biological condition scores are shown together with the mini-PHab scores in Table 4.13, and correlations between mini-PHab scores and the key biological condition scores are shown in Table 4.14.

For the 2017 analysis, only the two algal indices (D18 and H20) were well correlated. No other factors produced a correlation coefficient higher than 0.5. For the 2016 data, the CC-IBI scores correlated well with the CSCI scores, and with both the D18 and H20 algal-IBI scores. The two algal-IBI scores also correlated well to each other.

The mini-PHab scores did not correlate well with any of the biological condition indicators, following a pattern observed in prior years. Based on these observations, it is difficult to conclude that the physical habitat, as represented by these limited metrics, has any significant effect on the biological parameters.

Table 4.13 Summary of PHab and Biological Condition Scores for CCCWP Bioassessment Sites Monitored in WY 2017

Site Code	Creek Name	CSCI Score	D18 Algal IBI Score	H20 Algal IBI Score	CC IBI	Mini-PHab Score
204R01819	Tributary of Laguna Creek	0.366	64	40	41	30
207R01547	Grayson Creek	0.471	92	58	32	29
207R01591	Tributary of Walnut Creek	0.418	42	29	20	31
207R01595	Mt. Diablo Creek	0.652	74	46	30	47
207R01643	Mt. Diablo Creek	0.613	62	39	34	45
207R01675	Sans Crainte Creek	0.418	60	38	29	43
207R01812	Sycamore Creek	0.456	30	32	28	23
207R01847	Pine Creek	0.553	34	24	34	7
207R01860	Sycamore Creek	0.448	62	38	25	41
207R01931	San Ramon Creek	0.605	6	9	43	33

Table 4.14 Correlations for PHab and Biological Condition Scores for CCCWP Bioassessment Sites Monitored in WY 2017

Comparison	Correlation Coefficient	R Squared
CSCI : D18 A-IBI	-0.16	0.03
CSCI : H20 A-IBI	-0.20	0.04
D18 A-IBI : H20 A-IBI	0.97	0.94
CSCI : Mini-PHab	0.19	0.035
D18 A-IBI : Mini-PHab	0.41	0.17
H20 A-IBI : Mini-PHab	0.34	0.11
CSCI : Contra Costa B-IBI	0.29	0.083
D18 A-IBI : Contra Costa B-IBI	-0.22	0.049
H20 A-IBI : Contra Costa B-IBI	-0.27	0.07
Contra Costa B-IBI : Mini-PHab	-0.14	0.02

Note: Correlations are based on scores shown in Table 4.13. Highly correlated results are highlighted in green.

4.3.2 Water Chemistry Parameters

At all 10 bioassessment sites, water samples were collected for nutrient and other conventional analyses using the standard grab sample collection method, as described in SOP FS-2 (BASMAA, 2016b). Standard field parameters (temperature, dissolved oxygen, pH, and specific conductance) were also measured in the field using a portable multi-meter and sonde.

Of the 12 water quality constituents monitored in association with the bioassessment monitoring, water quality standards or established thresholds are available only for ammonia (unionized form[5]), chloride[6], and nitrate-plus-nitrite[7] – the latter for waters with MUN beneficial use only, as indicated in Table 4.15.

The comparisons of the measured nutrients data to the thresholds listed in Table 4.15 are shown in Table 4.16. There were no exceedances of the applicable criteria at any of the 10 sites monitored in WY 2017.

Table 4.15 Water Quality Thresholds Available for Comparison to WY 2017 Water Chemistry Constituents

Sample Parameter	Threshold	Units	Frequency/Period	Application	Source
Ammonia	0.025	mg/L	Annual Median	Un-ionized ammonia, as N (maxima also apply to Central Bay and u/s [0.16] and Lower Bay [0.4])	SF Bay Basin Plan (Ch. 3)
Chloride	230	mg/L	Criterion Continuous Concentration	Freshwater aquatic life	EPA National Recreation Water Quality Criteria, Aquatic Life Criteria
Chloride	860	mg/L	Criteria Maximum Concentration	Freshwater aquatic life	EPA National Recreation Water Quality Criteria, Aquatic Life Criteria Table
Chloride	250	mg/L	Secondary Maximum Contaminant Level	Alameda Creek watershed above Niles and MUN waters; Title 22 drinking waters	SF Bay Basin Plan (Ch. 3); California Title 22; EPA Drinking Water Standards Secondary MCL
Nitrate + Nitrite (as N)	10	mg/L	Maximum Contaminant Level	Areas designated as MUN	SF Bay Basin Plan (Ch. 3)

[5] For ammonia, the standard provided in the Basin Plan (SFBRWQCB, 2013; section 3.3.20) applies to the un-ionized fraction, as the underlying criterion is based on un-ionized ammonia, which is the more toxic form. Conversion of RMC monitoring data from the measured total ammonia to un-ionized ammonia was based on a formula provided by the American Fisheries Society, and calculates un-ionized ammonia in freshwater systems from analytical results for total ammonia and field-measured pH, temperature, and electrical conductivity (see: http://fisheries.org/hatchery).

[6] For chloride, a Secondary Maximum Contaminant Level (MCL) of 250 mg/L applies to those waters with MUN beneficial use, per the Basin Plan (Table 3-5), Title 22 of the California Code of Regulations, and the EPA drinking water quality standards, and applies per the Basin Plan (Table 3-7) to waters in the Alameda Creek watershed above Niles. For all other waters, the criteria maximum concentration water quality criterion of 860 mg/L (acute) and the Criterion Continuous Concentration (CCC) of 230 mg/L (EPA Water Quality Criteria*) for the protection of aquatic life can be used for comparison. Per the WY 2012 UCMR (BASMAA, 2012) the RMC participants used the 230 mg/L threshold as a conservative benchmark for comparison purposes for all locations not specifically identified within the Basin Plan (i.e., sites not within the Alameda Creek watershed above Niles nor identified as MUN, rather than the maximum concentration criterion of 830 mg/L).

*See: http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm

[7] The nitrate+nitrite primary MCL applies to those waters with MUN beneficial use, per the Basin Plan (Table 3-5), Title 22 of the California Code of Regulations, and the EPA Drinking Water Quality Standards.

Table 4.16 Comparison of Water Quality (Nutrient) Data to Associated Water Quality Thresholds for WY 2017 Water Chemistry Results

Site Code	Creek Name	MUN?	Parameter and Threshold: Un-ionized Ammonia (as N) 25 µg/L	Chloride 230/250 mg/L[a]	Nitrate + Nitrite (as N) 10 mg/L[b]	Number of Parameters >Threshold/ Water Body
204R01819	Tributary of Laguna Creek	No	1.18	30	0.081	0
207R01547	Grayson Creek	No	1.25	170	0.029[c]	0
207R01591	Tributary of Walnut Creek	No	1.58	130	3.409	0
207R01595	Mt. Diablo Creek	No	1.36	75	0.824	0
207R01643	Mt. Diablo Creek	No	0.47[c]	39	1.807	0
207R01675	Sans Crainte Creek	No	0.82	38	0.416	0
207R01812	Sycamore Creek	No	1.75	68	0.027[c]	0
207R01847	Pine Creek	No	2.31	130	1.606	0
207R01860	Sycamore Creek	No	0.66[c]	42	0.243	0
207R01931	San Ramon Creek	No	3.69	60	0.048	0
	Number of Values >Threshold		0	0	0	0
	Percent of Values >Threshold		0%	0%	0%	0%

a 250 mg/L threshold applies for sites with MUN beneficial use and Alameda Creek above Niles per Basin Plan

b Nitrate + nitrite threshold applies only to sites with MUN beneficial use. No WY 2017 sites have MUN beneficial use.

c Calculated from non-detect data

Water samples also were collected and analyzed for free and total chlorine in the field using CHEMetrics test kits during bioassessment monitoring.

As shown in Table 4.17, no water samples produced measurable levels of free or total chlorine (all results were 0.0).

Table 4.17 Summary of Chlorine Testing Results for Samples Collected in WY 2017 in Comparison to Municipal Regional Permit Trigger Criteria

Site Code	Creek Name	Sample Date	Chlorine, Free	Chlorine, Total	Exceeds Trigger Threshold?
204R01819	Tributary of Laguna Creek	06/01/17	0	0	No
207R01547	Grayson Creek	05/31/17	0	0	No
207R01591	Tributary of Walnut Creek	05/17/17	0	0	No
207R01595	Mt. Diablo Creek	05/17/17	0	0	No
207R01643	Mt. Diablo Creek	05/15/17	0	0	No
207R01675	Sans Crainte Creek	05/15/17	0	0	No
207R01812	Sycamore Creek	05/18/17	0	0	No
207R01847	Pine Creek	05/30/17	0	0	No
207R01860	Sycamore Creek	05/16/17	0	0	No
207R01931	San Ramon Creek	06/15/17	0	0	No
Number of Samples Exceeding 0.1 mg/L			0	0	
Percentage of Samples Exceeding 0.08 mg/L			0%	0%	

4.3.3 Water Column Toxicity (Dry Weather)

Water samples were collected on July 13, 2017 from one regional/probabilistic monitoring site (West Branch Alamo Creek, site 204R01412), and tested for toxicity to several different aquatic species, as required by the MRP. The dry weather water toxicity test results are shown in Table 4.18.

All test results were determined not to be toxic except the *Ceriodaphnia dubia* chronic effects assay for reproduction. The average reproduction for the Rimer Creek test samples was 22.0 neonates per female, compared to 30.2 neonates per female for the control samples. At 73 percent of the control result (27 percent effect), this test was not required to be repeated by the follow-up provisions of MRP provision C.8.g.iv. (toxicity test results which are less than 50 percent of the control; see Tables 3.3 and 4.18).

The *Ceriodaphnia* chronic water sample test included one replicate that was determined to be a statistical outlier, but even when the outlier data point was included in the analysis, the result still was not less than 50 percent of the control (at 34 percent effect).

Table 4.18 Summary of CCCWP WY 2017 Dry Season Water Toxicity Results

Dry Season Water Samples			Toxicity Test Results						
			S. capricornutum	*C. dubia*		*C. dilutus*	*H. azteca*	*P. promelas*	
Site Code	Creek Name	Sample Collection Date	Growth (cells/mL x 10^6)	Survival (%)	Reproduction (No. of neonates/ female)	Survival (%)	Survival (%)	Survival (%)	Growth (mg)
Lab Control			3.00	100	30.2	95.0	98	97.5	0.55
204R01412	West Branch Alamo Creek	07/13/17	6.58	100	22.0[a]	97.5	100	97.5	0.65

a The response at this test treatment was significantly less than the lab control treatment response at $p < 0.05$, and was determined to be toxic, but the test result did not meet the MRP aquatic toxicity threshold for follow-up (less than 50 percent of the control).

4.3.4 Sediment Toxicity and Sediment Chemistry

Sediment samples were collected on July 13, 2017 after water samples were collected at the same regional/probabilistic monitoring site sampled for water column toxicity (West Branch Alamo Creek, site 204R01412), and tested for acute toxicity (survival) to *Hyalella azteca* and *Chironomus dilutus*.

Neither sample was determined to be toxic to either of the two sediment test species. The sediment toxicity test results are shown in Table 4.19.

Table 4.19 Summary of CCCWP WY 2017 Dry Season Sediment Toxicity Results

Dry-Season Sediment Samples			Toxicity Test Results	
			Hyalella azteca	*Chironomus dilutus*
Site Code	Creek Name	Sample Collection Date	Survival (%)	Survival (%)
Lab Control			97.5	96.2
204R01412	West Branch Alamo Creek	07/13/17	97.5	97.5

Note: No test treatment was determined to be significantly less than the lab control treatment response at $p < 0.05$

The sediment sample also was tested for a suite of potential sediment pollutants, as required by the MRP, and the results were compared to the trigger threshold levels specified for follow-up in MRP provision C.8.g.iv. (see Table 3.3). The complete sediment chemistry results are shown in Table 4.20, and the results are shown in comparison to the applicable MRP threshold triggers in Table 4.21.

As shown in Table 4.21, three constituents exhibited results with a TEC value greater than 1.0 in the West Branch Alamo Creek sediment sample: copper, nickel and zinc. These three metals are among the most common urban stormwater pollutants. Nickel is a naturally occurring element throughout much of the San Francisco Bay area, and commonly occurs at elevated levels in creek status monitoring.

Table 4.20 CCCWP WY 2017 Sediment Chemistry Results

Analyte	Units[a]	204R01412 West Branch Alamo Creek Result	MDL	RL
Metals				
Arsenic	mg/Kg	4.9	0.38	0.62
Cadmium	mg/Kg	0.16	0.012	0.05
Chromium	mg/Kg	24	0.62	0.62
Copper	mg/Kg	32	0.094	0.25
Lead	mg/Kg	8.5	0.05	0.12
Nickel	mg/Kg	35	0.075	0.12
Zinc	mg/Kg	140	1.0	2.5
Polycyclic Aromatic Hydrocarbons (PAHs)				
Acenaphthene	ng/g	ND	3.8	5.0
Acenaphthylene	ng/g	ND	3.8	5.0
Anthracene	ng/g	ND	3.8	5.0
Benz(a)anthracene	ng/g	ND	3.8	5.0
Benzo(a)pyrene	ng/g	ND	3.8	5.0
Benzo(b)fluoranthene	ng/g	ND	3.8	5.0
Benzo(e)pyrene	ng/g	ND	3.8	5.0
Benzo(g,h,i)perylene	ng/g	ND	3.8	5.0
Benzo(k)fluoranthene	ng/g	ND	3.8	5.0
Biphenyl	ng/g	ND	4.1	5.0
Chrysene	ng/g	ND	3.8	5.0
Dibenz(a,h)anthracene	ng/g	ND	3.8	5.0
Dibenzothiophene	ng/g	ND	4.1	5.0
Dimethylnaphthalene, 2,6-	ng/g	8.8	3.8	5.0
Fluoranthene	ng/g	ND	3.8	5.0
Fluorene	ng/g	ND	3.8	5.0
Indeno(1,2,3-c,d)pyrene	ng/g	ND	3.8	5.0
Methylnaphthalene, 1-	ng/g	ND	3.8	5.0
Methylnaphthalene, 2-	ng/g	ND	3.8	5.0
Methylphenanthrene, 1-	ng/g	ND	3.8	5.0
Naphthalene	ng/g	ND	3.8	5.0
Perylene	ng/g	ND	3.8	5.0
Phenanthrene	ng/g	ND	3.8	5.0
Pyrene	ng/g	ND	3.8	5.0
Pyrethroid Pesticides				
Bifenthrin	ng/g	9.0	0.12	0.33
Cyfluthrin, total	ng/g	1.0	0.14	0.33
Cyhalothrin, lambda-	ng/g	0.24[b]	0.075	0.33
Cypermethrin, total	ng/g	ND	0.12	0.33

Table 4.20 CCCWP WY 2017 Sediment Chemistry Results

Analyte	Units[a]	204R01412 West Branch Alamo Creek		
		Result	MDL	RL
Deltamethrin/Tralomethrin	ng/g	1.2	0.15	0.33
Esfenvalerate/Fenvalerate	ng/g	ND	0.16	0.33
Permethrin	ng/g	1.2	0.14	0.33
Other Pesticides				
Carbaryl	ng/g	ND	0.12	0.12
Fipronil	ng/g	ND	0.12	0.33
Fipronil Desulfinyl	ng/g	0.20[b]	0.12	0.33
Fipronil sulfide	ng/g	0.25[b]	0.12	0.33
Fipronil sulfone	ng/g	1.4	0.12	0.33
Organic Carbon				
Total Organic Carbon	%	8.0	0.012	0.12

a All measurements reported as dry weight

b Results were j-flagged by the laboratory as estimated concentrations, detected between the MDL and RL

ND not detected

Table 4.21 Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC) Quotients for WY 2017 Sediment Chemistry Constituents

		204R01412 West Branch Alamo Creek		
	Sample Units[a]	Sample	TEC Ratio	PEC Ratio
Metals				
Arsenic	mg/Kg	4.9	0.50	0.15
Cadmium	mg/Kg	0.16	0.16	0.03
Chromium	mg/Kg	24	0.55	0.22
Copper	mg/Kg	32	1.01	0.21
Lead	mg/Kg	8.5	0.24	0.07
Nickel	mg/Kg	35	1.54	0.72
Zinc	mg/Kg	140	1.16	0.31
Polycyclic Aromatic Hydrocarbons (PAHs)				
Anthracene	ng/g	ND		
Fluorene	ng/g	ND		
Naphthalene	ng/g	ND		
Phenanthrene	ng/g	ND		
Benz(a)anthracene	ng/g	ND		
Benzo(a)pyrene	ng/g	ND		
Chrysene	ng/g	ND		
Fluoranthene	ng/g	ND		
Pyrene	ng/g	ND		
Total PAHs*	ng/g	52.5	0.033	0.0023
		Number with TECq > 1.0	3	
		Combined TEC Ratio	5.20	
		Average TEC Ratio	0.37	
		Combined PEC Ratio		1.71
		Average PEC Ratio		0.21

Note: All measurements reported as dry weight. TECs and PECs per MacDonald et al. (2000).
Bold TEC or PEC ratio indicates ratio >1.0
ND not detected
a Total PAHs include 24 individual PAH compounds; NDs were substituted at 1/2 MDL to compute total PAHs.

Pyrethroid pesticide concentrations were compared to sediment concentrations known to cause toxicity. Table 4.22 provides a summary of the calculated TU equivalents for the pyrethroids for which there are published toxic levels, known as LC_{50} values, and a sum of the calculated TU equivalents for each monitored site. Because organic carbon mitigates the toxicity of pyrethroid pesticides in sediments, the LC_{50} values are based on organic carbon-normalized pyrethroid concentrations. Therefore, the pyrethroid concentrations, as reported by the lab, were divided by the measured TOC concentration (as a percentage) at each site, and the TOC-normalized concentrations were then used to compute TU equivalents for each pyrethroid.

The most common urban pyrethroid pesticide, bifenthrin, was detected at the WY 2017 sediment monitoring site (Tables 4.20 and 4.22), along with several other pyrethroid pesticides. The absence of toxicity in the sediment toxicity testing for this sample conforms with the predicted lack of toxicity derived from the pyrethroid pesticides analysis, based on the TU calculations shown in Table 4.22.

Table 4.22 Calculated Pyrethroid Toxic Unit Equivalents, WY 2017 Sediment Chemistry Data

Pyrethroid Pesticides	LC_{50} (µg/g organic carbon)	204R01412 West Branch Alamo Creek		
		Sample (ng/g)	Sample (µg/g organic carbon)	TU Equivalents[a]
Bifenthrin	0.52	9.0	0.11	0.22
Cyfluthrin	1.08	1.0	0.01	0.012
Cyhalothrin, lambda	0.45	0.24	0.003	0.007
Cypermethrin	0.38	ND		
Deltamethrin/Tralomethrin	0.79	1.2	0.02	0.019
Esfenvalerate/Fenvalerate	1.54	ND		
Permethrin	10.8	1.2	0.02	0.001
			Sum (Pyrethroid TUs)	0.255

Note: All sample measurements reported as dry weight.

ND not detected

a Toxic Unit Equivalents (TUs) are calculated as ratios of organic carbon-normalized pyrethroid sample concentrations to published *H. azteca* LC_{50} values. See http://www.tdcenvironmental.com/resources/Pyrethroids-Aquatic-Tox-Summary.pdf for associated references.

4.3.5 Sediment Triad Analysis

Table 4.23 summarizes stressor evaluation results for sites with data collected for sediment chemistry, sediment toxicity, and bioassessment parameters by CCCWP over the first five years of the RMC regional/probabilistic monitoring effort (WY 2012-2017).

Pyrethroid pesticide sediment concentrations appear to be potent predictors of sediment toxicity, as samples with calculated pyrethroid TU equivalents greater than 1.0 exhibited significant sediment toxicity. The samples with TU equivalents less than 1.0 did not exhibit sediment toxicity, as shown in Table 4.23.

Table 4.23 Summary of Sediment Quality Triad Evaluation Results, WY 2012-WY 2017 Data

Water Year	Water Body	Site ID	B-IBI Condition Category	Sediment Toxicity	No. of TEC Quotients ≥ 1.0	Mean PEC Quotient	Sum of TU Equivalents
2012	Grayson Creek	207R00011	Very Poor	Yes	10	0.14	2.17
2012	Dry Creek	544R00025	Very Poor	Yes	11	0.51	3.62
2013	Sycamore Creek	207R00271	Very Poor	Yes	0	0.04	10.5
2013	Marsh Creek	544R00281	Very Poor	Yes	4	0.13	1.03
2014	San Pablo Creek	206R00551	Very Poor	No	1	0.09	.016
2014	Grizzly Creek	207R00843	Very Poor	No	1	0.12	.11
2015	Rodeo Creek	206R01024	Poor	No	1	0.11	0.32
2015	Green Valley Creek	207R00891	Very Poor	Yes	3	0.12	1.11
2016	Rimer Creek	204R01519	Degraded (CSCI)	No	1	0.12	0.89
2017	West Branch Alamo Creek	204R01412	Degraded (CSCI)[a]	No	3	0.21	0.255

Note: Yellow-highlighted cells indicate results exceed permit trigger threshold.

a Based on WY 2016 bioassessment data

4.3.6 Analysis of Condition Indicators and Stressors

CSCI scores were calculated from the CCCWP bioassessment data beginning in WY 2016. The CSCI uses location-specific GIS data to compare the observed BMI taxonomic data to expected BMI assemblage characteristics from reference sites with similar geographical characteristics. All calculated CSCI scores for 2017 samples were below the MRP 2.0 threshold of 0.795, indicating degraded benthic biological communities at the 10 sites monitored by CCCWP in WY 2017, per the MRP threshold. Additional work will need to be done with the CSCI scores in relation to this threshold to make a clearer assessment of relative biological conditions for these urban streams. While the CSCI scores did not correlate well with other biological condition indices in the 2017 data analysis, the CSCI scores did correlate well with the Contra Costa benthic-IBI scores for WY 2016 data.

There was one instance of toxicity in the limited dry weather testing performed in WY 2017, in the chronic *Ceriodaphnia dubia* test for the West Branch Alamo Creek sample. This result was consistent with the results of toxicity testing for Rimer Creek in WY 2016, in which chronic toxicity to *C. dubia* was also found in the water sample, but those results are inconsistent with the results from previous years, in which toxicity to *Hyalella azteca* was more common.

The principal stressors identified in the chemical analyses from the 2017 sampling are the heavy metals copper, nickel and zinc, with less emphasis on pyrethroid pesticides in sediments.

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5. Conclusions and Next Steps

During WY 2017, 10 sites were monitored by CCCWP under the RMC regional/probabilistic design for bioassessment, physical habitat, and water chemistry parameters. One site also was monitored for water and sediment toxicity and sediment chemistry. Based on the results of the bioassessment monitoring, all 10 sites monitored in WY 2017 produced CSCI scores below the MRP threshold, indicating sub-optimal biological conditions in the benthos of the monitored streams.

The water and sediment chemistry and toxicity data were used to evaluate potential stressors which may affect aquatic habitat quality and beneficial uses. The bioassessment and related data are also used to develop a preliminary condition assessment for the monitored sites, to be used in conjunction with the stressor assessment based on sediment chemistry and toxicity.

5.1 Summary of Stressor Analyses

Based on an analysis of the regional/probabilistic data collected by CCCWP during WY 2017, the stressor analysis is summarized as follows:

Physical Habitat Conditions: Limited analysis of PHab metrics did not produce any significant correlations with biological condition indicators for WY 2017 data.

Water Quality: Of 12 water quality parameters required in association with bioassessment monitoring, applicable water quality standards were only identified for ammonia, chloride, and nitrate + nitrite (for sites with MUN beneficial use only). None of the results generated at the 10 sites monitored by CCCWP for those three parameters during WY 2017 exceeded the applicable water quality standard or threshold.

Water Toxicity: Toxicity testing was performed for four test species in water samples collected from West Branch Alamo Creek (site 204R01412) during one dry season sampling event in WY 2017. Only the *C. dubia* chronic (reproduction) water sample test was significantly toxic. This result did not meet the MRP threshold for follow-up testing.

Sediment Toxicity: The West Branch Alamo Creek sediment sample was not toxic to either of the test species (*H. azteca and C. dilutus*).

Sediment Chemistry: The pyrethroid pesticide bifenthrin was detected at quantifiable levels in the creek sediment sample, but the sum of pyrethroid pesticides did not exceed 1 TU. Another common current-use pesticide, fipronil, was not detected, but all three of the fipronil degradates were detected in the sediment sample.

Sediment Triad Analyses: Bioassessment, sediment toxicity, and sediment chemistry results were evaluated as the three lines of evidence used in the triad approach for assessing overall stream condition and added to the compiled results for water years 2012-2017. Good correlation is observed throughout that period in the triad analysis between pyrethroid concentrations (TU >1) and sediment toxicity.

Chemical stressors, particularly pesticides, may be contributing to the degraded biological conditions indicated by the low B-IBI scores in many of the monitored streams.

5.2 Next Steps

The analysis presented in this report identifies several potentially impacted sites which may deserve further evaluation and/or investigation to provide better understanding of the sources/stressors which might contribute to reduced water quality and lower biological conditions.

During the initial MRP term, the RMC collaboratively reviewed trigger results from WY 2012 and selected a total of 10 sites in four counties for implementation of SSID projects, based on prioritization of the type, extent, and geographic spread of the triggers. For CCCWP, this involved two projects designed to evaluate and further characterize causes of toxicity impacting urban creek systems, specifically Grayson Creek (Region 2) and Dry Creek (Region 5).

Efforts are currently underway by the RMC to evaluate data for selection of a new set of SSID projects for implementation during the current MRP term. CCCWP will continue to collaborate in this regional effort. Eight SSID projects are required regionally per MRP 2.0 if performed within a regional collaborative. CCCWP will be required to perform one new SSID project during the MRP 2.0 permit term, per agreement within the RMC; this project may not involve toxicity. The current list of potential SSID projects is included as Appendix 3 to the CCCWP WY 2017 UCMR.

CCCWP and the other RMC participants will continue to implement the regional/probabilistic monitoring design in WY 2018, under the terms of MRP 2.0 (effective January 1, 2016). Additional data also might permit a better assessment as to the potential effects of drought and rising temperatures on urban stream quality.

In compliance with the MRP, the RMC is undertaking a comprehensive, regional analysis of the first five years of bioassessment monitoring performed under the MRP, as a BASMAA regional project. In addition to the regional data analysis, this project will include an evaluation of the existing Creek Status Monitoring Plan and probabilistic design, and recommendations for next steps in the monitoring design

Wet season toxicity and chemistry monitoring will commence in WY 2018, as required by MRP 2.0, Provision C.8.g.iii.

Candidate probabilistic sites previously classified with “unknown" sampling status in the RMC probabilistic site evaluation process may continue to be evaluated for potential sampling in WY 2018.

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Appendix 2

Local/Targeted Creek Status Monitoring Report

Water Year 2017

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Local/Targeted Creek Status Monitoring Report
Water Year 2017
(October 2016 – September 2017)

Submitted to the San Francisco Bay and Central Valley Regional Water Quality Control Boards in Compliance with NPDES Permit Provisions C.8.h.iii and C.8.g.iii

NPDES Permit Nos. CAS612008 and CAS083313

March 23, 2018

A Program of Contra Costa County, its Incorporated Cities and Towns, and the Contra Costa Flood Control & Water Conservation District

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This report is submitted by the participating agencies of the

Program Participants:

- Cities and Towns of: Antioch, Brentwood, Clayton, Concord, Danville (Town), El Cerrito, Hercules, Lafayette, Martinez, Moraga (Town), Oakley, Orinda, Pinole, Pittsburg, Pleasant Hill, Richmond, San Pablo, San Ramon and Walnut Creek
- Contra Costa County
- Contra Costa County Flood Control & Water Conservation District

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List of Acronyms and Abbreviations

ACCWP	Alameda Countywide Clean Water Program
ADH	ADH Environmental
ARC	Armand Ruby Consulting
BASMAA	Bay Area Stormwater Management Agencies Association
CCCWP	Contra Costa Clean Water Program
CFS	cubic feet per second
CFU	colony forming units
COLD	cold freshwater habitat
CVRWQB	Central Valley Regional Water Quality Control Board
DO	dissolved oxygen
EBMUD	East Bay Municipal Utility District
EPA	U.S. Environmental Protection Agency
FSURMP	Fairfield-Suisun Urban Runoff Management Program
GM	geometric mean
MPN	most probable number
MRP	municipal regional permit
MWAT	maximum weekly average temperature
NPDES	National Pollutant Discharge Elimination System
pH	hydrogen in concentration
QAPP	quality assurance project plan
Region 2	San Francisco Regional Water Quality Control Board
Region 5	Central Valley Regional Water Quality Control Board
RMC	Regional Monitoring Coalition
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
SOP	standard operating procedure
SSID	stressor/source identification
STV	statistical threshold value
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
WARM	warm water habitat
WAT	weekly average temperature
WQOs	water quality objectives
WY	water year
YSI	Yellow Springs International

Preface

Contra Costa County lies within both the Region 2 and Region 5 jurisdictions of the State Water Resources Control Board (SWRCB). The countywide stormwater program is subject to both the Region 2 municipal regional stormwater National Pollutant Discharge Elimination System (NPDES) permit (MRP)[1] and the equivalent Region 5 permit (Central Valley Permit)[2].

This Local/Targeted Creek Status Monitoring Report documents the results of targeted (non-probabilistic) monitoring performed by Contra Costa Clean Water Program (CCCWP) in water year (WY) 2017 (October 1, 2016-September 30, 2017). Together with the creek status monitoring data reported in *Regional/Probabilistic Creek Status Monitoring Report* (ARC, 2018), this submittal fulfills monitoring requirements specified in provision C.8.d of the permit, complies with reporting provision C.8.h of the MRP (SWRCB, 2015), and fulfills the monitoring requirements highlighted in Table 8.1 and the reporting requirements of provision C.8.g of the Central Valley Permit.

In early 2010, several members of the Bay Area Stormwater Management Agencies Association (BASMAA) joined together to form the Regional Monitoring Coalition (RMC) to coordinate and oversee water quality monitoring required by the MRP. The RMC includes the following stormwater program participants:

- Alameda Countywide Clean Water Program (ACCWP)
- Contra Costa Clean Water Program (CCCWP)
- San Mateo Countywide Water Pollution Prevention Program (SMCWPPP)
- Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)
- Fairfield-Suisun Urban Runoff Management Program (FSURMP)
- City of Vallejo and Vallejo Sanitation and Flood Control District

In accordance with the RMC *Creek Status and Long-Term Trends Monitoring Plan* (EOA and ARC, 2011), targeted monitoring data were collected following methods and protocols specified in the BASMAA RMC *Quality Assurance Project Plan* (QAPP; BASMAA, 2014a) and BASMAA RMC *Standard Operating Procedures* (BASMAA, 2014b). Where applicable, monitoring data were derived using methods comparable with methods specified by the California Surface Water Ambient Monitoring Program (SWAMP) QAPP[3]. Data presented in this report were also submitted to the San Francisco Estuary Institute for submittal to the SWRCB on behalf of CCCWP's permittees and pursuant to permit provision C.8.h. requirements for electronic data reporting.

[1] The San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) issued the MRP to 76 cities, counties and flood control districts (i.e., the permittees) in the Bay Area on October 14, 2009 (SFBRWQCB, 2009). On November 19, 2015, SFBRWQCB issued Order No. R2-2015-0049. This amendment supersedes and rescinds Order Nos. R2-2009-0074 and R2-2011-0083, and became effective January 1, 2016. The BASMAA programs supporting MRP regional projects include all MRP permittees, as well as the cities of Antioch, Brentwood and Oakley, which are not named as permittees under the MRP, but have voluntarily elected to participate in MRP-related regional activities.

[2] The Central Valley Regional Water Quality Control Board (CVRWQCB) issued the East Contra Costa County Municipal NPDES Permit (Central Valley Permit, Order No. R5-2010-0102) on September 23, 2010 (CVRWQB, 2010).

[3] The current SWAMP QAPP is available at: http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/qapp/swamp_qapp_master090108a.pdf

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Executive Summary

This Local/Targeted Creek Status Monitoring Report documents the results of targeted monitoring performed by CCCWP during WY 2017. Together with the creek status monitoring data reported in *Regional/Probabilistic Creek Status Monitoring Report* (ARC, 2018), this submittal fulfills reporting requirements for status monitoring specified under provision C.8.d of the MRP for urban stormwater issued by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB; Order No. R2-2015-0049) and for monitoring specified in Table 8.1 under provision C.8.c of the East Contra Costa County municipal NPDES permit (Central Valley Permit) issued by the Central Valley Regional Water Quality Control Board (CVRWQCB; Order No. R5-2010-0102). Reporting requirements for constituents under SFBRWQCB are established in provision C.8.d and reporting requirements for CVRWQCB are established in provision C.8.g.iii. Both permits follow provisions promoting a coordinated countywide program of water quality management.

Within Contra Costa County, targeted monitoring was conducted at:

- Four continuous water temperature monitoring locations
- Two continuous water quality monitoring locations
- Five pathogen indicator monitoring locations

Continuous Water Temperature

Hourly water temperature measurements were recorded at 60-minute intervals using Onset® HOBO® data loggers (HOBOs) deployed at three creeks in four separate locations on April 26, 2017. One device each was deployed in Franklin Creek and Alhambra Creek, and two devices were deployed in Las Trampas Creek. The HOBOs were retrieved on October 4, 2017. As the permit term reporting requirements apply only to the extent of a given water year, all data collected after September 30, 2017 are not included in this report.

Pathogen Indicators

Samples were collected on July 24, 2017 at five stations along five separate creeks in Contra Costa County. Samples were analyzed for enterococci and *E. coli.* The five sampling locations were located at West Branch Alamo Creek, Sans Crainte Creek, Las Trampas Creek, Walnut Creek, and Alhambra Creek.

General Water Quality

Temperature, dissolved oxygen (DO), hydrogen in concentration (pH), and specific conductance were continuously monitored at 15-minute intervals by sondes during two time periods (May 16-30, 2017 and July 31-August 11, 2017) at locations along Las Trampas Creek (207R02635) and Alhambra Creek (207R04544).

Results of Targeted Monitoring Data

All targeted monitoring data were evaluated against numeric water quality objectives (WQOs) or other applicable criteria, as described in MRP provision C.8.d. Targeted monitoring locations for WY 2017 were located entirely within SFBRWQCB Region 2 boundaries. Therefore, numeric WQOs only as they are stated in MRP provision C.8.d will be discussed. The results are summarized below.

Temperature – HOBO and Sonde

Numeric WQOs for temperature are defined in the MRP for all streams as less than 20 percent of instantaneous results exceeding 24 °C. For streams documented to support steelhead fisheries (i.e., steelhead streams), a maximum temperature of 17 °C is used as the applicable criterion to evaluate temperature data. According to the MRP, if the temperature data is recorded by a HOBO device (versus a sonde), a maximum of one weekly average temperature (WAT) can reach a threshold of 17 °C. For temperature recorded by sonde devices, all WATs must be below 17 °C. The variation in total number of WATs signaling an exceedance are adjusted, as deployment times between the two devices differ.

At the four locations with continuously recorded HOBO temperature data from April until October, all three creeks (Franklin Creek, Las Trampas Creek and Alhambra Creek) are classified as steelhead streams.

Temperature was continuously monitored by sondes during two time periods (May 16-30, 2017 and September 31-August 11, 2017) at Las Trampas Creek and Alhambra Creek, which are both classified as steelhead streams.

No location where water temperature was measured recorded a 20 percent instantaneous results exceedance of 24 °C; there were no exceedances of this criterion. At locations classified as steelhead streams, there were exceedances of the 17 °C threshold in six of eight cases. These locations were Franklin Creek, both locations along Las Trampas Creek, and Alhambra Creek for the HOBO recorded data, and Las Trampas Creek and Alhambra Creek for the sonde recorded data during the August deployment. No exceedance occurred for the sonde recorded data during the May deployment at Las Trampas Creek or Alhambra Creek.

For the purpose of this report, designated beneficial uses listed and defined by Table ES.1 as cold freshwater habitat (COLD) will be discussed as steelhead streams, per the MRP definition. Streams designated as a warm freshwater habitat (WARM) are referred to as such or as a non-steelhead stream, per the MRP definition. For WY 2017, per permit guidelines, no streams designated as warm freshwater habitat were targeted over the course of this project. Data collected will focus on streams classified with a designated beneficial use of cold freshwater habitat.

Table ES.1. Designated Beneficial Uses Listed in the San Francisco Bay Region Basin Plan (SFBRWQCB, 2015) for CCCWP Targeted Monitoring Sites in WY 2017

Site ID	Water Body	Human Consumptive Uses							Aquatic Life Uses										Recreational Uses		
		AGR	MUN	FRSH	GWR	IND	PROC	COMM	SHELL	COLD	EST	MAR	MIGR	RARE	SPWN	WARM	WILD	REC-1	REC-2	NAV
207R01447	Franklin Creek									E			E	E	E	E	E	E	E	
207R02635	Las Trampas Creek									E				E		E	E	E	E	
207R02891	Las Trampas Creek									E				E		E	E	E	E	
207R04544	Alhambra Creek									E			E	E	E	E	E	E	E	

E Existing beneficial use

Notes: Per Basin Plan Ch. 2 (SFBRWQCB, 2015), beneficial uses for freshwater creeks include municipal and domestic supply (MUN), agricultural supply (AGR), industrial process supply (PRO), groundwater recharge (GWR), water contact recreation (REC1), noncontact water recreation (REC2), wildlife habitat (WILD), cold freshwater habitat (COLD), warm freshwater habitat (WARM), fish migration (MIGR), and fish spawning (SPWN). The San Francisco Bay Estuary supports estuarine habitat (EST), industrial service supply (IND), and navigation (NAV) in addition to all uses supported by streams. Beneficial uses for coastal waters include water contact recreation (REC1); noncontact water recreation (REC2); industrial service supply (IND); navigation (NAV); marine habitat (MAR); shellfish harvesting (SHELL); ocean, commercial and sport fishing (COMM); and preservation of rare and endangered species (RARE).

Dissolved Oxygen

WQOs for dissolved oxygen in non-tidal waters are applied as follows: for waters designated as steelhead habitat, less than 20 percent of instantaneous dissolved oxygen results may drop below 7.0 mg/L.

At locations classified as steelhead streams, there were exceedances during the August deployment at both Las Trampas Creek and Alhambra Creek, where 40 percent and 100 percent of dissolved oxygen concentrations were measured below the threshold, respectively.

pH

WQOs for pH in surface waters are defined as follows: less than 20 percent of instantaneous pH results may fall outside the range of 6.5 to 8.5. This range was used to evaluate the pH data collected at all targeted locations over WY 2017.

During both monitoring periods, pH measurements at Las Trampas Creek and Alhambra Creek did not exceed stated WQOs.

Specific Conductance

WQOs for specific conductance in surface waters are applied as follows: less than 20 percent of instantaneous specific conductance results may exceed 2,000 µS/cm, or readings should not detect any spike in specific conductance with no obvious natural explanation.

During both monitoring periods, specific conductance measurements at Las Trampas Creek and Alhambra Creek did not exceed stated WQOs.

Pathogen Indicator Bacteria

Single sample maximum concentrations of 130 CFU/100 ml enterococci and 410 CFU/100 ml *E. coli* (EPA, 2012) were used as water contact recreation evaluation criteria for the purposes of this evaluation. For enterococci, four out of five single sample concentrations (West Branch Alamo Creek, Sans Crainte Creek, Las Trampas Creek, and Alhambra Creek) exceeded the applicable threshold criteria. For *E. coli,* three of the five stations (Sans Crainte Creek, Las Trampas Creek, and Alhambra Creek) exceeded the single sample maximum concentration for water contact recreation criteria.

Exceedances for each of the above parameters are summarized in Table ES.2.

Table ES.2 CCCWP Exceedances for Water Year 2017

Creek	Index Period	Parameter	Criterion Exceedance
Franklin Creek	June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Las Trampas Creek (at Camino Posada Court)	May 3-May 9, 2017; May 17-May 23, 2017; May 31-June 6, 2017; June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Las Trampas Creek (at Camino Posada Court)	July 31-August 11, 2017	Continuous Water Temperature (sonde)	When one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Las Trampas Creek (at Camino Posada Court)	July 31-August 11, 2017	Continuous Water Quality - DO	When 20 percent of instantaneous results drop below 7.0 mg/L
Las Trampas Creek (at Reliez Station Road)	May 17-May 23, 2017; May 31-June 6, 2017; June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Alhambra Creek	May 31-June 6, 2017; June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Alhambra Creek	July 31-August 11, 2017	Continuous Water Temperature (sonde)	When one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Alhambra Creek	July 31-August 11, 2017	Continuous Water Quality - DO	When 20 percent of instantaneous results drop below 7.0 mg/L
West Branch Alamo Creek	July 24, 2017	Enterococci	Single grab sample exceeded EPA criterion of 130 CFU/100ml
Sans Crainte Creek	July 24, 2017	Enterococci	Single grab sample exceeded EPA criterion of 130 CFU/100ml
Las Trampas Creek (at Reliez Station Road)	July 24, 2017	Enterococci	Single grab sample exceeded EPA criterion of 130 CFU/100ml
Alhambra Creek	July 24, 2017	Enterococci	Single grab sample exceeded EPA criterion of 130 CFU/100ml
Sans Crainte Creek	July 24, 2017	*E. coli*	Single grab sample exceeded EPA criterion of 410 CFU/100ml
Las Trampas Creek (at Reliez Station Road)	July 24, 2017	*E. coli*	Single grab sample exceeded EPA criterion of 410 CFU/100ml
Alhambra Creek	July 24, 2017	*E. coli*	Single grab sample exceeded EPA criterion of 410 CFU/100ml

WAT = weekly average temperature
DO = dissolved oxygen

1. Introduction

Contra Costa County lies within the jurisdictions of both the San Francisco Bay Regional Water Quality Control Board (Region 2) and the Central Valley Regional Water Quality Control Board (Region 5). Municipal stormwater discharges in Contra Costa County are regulated by the requirements of both the MRP for urban stormwater in Region 2 (Order No. R2-2015-0049), and the East Contra Costa County municipal NPDES permit (Central Valley Permit) in Region 5 (Order No. R5-2010-0102)[4,5]. This Local/Targeted Creek Status Monitoring Report documents the results of targeted (non-probabilistic) monitoring performed by CCCWP during WY 2017 (October 1, 2016-September 30, 2017), and complies with reporting provision C.8.h of the Region 2 municipal NPDES permit, and provision C.8.g of the Region 5 municipal NPDES permit for creek status monitoring data collected during WY 2017. Together with the creek status monitoring data reported in *Regional/Probabilistic Creek Status Monitoring Report, Water Year 2017* (ARC, 2018), this submittal fulfills monitoring requirements in permit provision C.8.d of the Region 2 MRP and for Table 8.1 monitoring specified in provision C.8.c of the Region 5 Central Valley Permit.

Members of BASMAA formed the RMC in early 2010 to collaboratively implement the monitoring requirements found in provision C.8 of the MRP (see Table 1.1). The BASMAA RMC developed a QAPP (BASMAA, 2014a), standard operating procedures (SOPs; BASMAA, 2014b), data management tools, and reporting templates and guidelines. Costs for these activities are shared among RMC members on a population-weighted basis by direct contributions and provision of in-kind services by RMC members to complete required tasks. Participation in the RMC is facilitated through the BASMAA Monitoring and Pollutants of Concern Committee.

The goals of the RMC are to:

1. Assist RMC permittees in complying with requirements of MRP provision C.8 (water quality monitoring);

2. Develop and implement regionally consistent creek monitoring approaches and designs in the Bay Area through improved coordination among RMC participants and other agencies (e.g., regional water quality control boards, Regions 2 and 5, and the State Water Resources Control Water Board) which share common goals; and

3. Stabilize the costs of creek monitoring by reducing duplication of efforts and streamlining reporting.

The RMC divided the creek status monitoring requirements specified by permit provisions into those parameters which could reasonably be included within a regional/probabilistic design, and those which, for logistical and jurisdictional reasons, should be implemented locally using a targeted (non-probabilistic) design. The monitoring elements included in each category are specified in Table 1.2.

This report focuses on the creek status and long-term trends monitoring activities conducted to comply with provision C.8.d using a targeted (non-probabilistic) monitoring design (see Table 1.2).

[4] The SFBRWQCB issued the five-year municipal regional permit for urban stormwater (MRP, Order No. R2-2015-0049) to 76 cities, counties and flood control districts (i.e., permittees) in the Bay Area on November 19, 2015 (SFBRWQCB, 2015a). The BASMAA programs supporting MRP regional projects include all MRP permittees, as well as the cities of Antioch, Brentwood, and Oakley, which are not named as permittees under the MRP but have voluntarily elected to participate in MRP-related regional activities.

[5] The CVRWQCB issued the East Contra Costa County municipal NPDES permit (Central Valley Permit, Order No. R5-2010-0102) on September 23, 2010 (CVRWQB, 2010).

Table 1.1 Regional Monitoring Coalition Participants

Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)	Cities of Campbell, Cupertino, Los Altos, Milpitas, Monte Sereno, Mountain View, Palo Alto, San Jose, Santa Clara, Saratoga, Sunnyvale, Los Altos Hills, and Los Gatos; Santa Clara Valley Water District; and Santa Clara County
Alameda Countywide Clean Water Program (ACCWP)	Cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City; Alameda County; Alameda County Flood Control and Water Conservation District; and Zone 7
Contra Costa Clean Water Program (CCCWP)	City of Antioch, City of Brentwood, City of Clayton, City of Concord, Town of Danville, City of El Cerrito, City of Hercules, City of Lafayette, City of Martinez, Town of Moraga, City of Oakley, City or Orinda, City of Pinole, City of Pittsburg, City of Pleasant Hill, City of Richmond, City of San Pablo, City of San Ramon, City of Walnut Creek, Contra Costa County Flood Control and Water Conservation District and Contra Costa County Watershed Program
San Mateo County Wide Water Pollution Prevention Program (SMCWPPP)	Cities of Belmont, Brisbane, Burlingame, Daly City, East Palo Alto, Foster City, Half Moon Bay, Menlo Park, Millbrae, Pacifica, Redwood City, San Bruno, San Carlos, San Mateo, South San Francisco, Atherton, Colma, Hillsborough, Portola Valley, and Woodside; San Mateo County Flood Control District; and, San Mateo County
Fairfield-Suisun Urban Runoff Management Program (FSURMP)	Cities of Fairfield and Suisun City
Vallejo Permittees	City of Vallejo and Vallejo Sanitation and Flood Control District

Table 1.2 Creek Status Monitoring Parameters Sampled in Compliance with MRP Provisions C.8.d. and C.8.g. as Either Regional/Probabilistic or Local/Targeted Parameters

Bioassessment, physical habitat assessment, CSCI	X	
Nutrients (and other water chemistry associated with bioassessment)	X	
Chlorine	X	
Water toxicity (wet and dry weather)	X	
Water chemistry (pesticides, wet weather)	X	
Sediment toxicity	X	
Sediment chemistry	X	
Continuous water quality (sonde data: temperature, dissolved oxygen, pH, specific conductance)		X
Temperature (HOBO data loggers)		X
Bacteria		X

As a professional fisheries biologist familiar with Contra Costa County streams, Scott Cressey reviewed the tabulated and graphed water quality monitoring data from WY 2017 and compared these data to the San Francisco Bay Basin Plan's (CRWQCB, 2015) beneficial use designations for these streams and the Basin Plan WQOs, especially those associated with COLD objectives. His assessment of these data was provided to ADH in a memorandum (Cressey, 2017). Relevant information from this assessment are incorporated into the narrative in the following sections, as appropriate.

The remainder of this report describes the study area and design (Section 2.0), monitoring methods (Section 3.0), results and discussion (Section 4.0), and next steps (Section 5.0).

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2. Study Area and Design

2.1. Regional Monitoring Coalition Area

The RMC area encompasses 3,407 square miles of land in the San Francisco Bay Area. This includes the portions of the five participating counties which fall within the jurisdiction of the SFBRWQCB (Figure 2.1). Figure 2.2 illustrates the boundaries of the State Water Resources Control Board, Regions 2 and 5, as well as the Contra Costa County delta boundaries[6]. The eastern portion of Contra Costa County drains to the CVRWQCB region (Region 5), while the rest of the county drains into Region 2. Status and trends monitoring is conducted in flowing water bodies (i.e., creeks, streams and rivers) interspersed among the RMC area, including perennial and non-perennial creeks and rivers running through both urban and non-urban areas.

2.2. Contra Costa County Targeted Monitoring Areas and Siting Rationale

Contra Costa County has 31 major watersheds and sub-watersheds containing more than 1,300 miles of creeks and drainages (CCCDD, 2003). The County's creeks discharge into the Sacramento-San Joaquin delta in the east, along the series of bays to the north (including Suisun and San Pablo bays), and to North San Francisco Bay in the west. In addition, two watersheds (Upper San Leandro and Upper Alameda Creek) originate in Contra Costa County and continue through Alameda County before reaching San Francisco Bay.

The Walnut Creek and Alhambra Creek watersheds were the focus of the CCCWP's targeted sampling in WY 2017. Both watersheds were sampled for pathogen indicators and selected for monitoring of continuous water temperature or continuous water quality parameters. Further details and discussion about the targeted sampling areas can be found in the Monitoring Methods and Results sections of this report (Sections 3 and 4, respectively).

All targeted sampling in WY 2017 was conducted in Region 2.

2.2.1. Walnut Creek Watershed – Las Trampas Creek Sub-watershed

The Walnut Creek watershed is in central Contra Costa County, with boundaries demarcated by the west side of Mount Diablo and the east side of the East Bay Hills. At 93,556 acres, it is the largest watershed in the county. The watershed has eight major tributaries which flow into the generally south-north trending direction of Walnut Creek. These tributaries include San Ramon Creek, Bollinger Creek, Las Trampas Creek, Lafayette Creek, Grayson Creek, Murderers Creek, Pine Creek, and Galindo Creek.

Due to steep slopes and land protection efforts, the upper watersheds along the perimeter of the Walnut Creek watershed generally remain undeveloped open space. The valleys of the watershed are densely urbanized and populated by the cities of Walnut Creek, Lafayette, Pleasant Hill and Danville. The cities of Concord and Martinez, as well as small areas of Moraga and San Ramon, also are partly within the watershed (Walkling, 2013).

[6]Divide between the basin boundary watershed/hydrologic sub basins within the Sacramento-San Joaquin Rivers and Delta Waterways.

Figure 2.1 Map of BASMAA RMC Area, County Boundaries and Major Creeks

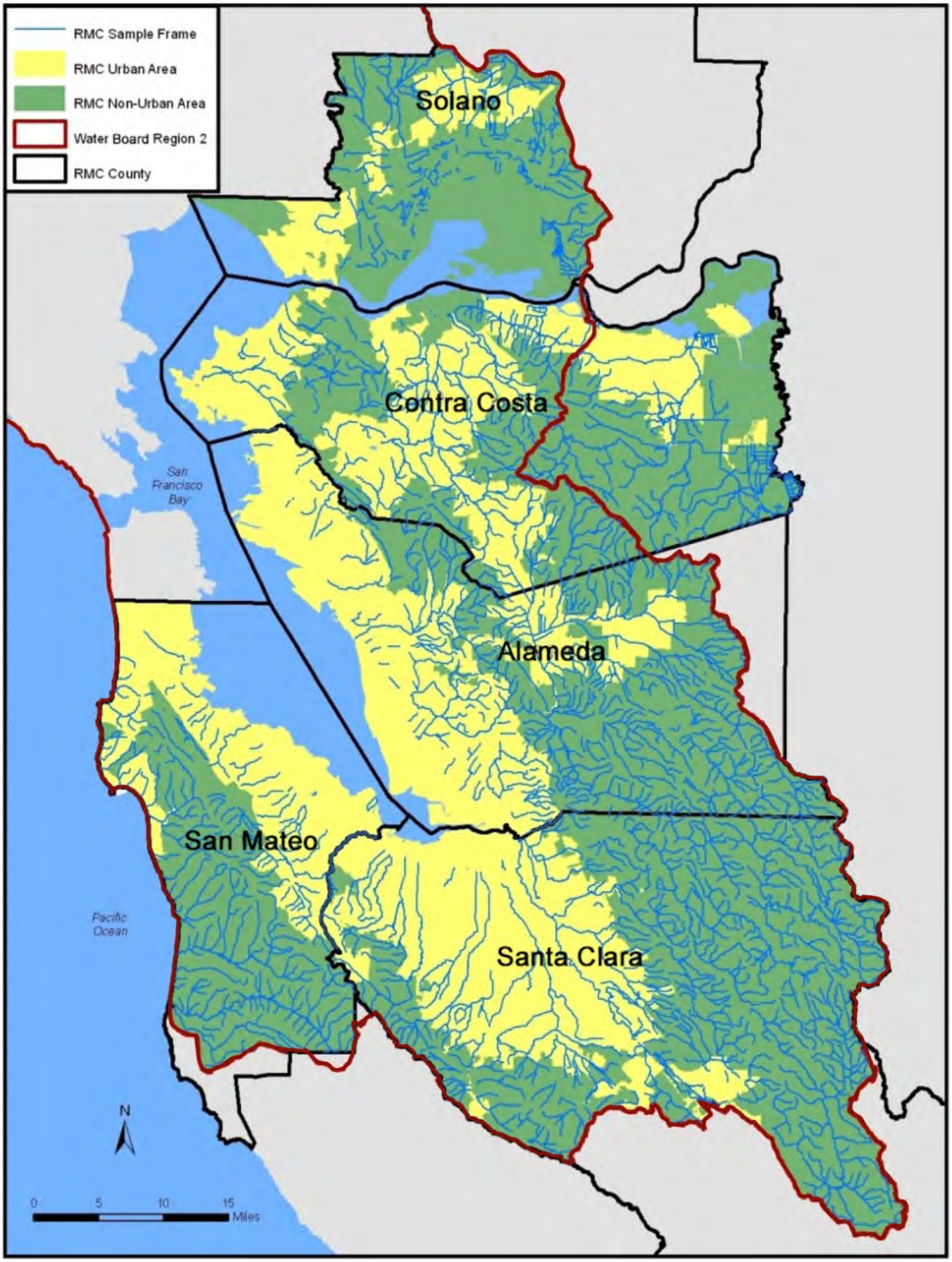
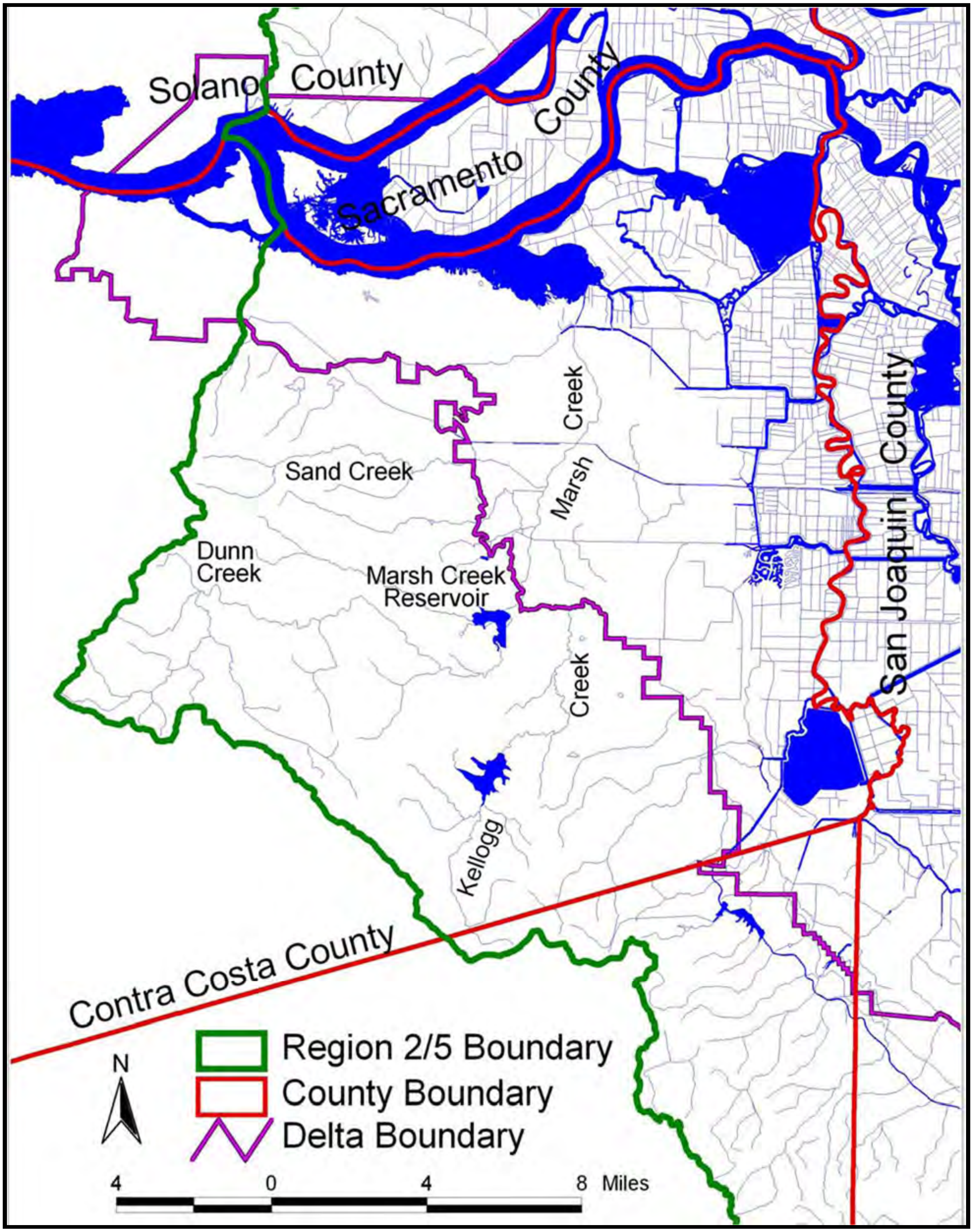


Figure 2.2 State Water Resources Control Board Region 2 and 5 Boundaries



Source Map: CVRWQB, 2010

Walnut Creek has the second longest running stream length in the county at 28.74 miles. Its highest elevation lies at 3,849 feet, while the mouth joins sea level at Suisun Bay. An estimated 71.5 percent of its stream channel remains in a natural state, with the remaining portion containing man-made reinforcements. Estimated impervious surfaces make up 30 percent of its watershed. Walnut Creek's estimated mean daily flow is 81.4 cubic feet per second (CCCDD, 2003).

Two locations in the Walnut Creek watershed, both along Las Trampas Creek, were selected for targeted monitoring in WY 2017. Las Trampas Creek is a sub-watershed to Walnut Creek, with a 12.37-mile branch which eventually joins with San Ramon Creek to form Walnut Creek on the south side of the City of Walnut Creek. The 17,238-acre Las Trampas Creek sub-watershed is predominantly natural, with 79.1 percent of the 64.1 miles of channel containing no obvious reinforcements. Impervious surface in the Las Trampas Creek sub-watershed is calculated at 13.5 percent (CCCDD, 2003).

Historically, Las Trampas Creek likely supported a population of steelhead, as steelhead migrated up the Walnut Creek/San Ramon Creek drainage system into which Las Trampas Creek flows. Leidy et al. (2005) states that steelhead are no longer in Las Trampas Creek and its tributaries. Drop structures on Walnut Creek immediately below the City of Walnut Creek have prevented steelhead and chinook salmon migration into the watershed for many years. Lafayette Creek, a tributary of Las Trampas Creek, is reported to support rainbow trout (Cressey, 2016); however, those fish are believed to come from Lafayette Reservoir and transported into the creek by storm flows and spill events (ADH, 2016). Sustainable numbers of rainbow trout are still believed to be present in Lafayette Creek, suggesting Las Trampas Creek likely could support a viable population of resident rainbow trout in its upper watershed (Cressey, 2017).

2.2.2. Alhambra Creek Watershed

The full watershed of Alhambra Creek is 10,735 acres. The watershed originates in the Briones Hills, encompassed by Briones Regional Park, and travels 7.88 miles to the Carquinez Strait in the City of Martinez. From the Briones Hills, the upper watershed retains a rural character traveling through open tracts and agricultural lands. Upon its descent, the lower watershed maintains a rural feeling at higher elevations, while the flood plain at lower elevations is defined by a heavily urbanized area driven by 100 years of industrialization in the City of Martinez (CCCDD, 2003).

The Alhambra Creek watershed has two major tributaries, Franklin Creek and Arroyo Del Hambre, helping comprise the watershed's total channel length of 48.08 miles. The watershed is predominantly natural, with 87 percent of the channel length containing no obvious reinforcements and 13 percent containing either concrete or earthen reinforcements (CCCDD, 2003).

Historically, steelhead ran up Alhambra Creek from Carquinez Strait. As there are presently no barriers to impede the upstream migration of steelhead on this creek (Cressey, 2017), it is probable that a remnant population of steelhead still migrate up Alhambra Creek to spawn, with juvenile fish rearing in the creek for two years before returning to marine waters. Maps of historical and present distribution of steelhead in Contra Costa County indicate Alhambra Creek and its tributaries continue to support small numbers of salmonids (Cressey, 2017).

2.3. Contra Costa Targeted Monitoring Design

During WY 2017, water temperature, continuous water quality, and pathogen indicators were monitored at the targeted locations listed in Table 2.1 and illustrated in the overview map (Figure 2.3).

Site locations were identified using a targeted monitoring design based on the directed principle[7] to address the following management questions:

1. What is the range of continuous water quality measurements at targeted sites of interest?
2. Do continuous water quality measurements indicate potential impacts to aquatic life?
3. What are the pathogen indicator concentrations at creek sites where water contact recreation may occur?

Within Contra Costa County, the following targeted monitoring was conducted in WY 2017:

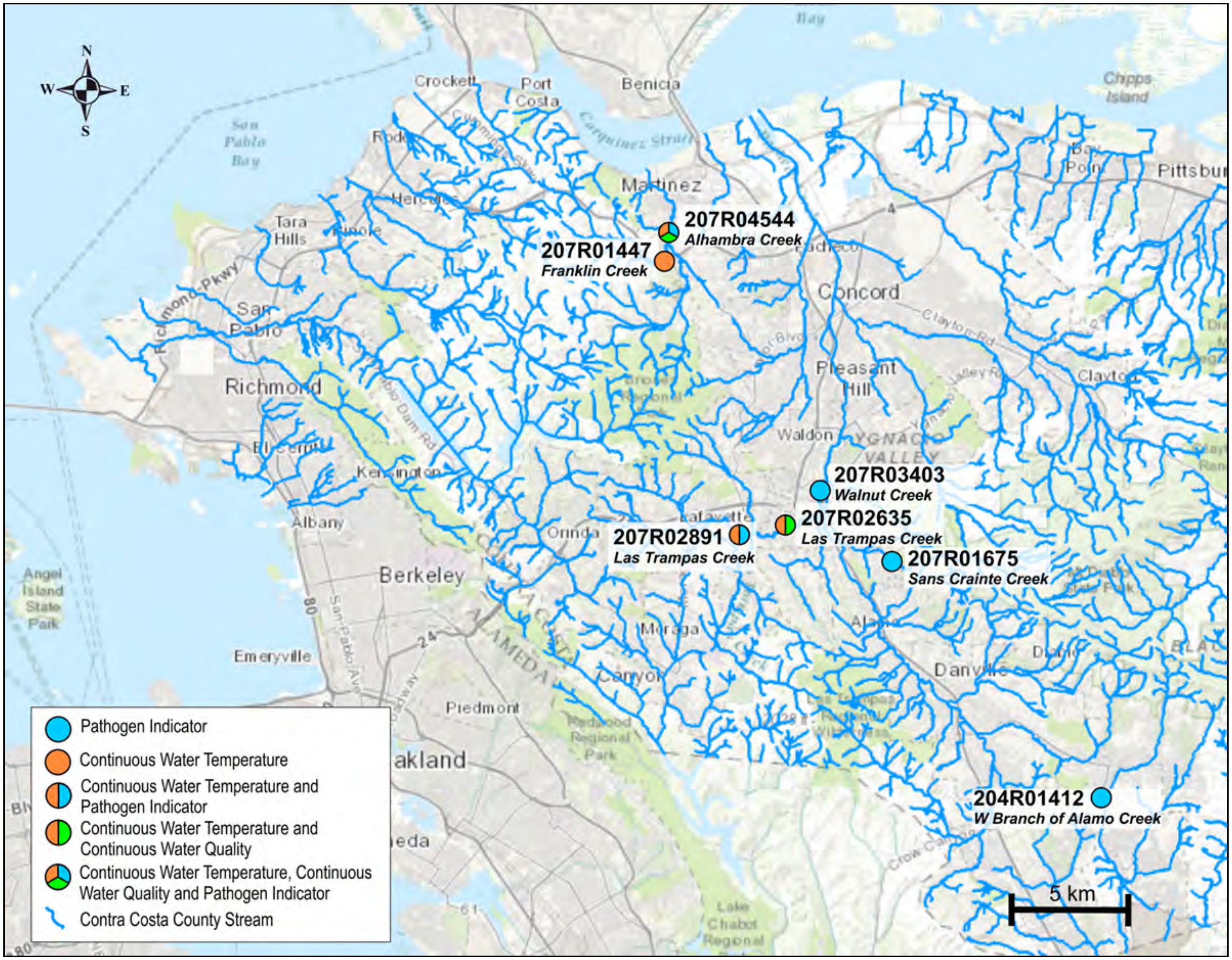
- Four continuous water temperature monitoring locations
- Two continuous water quality monitoring locations
- Five pathogen indicator monitoring locations

Table 2.1 Targeted Sites and Local Reporting Parameters Monitored in Water Year 2017 in Contra Costa County

Site Code	Creek Name	Latitude	Longitude	Temperature	Continuous Water Quality	Pathogen Indicators
204R01412	West Branch Alamo Creek	37.78720	-121.92397			X
207R01447	Franklin Creek	37.99104	-122.13245	X		
207R01675	Sans Crainte Creek	37.87695	-122.02433			X
207R02635	Las Trampas Creek	37.89013	-122.07435	X	X	
207R02891	Las Trampas Creek	37.88708	-122.09708	X		X
207R03403	Walnut Creek	37.90314	-122.05892			X
207R04544	Alhambra Creek	37.99977	-122.13044	X	X	X

[7] Directed Monitoring Design Principle: A deterministic approach in which points are selected deliberately based on knowledge of their attributes of interest as related to the environmental site being monitored. This principle is also known as "judgmental," "authoritative," "targeted," or "knowledge-based."

Figure 2.3 Overview of Targeted Sites Monitored by CCCWP in Water Year 2017



3. Monitoring Methods

Targeted monitoring data were collected in accordance with the BASMAA RMC QAPP (BASMAA, 2016a) and BASMAA RMC SOP (BASMAA, 2016b). Where applicable, monitoring data were collected using methods comparable to those specified by the SWAMP QAPP[8], and were submitted in SWAMP-compatible format by CCCWP to the SFBRWQCB and the CVRWQCB on behalf of CCCWP permittees and pursuant to provision C.8.h.

3.1. Data Collection Methods

Water quality data were collected in accordance with SWAMP-comparable methods and procedures described in the BASMAA RMC SOPs (BASMAA, 2016b) and associated QAPP (BASMAA, 2016a). These documents are updated as needed to maintain current and optimal applicability. The SOPs were developed using a standard format describing health and safety precautions and considerations, relevant training, site selection, and sampling methods and procedures, including pre-fieldwork mobilization activities to prepare equipment, sample collection, and demobilization activities to preserve and transport samples.

The monitoring locations for continuous water quality parameters (dissolved oxygen, specific conductivity, pH, and temperature) were in Las Trampas Creek and Alhambra Creek for this monitoring year, as discussed below.

3.1.1. Continuous Water Quality Measurements

Continuous water quality monitoring equipment (YSI 6600 V2 Sondes) were deployed over two time periods at one location each in both Las Trampas Creek and Alhambra Creek. Continuous water quality parameters (dissolved oxygen, specific conductivity, pH, and temperature) were recorded every 15 minutes. The equipment was deployed for two time periods at each creek as follows:

- Las Trampas Creek: Once during spring concurrent with bioassessment sampling (May 16-30) and once during summer (July 31-August 11)
- Alhambra Creek: Once during spring concurrent with bioassessment sampling (May 16-30) and once during summer (July 31-August 11)

Procedures used for calibrating, deploying, programming, and downloading data are described in RMC SOP FS-4 (BASMAA, 2016b).

3.1.2. Continuous Temperature Monitoring

In WY 2017, CCCWP monitored water temperature at four locations in the county. Digital temperature loggers (Onset® HOBO® Water Temp Pro V2) were deployed at each of the following locations: Franklin Creek, Las Trampas Creek, and Alhambra Creek. Hourly temperature measurements were recorded at each respective site from April 26, 2017 to September 30, 2017.

[8] The current SWAMP QAPP is available at:
http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/qapp/swamp_qapp_master090108a.pdf

Procedures used for calibrating, deploying, programming and downloading data are described in RMC SOP FS-5 (BASMAA, 2016b).

3.1.3. Pathogen Indicator Sampling

In compliance with permit requirements, a set of pathogen indicator samples was collected on July 24, 2017 at five locations. All five sampling locations were selected based upon their potential to detect anthropogenic sources of contamination or targeted due to site location within public parks, giving increased potential of public contact with waterways. Pathogen indicator samples for enterococci and *E. coli* were analyzed at all sites.

Sampling techniques included direct filling of containers and immediate transfer of samples to analytical laboratories within specified holding time requirements. Procedures used for sampling and transporting samples are described in RMC SOP FS-2 (BASMAA, 2016b).

3.2. Quality Assurance/Quality Control

Data quality assessment and quality control procedures are described in detail in the BASMAA RMC QAPP (BASMAA, 2016a). Data quality objectives (DQOs) were established to ensure data collected are of adequate quality and sufficient for the intended uses. DQOs address both quantitative and qualitative assessment of the acceptability of data. The qualitative goals include representativeness and comparability. The quantitative goals include specifications for completeness, sensitivity (detection and quantization limits), precision, accuracy, and contamination. Data were collected according to the procedures described in the relevant BASMAA RMC SOPs (BASMAA, 2016b), including appropriate documentation of data sheets and samples, and sample handling and custody. Laboratories providing analytical support to the RMC were selected based on the demonstrated capability to adhere to specified protocols.

3.3. Data Quality Assessment Procedures

Following completion of the field and laboratory work, the field data sheets and laboratory reports were reviewed by the local quality assurance officer and compared against the methods and protocols specified in the RMC SOPs and QAPP. The findings and results were then evaluated against the relevant DQOs to provide the basis for an assessment of programmatic data quality. A summary of data quality steps associated with water quality measurements is shown in Table 3.1. The data quality assessment consisted of the following elements:

- Conformance with field and laboratory methods, as specified in RMC SOPs and QAPP, including sample collection and analytical methods, sample preservation, sample holding times, etc.
- Numbers of measurements/samples/analyses completed versus planned, and identification of reasons for any missed samples.
- Temperature data were checked for accuracy by comparing measurements taken by HOBOs with National Institute of Standards Technology thermometer readings in room temperature water and ice water.

- Continuous water quality data were checked for accuracy by comparing measurements taken before and after deployment with measurements taken in standard solutions to evaluate potential drift in readings.
- Quality assessment laboratory procedures for accuracy and precision (i.e., lab duplicates and lab blanks) were not implemented for pathogen samples collected this year but will be in subsequent years.

Table 3.1 Data Quality Steps Implemented for Temperature and Continuous Water Quality Monitoring

Step	Temperature (HOBOs)	Continuous Water Quality (Sondes)
Pre-event calibration / accuracy check conducted	X	X
Readiness review conducted	X	X
Check field datasheets for completeness	X	X
Post-deployment accuracy check conducted		X
Post-sampling event report completed	X	X
Post-event calibration conducted		X
Data review-compare drift against SWAMP MQOs		X
Data review-check for outliers / out of water measurements	X	X

3.4. Data Analysis and Interpretation

Targeted monitoring data were evaluated against WQOs or other applicable thresholds, as described in provision C.8.d of the MRP and Table 8.1 of the Central Valley Permit. Table 3.2 defines thresholds used for selected targeted monitoring parameters as they apply to WY 2017. The subsections below provide details on thresholds selected and the underlying rationale.

Table 3.2 Requirements for Follow-Up for Local/Targeted Creek Status Monitoring Results Per MRP Provision C.8.d

Constituent	Trigger Level[1]	MRP 2 Provision	Provision Text
Temperature	≥ 2 weekly averages > 17 °C (steelhead streams); or 20% of results > 24 °C instantaneous maximum (per station)	C.8.d.iii.(4)	The temperature trigger is defined as when two or more WAT[2] measurements exceed the MWAT[3] of 17 °C for a steelhead stream, or when 20 percent of the results at one sampling station exceed the instantaneous maximum of 24 °C. Permittees shall calculate the WAT by breaking the measurements into non-overlapping, 7-day periods.
Temperature (continuous, sonde)	A weekly average >17.0°C (steelhead streams); OR 20% of results >24.0°C instant. max. (per station)	C.8.d.iv.(4)a.	The temperature trigger is defined as any of the following: MWAT exceeds 17 °C for a steelhead stream or 20 percent of the instantaneous results exceed 24 °C. The permittees shall calculate the WAT by separating the measurements into non-overlapping, 7-day periods.
pH (continuous, sonde)	≥ 20% results < 6.5 or > 8.5	C.8.d.iv.(4)b.	The pH trigger is defined as 20 percent of instantaneous pH results are < 6.5 or > 8.5.
Electrical conductivity (continuous, sonde)	≥ 20% results > 2000 µS	C.8.d.iv.(4)c.	The conductivity trigger is defined as 20 percent of the instantaneous specific conductance results are >2000 µS or there is a spike in readings with no obvious natural explanation.
Dissolved Oxygen (continuous, sonde)	≥ 20% results < 7 mg/L (cold water fishery streams)	C.8.d.iv.(4)d.	The dissolved oxygen trigger is defined as 20 percent of instantaneous dissolved oxygen results are < 7 mg/L in a cold fishery stream.
Enterococci	>130 CFU/100 mL	C.8.d.v.(4)	If the EPA's statistical threshold value for 36 per 1000 primary contact recreators is exceeded, the water body reach shall be identified as a candidate SSID[4] project. (Per RMC/SFBRWQCB staff agreement, CFU and MPN units are deemed to be comparable for this purpose.)
E. coli	> 410 CFU/100 mL	C.8.d.v.(4)	If the EPA's statistical threshold value for 36 per 1000 primary contact recreators is exceeded, the water body reach shall be identified as a candidate SSID project. (Per RMC/SFBRWQCB staff agreement, CFU and MPN units are deemed to be comparable for this purpose.)

1 Per MRP provision C.8.d., these are the data thresholds which trigger listings as candidate SSID projects per MRP provision C.8.e.
2 WAT weekly average temperature
3 MWAT maximum weekly average temperature
4 SSID stressor/source identification

3.4.1. Dissolved Oxygen (DO)

The Basin Plan (SFBRWQCB, 2015b) lists WQOs for dissolved oxygen in non-tidal waters as follows: 7.0 mg/L minimum for waters designated as COLD (i.e., a steelhead stream). Although this WQO is suitable criteria for an initial evaluation of water quality impacts, further evaluation may be needed to determine the overall extent and degree to which cold water beneficial uses are supported at a site. For example, further analyses may be necessary at sites in lower reaches of a water body which may not support salmonid spawning or rearing habitat but may be important for upstream or downstream fish migration. In these cases, dissolved oxygen data will be evaluated for the salmonid life stage and/or fish community expected to be present during the monitoring period. Such evaluations of both historical and current ecological conditions will be made, where possible, when evaluating water quality information.

To evaluate the results against the relevant trigger in MRP section C.8.d, the dissolved oxygen data were evaluated to determine whether 20 percent or more of the measurements were below the applicable WQOs.

3.4.2. Hydrogen in Concentration (pH)

WQOs for pH in surface waters are stated in the Basin Plan (SFBRWQCB, 2015b) as follows: the pH shall not be depressed below 6.5 nor raised above 8.5. This range was used in this report to evaluate the pH data collected from creeks.

To evaluate the results against the relevant trigger in MRP provision C.8.d, the pH data were evaluated to determine whether 20 percent or more of the measurements were outside of the WQOs.

3.4.3. Pathogen Indicators

In 2012, the U.S. Environmental Protection Agency (EPA) released its recreational water quality criteria recommendations for protecting human health in all coastal and non-coastal waters designated for primary contact recreation use. The Regional Water Quality Criterion (RWQC) includes two sets of recommended criteria, as shown in Table 3.3. Primary contact recreation is protected if either set of criteria recommendations are adopted into state water quality standards. However, these recommendations are intended as guidance to states, territories and authorized tribes in developing water quality standards to protect swimmers from exposure to water containing organisms which indicate the presence of fecal contamination. They are not regulations themselves (EPA, 2012), but are considered to represent "established thresholds" for purposes of evaluating threshold triggers per the MRP and Central Valley Permit. Regarding the EPA 2012 RWQC standard threshold values, since the geometric mean (GM) cannot be determined from the data collected, the only applicable recommended exceedance is the *E. coli* standard threshold values (STV) of 410 colony forming units (CFU) per 100 ml and 320 CFU/ml, for Recommendation 1 and 2, respectively. For interpretive purposes, CFU and most probable number (MPN) are considered equivalent.

Section C.8.d.v of the MRP requires use of the EPA statistical threshold value for 36/1000 primary contact recreation for determining if a pathogen indicator collection sample site is a candidate for a stressor/source identification *(*SSID) project.

Table 3.3 EPA 2012 Recreational Water Quality Criteria

Criteria Elements	Recommendation 1 Estimated Illness Rate 36/1,000		Recommendation 2 Estimated Illness Rate 32/1,000	
Indicator	GM (CFU/100 mL)	STV (CFU/100 mL)	GM (CFU/100 mL)	STV (CFU/100 mL)
Enterococci	35	130	30	110
E. coli (fresh)	126	410	100	320

3.4.4. Temperature

Temperature is one indicator of the ability of a water body to support a salmonid fisheries habitat (e.g., a steelhead stream). In California, the beneficial use of a steelhead stream is generally associated with suitable spawning habitat and passage for anadromous fish.

In Section C.8.d.iii.(4) of the MRP, the temperature trigger threshold specification is defined as follows:

> "The permittees shall identify a site for which results at one sampling station exceed the applicable temperature trigger or demonstrate a spike in temperature with no obvious natural explanation as a candidate SSID project. The temperature trigger is defined as when two or more weekly average temperatures exceed … 17 °C for a steelhead stream, or when 20 percent of the results at one sampling station exceed the instantaneous maximum of 24 °C."

In Section C.8.d.iv.(4).a of the MRP, which deals with continuous monitoring of dissolved oxygen, temperature and pH, the temperature trigger threshold specification is defined as follows:

> "…(the) maximum weekly average temperature (MWAT) exceeds 17 °C for a steelhead stream, or 20 percent of the instantaneous results exceed 24 °C."

The first cited section applies to temperature data recorded by the HOBO devices through the period of April to October 2017. The second cited section applies to temperature data recorded by the YSI sonde devices during the two periods in May and late July into August 2017.

In either case, the WAT was calculated as the average of seven daily average temperatures in non-overlapping seven-day periods. In all cases of the recorded temperature data, the first day's data was not included in the WAT calculations to eliminate the probable high bias of the average daily temperature of that day, because the recording devices were all deployed during daylight hours, the typically warmer part of a standard 24-hour day. As the WATs were calculated over the disjunctive seven-day periods, the last periods not containing a full seven days of data were also excluded from the calculations.

In compliance with the cited sections of the MRP, sites for which results exceeded the applicable temperature trigger were identified as candidates for an SSID project in the following three ways:

1. If a site had temperature recorded by a HOBO device, and two or more WATs calculated from the data were above 17 °C.

2. If a site had temperature recorded by a YSI sonde device, and one or more WATs calculated from the data were above 17 °C. This is equivalent to determining the MWAT at one of these sites was above 17 °C for the period in question.

3. If a site had 20 percent of its instantaneous temperature results above 24 °C, regardless of the recording device.

While the maximum temperature at both Las Trampas Creek locations did exceed threshold criteria of 24 °C, the occurrence was recorded during only 2 percent of the monitoring period. As this does not exceed the 20 percent threshold criteria, no locations were identified as SSID candidates based upon the third criterion cited above.

The potential responsive action to the analysis of temperature as it relates to fish habitat in Franklin Creek, Las Trampas Creek and Alhambra Creek is discussed below. After a brief description of the site locations monitored, the potential responsive action to the analysis of temperature as it relates to fish habitats follows.

3.4.4.1. Franklin Creek

The WY 2017 water temperature monitoring station (207R01447) on Franklin Creek was located on the property of the John Muir National Historic Site next to Highway 4 and Alhambra Avenue in Martinez. From the monitoring station, Franklin Creek flows for another 0.4 miles before entering Alhambra Creek near J Street in Martinez. Very little of the watershed draining into Franklin Creek is located on the north side of Highway 4. The great majority of the watershed lies on the south side of Highway 4 up Franklin Canyon before passing through a culvert beneath Highway 4 to enter the John Muir National Historic Site.

Named in the 2015 Basin Plan, Franklin Creek is designated with both COLD and WARM existing benefits. Apparently, Franklin Creek has suitably cold water for the summer survival of salmonids in its upper drainage, but not in the lower end. As Alhambra Creek historically supported steelhead, it is assumed Franklin Creek did as well. It is likely this creek continues to support small numbers of salmonids, and this is indicated in the Leidy et al. (2005) maps of historical and present distribution of steelhead in Contra Costa County (Cressey, 2017).

When discussing the Alhambra Creek watershed, it is important to note that barriers in the lower watershed and siltation may present limitations to the amount of salmonid habitat remaining in this system. However, the creek's major tributaries, Arroyo Del Hambre and Franklin Creek, are perennial, which may help support steelhead restoration in the watershed (Leidy et al., 2005).

3.4.4.2. Las Trampas Creek

There were two water temperature monitoring stations located in Las Trampas Creek for WY 2017. Of the two monitoring stations, the upstream site is in Lafayette at Reliez Station Road (207R02891), while the downstream site is in Walnut Creek at Camino Posada Court (207R02635). The distance between the two sites is roughly 1.75 miles along the stream corridor. Fed by several tributaries, including Lafayette Creek, Las Trampas Creek eventually joins with San Ramon Creek to form Walnut Creek on the south side of the City of Walnut Creek. The 2015 edition of the Basin Plan for the San Francisco Bay Region designates Las Trampas Creek as having both COLD and WARM existing benefits. Once again, this indicates the upstream portion of this creek has year-round water temperatures suitably cold to support salmonids, but the lower portions of the creek are too warm to support salmonids through the summer.

Historically, Las Trampas Creek likely supported a population of steelhead, as steelhead migrated up the Walnut Creek/San Ramon Creek drainage system into which Las Trampas Creek flows. Leidy et al. (2005) states steelhead are no longer in Las Trampas Creek and its tributaries. Drop structures on Walnut Creek immediately below the City of Walnut Creek have prevented steelhead and chinook salmon migration into the watershed for many years.

Lafayette Creek, a tributary of Las Trampas Creek, is reported to support rainbow trout, as reported by Bert Mulchaey of East Bay Municipal Utility District's (EBMUD) East Bay Fishery and Wildlife Division (ADH, 2016). Although it is reported EBMUD has very limited information on Lafayette Creek, the East Bay Fishery and Wildlife Division believes one would find small sustainable numbers of rainbow trout in the creek. Based on this information, Lafayette Creek and upper Las Trampas Creek may support a viable population of resident rainbow trout in its upper watershed, but there is little evidence of this in Las Trampas Creek to date (Cressey, 2017).

3.4.4.3. Alhambra Creek

The water quality and water temperature monitoring devices located on Alhambra Creek (207R04544) were deployed in a section of natural stream where F Street ends and comes to a pedestrian foot bridge at Brookside Drive near Martinez Adult School. This location is almost one mile north toward Martinez from the Alhambra Avenue exit off Highway 4. The HOBO recorded stream temperature for the monitoring season, while a sonde recorded general water quality data over two separate deployment periods.

The 2015 edition of the Basin Plan for the San Francisco Bay Region designates Alhambra Creek as having both COLD and WARM existing benefits. This indicates the upstream portion of this creek has year-round water temperatures suitably cold to support salmonids, but the lower portions of the creek are too warm to support salmonids through the summer.

Historically, steelhead ran up Alhambra Creek from Carquinez Strait. As there are presently no barriers to impede the upstream migration of steelhead on this creek (Cressey, 2017), it is probable a remnant population of steelhead still migrate up Alhambra Creek to spawn, with juvenile fish rearing in the creek for two years before returning to marine waters. During a September 2004 dewatering event at F Street near the Martinez Adult School, an Alhambra Creek Restoration Project found eight steelhead in excellent condition (Leidy et al., 2005). In 2001, electrofishing was conducted by Scott Cressey under contract to Contra Costa County to determine the presence of steelhead and rainbow trout in lower Alhambra Creek. Only one steelhead/rainbow trout was found, a nearly 8-inch fish found just below D Street about .35 miles downstream of this year's monitoring location. The captured fish showed no signs of hatchery origin (eroded fins) and were assumed to be wild (Cressey, 2017).

4. Results

4.1. Statement of Data Quality

Field data sheets and laboratory reports were reviewed by the local quality assurance officer, and the results were evaluated against the relevant data quality objectives. Results were compiled for qualitative metrics (representativeness and comparability) and quantitative metrics (completeness, precision and accuracy). The following summarizes the results of the data quality assessment:

- Temperature data from HOBOs were collected from four stations. HOBOs were deployed on April 26, 2017 and remained deployed until the pickup date of October 4, 2017. One hundred percent of the expected data was collected at three out of four locations: Las Trampas Creek at Camino Posada (207R02635), Las Trampas Creek at Reliez Station Road (207R02891), and Alhambra Creek (207R04544). Ninety-seven percent of the expected data was collected at the Franklin Creek location (207R01447) near the John Muir National Historic Site. This location logged an incomplete set of temperature data because the HOBO at station 207R01447 (Franklin Creek), experienced a drop in surface flow conditions, exposing the stream bed. The monitoring device could no longer be submerged and temperature data after September 25, 2017 at 23:00 no longer reflect water temperature. This resulted in a data loss due to seasonal conditions.

- Continuous water quality data (temperature, pH, dissolved oxygen and specific conductance) were collected during the spring and summer seasons; 100 percent of the expected data was collected.

- Continuous water quality data generally met measurement quality objectives (accuracy) as presented in Table 4.1.

- Quality assurance laboratory procedures were implemented for pathogen indicator analyses this year. All quality assurance samples successfully met data quality objectives.

Table 4.1 Accuracy[1] Measurement Taken for Dissolved Oxygen, pH and Specific Conductivity

Parameter	Measurement Quality Objectives	Site 207R02635 Las Trampas Creek		Site 207R04544 Alhambra Creek	
		Event 1[2]	Event 2[2]	Event 1[2]	Event 2[2]
Dissolved oxygen (mg/l)	± 0.5 or 10%	-0.27	-0.09	-0.21	-0.40
pH 7.0	± 0.2	0.01	0.11	0.04	-0.17
pH 10.0	± 0.2	-0.01	-0.22	0.00	0.29
Specific conductance (µS/cm)	± 10%	-0.01	-0.02	-0.08	-0.07

1 Accuracy of the water quality measurements were determined by calculating the difference between the YSI sonde readings using a calibration standard versus the actual concentration of the calibration standard. The results displayed are those taken following measurements within the stream, defined as "post calibration" as opposed to the "pre calibration values", where all the YSI sonde probes were offset to match the calibration standard prior to deployment.

2 Values in **Bold** exceed the data quality objectives.

4.2. Water Quality Monitoring Results

4.2.1. Water Temperature

Summary statistics for water temperature data collected at the four continuous monitoring locations from April to October 2017 are shown in Table 4.2. At both Las Trampas Creek locations and the Alhambra Creek station, approximately 158 days of hourly temperature data was collected. All data were collected successfully with no device issues or equipment movement, resulting in 100 percent capture of targeted data. At the Franklin Creek location, approximately 154 days of hourly temperature data were recorded. Water temperatures measured at each station, along with the WAT threshold of 17 °C for juvenile salmonid rearing, are illustrated in Figures 4.1, 4.2 and 4.3.

Table 4.2 Descriptive Statistics for Continuous Water Temperature Measured at Four Sites in Contra Costa County (Franklin Creek, Las Trampas Creek and Alhambra Creek), April 26-September 30, 2017

Site Temperature	207R01447 Franklin Creek (°C)	207R02635 Las Trampas Creek (°C)	207R02891 Las Trampas Creek (°C)	207R04544 Alhambra Creek (°C)
Minimum	12.55	12.94	12.87	12.87
Median	17.43	19.15	18.69	18.05
Mean	17.27	19.01	18.65	17.70
Maximum	23.04	25.67	25.01	22.82
MWAT[1]	18.99	21.10	21.10	19.62
Number of Measurements	3,656	3,780	3,781	3,777

1 The maximum of the 7-day average of the daily average temperature

The minimum and maximum temperature for all four stations was 12.55 °C and 25.67 °C, respectively. The median temperature range for all four stations was 17.43 °C to 19.15 °C, and the MWAT range was 18.99 °C to 21.10 °C.

Figure 4.1 Water Temperature Data Collected Using HOBOs at Four Sites in Contra Costa County (Franklin Creek, Las Trampas Creek and Alhambra Creek), April 26-September 30, 2017

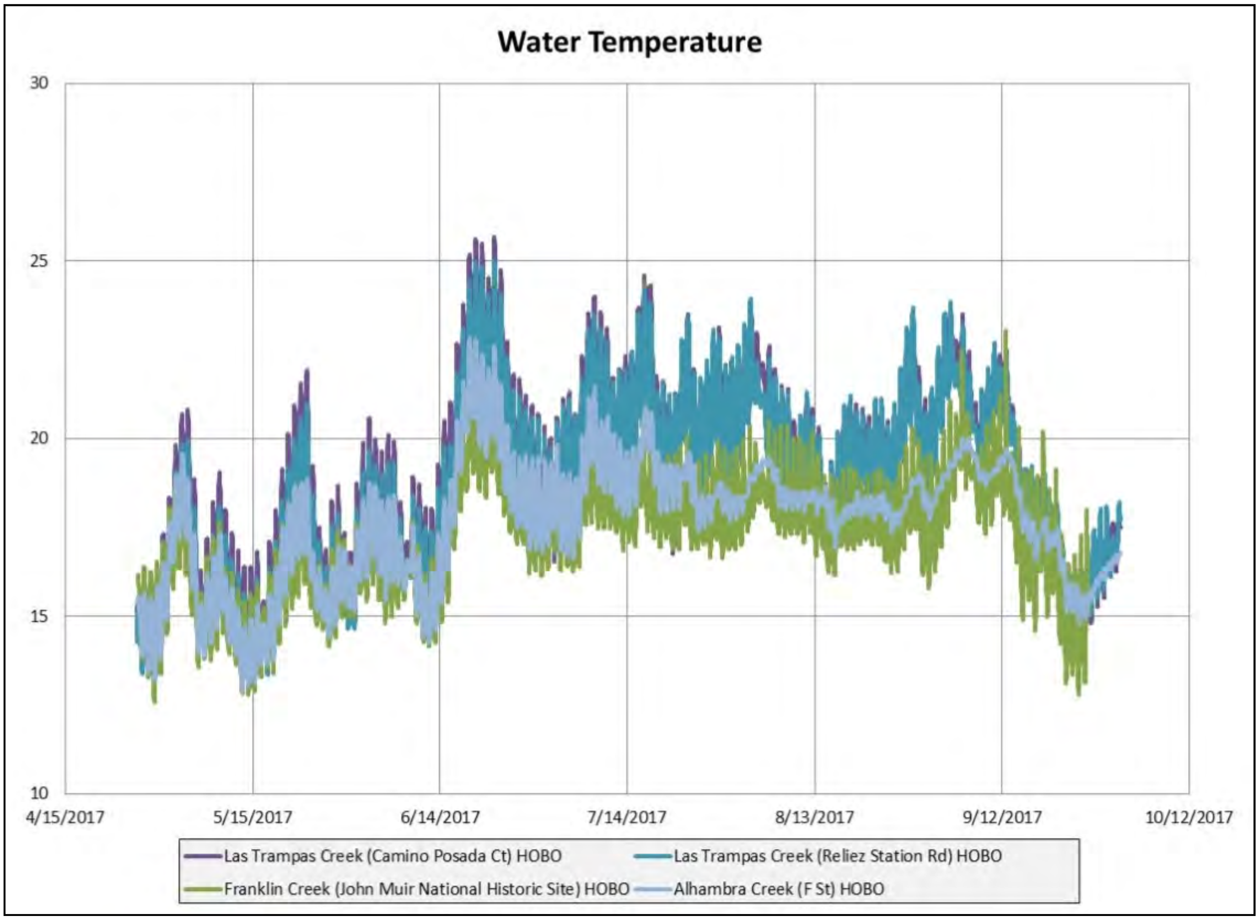


Figure 4.2 Weekly Average Water Temperature Data Collected Using HOBOs at Four Sites (Franklin Creek, Las Trampas Creek and Alhambra Creek) and Weekly Average Air Temperature Derived from Two Weather Underground Stations (Martinez and Walnut Creek) in Contra Costa County, April 26-September 30, 2017

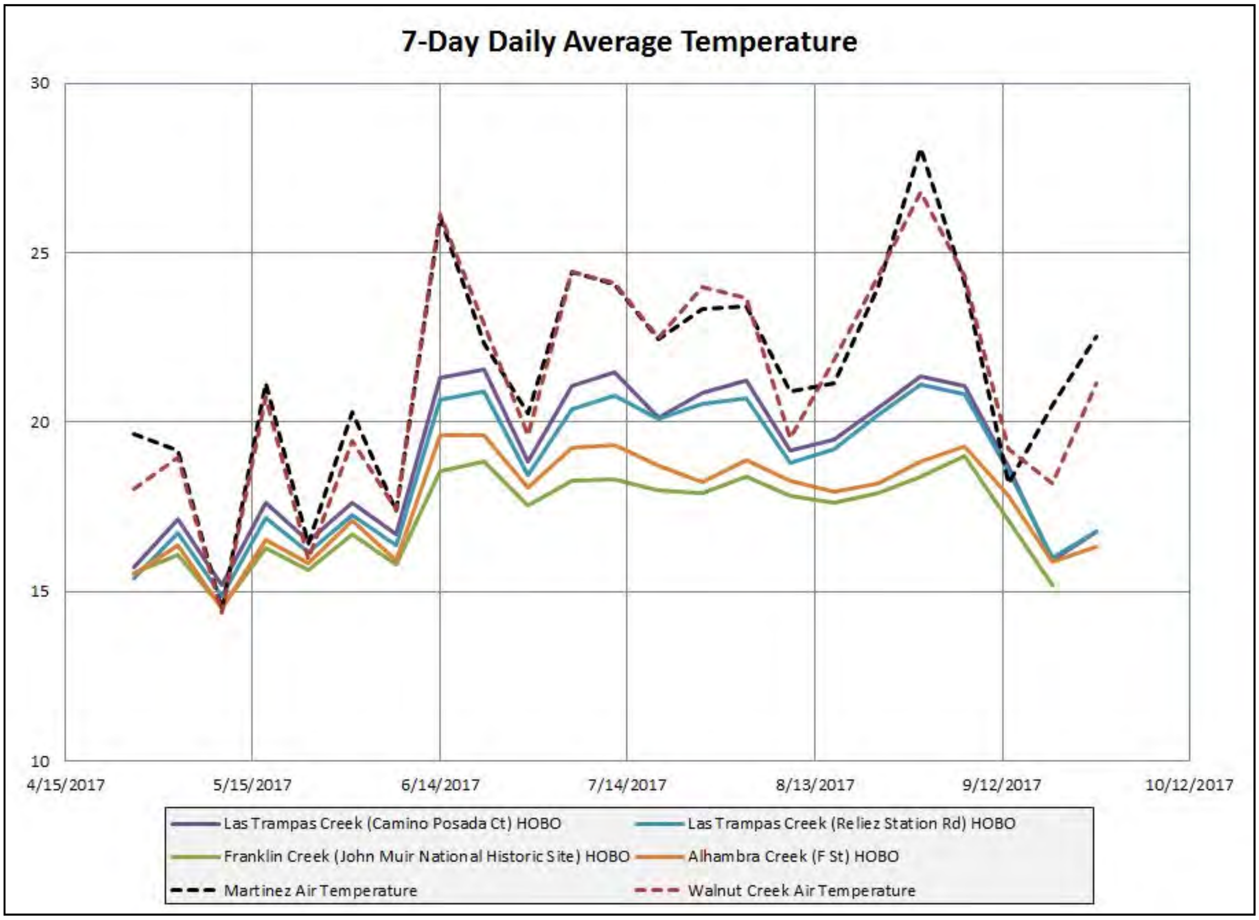
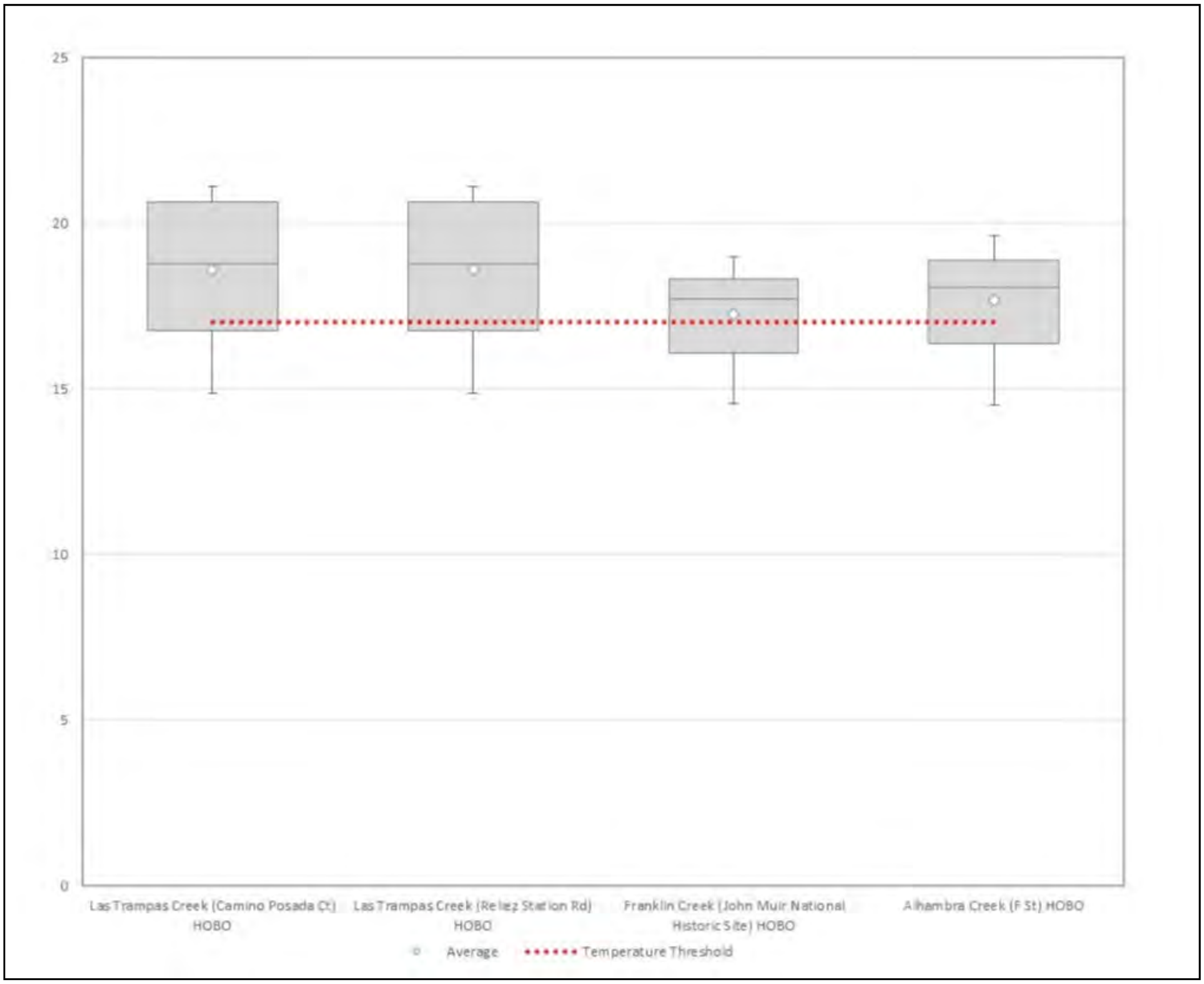


Figure 4.3 Box Plots of Weekly Average Temperature at Four Sites in Contra Costa County (Franklin Creek, Las Trampas Creek, Alhambra Creek), April 26-September 30, 2017



As shown in Table 4.3, the MWAT measured at Franklin Creek, Alhambra Creek, and both Las Trampas Creek locations exceeded the threshold for steelhead streams. The number of results ranged from 14 to 17 instances during the monitoring period. Therefore, all four stations exceeded the MRP trigger thresholds for temperature (two or more values exceed the applicable threshold; see Table 4.3).

Table 4.3 Water Temperature Data Measured at Four Sites Exceeding Water Quality Criteria for Steelhead Streams

Site ID	Creek Name	Monitoring Period	Number of Results Where WAT > 17 °C
207R01447	Franklin Creek	April 26-September 30, 2017	14
207R02635	Las Trampas Creek	April 26-September 30, 2017	17
207R02891	Las Trampas Creek	April 26-September 30, 2017	16
207R04544	Alhambra Creek	April 26-September 30, 2017	15

Several factors can contribute to elevated water temperatures in urban streams. The following factors were evaluated with respect to WAT exceedances observed in the WY 2017 temperature monitoring (NCRWQCB, 2013):

- Lack of riparian habitat
- Channel dynamics and channel alteration
- Air temperature (heat conduction)
- Flow conditions
- Non-stormwater related dry weather discharges

Factors thought to be associated with observed water temperature exceedances from WY 2017 are discussed below. The differences in minimum, median, and maximum temperatures recorded at the two Las Trampas Creek stations (Table 4.2) also indicate specific primary drivers may be affecting water temperature in this urban stream, as described below.

Removal of shade-providing riparian vegetation, as evident along Las Trampas Creek, increases the stream's exposure to solar radiation, affecting the stream's water temperature (NCRWQCB, 2013). The watercourse between the upstream (207R02891) and downstream (207R02635) HOBOs deployed at Las Trampas Creek covers roughly 1.75 miles. The channel is predominantly natural, but contains areas of artificial reinforcement (CCCDD, 2003). Between the two monitoring stations, removal of riparian habitat for flood control infrastructure can be observed via satellite imagery (Figure 4.4). Field crew observations at deployment locations further document historic removal of riparian habitat to facilitate urban development. Along Alhambra Creek, the removal of shade-providing riparian vegetation is present at upstream perennial tributaries, while the main branch remains predominantly natural.

The introduction of flood control infrastructure can contribute to an increase in stream water temperatures (NCRWQCB, 2013) through increased exposure to solar radiation. The introduction of flood control infrastructure often presents substantial changes in stream channel dynamics, including increased channel width-to-depth ratios. A higher width-to-depth ratio primarily affects temperature through increased exposure of the stream's surface area to solar radiation, thus leading to elevated water temperatures (NCRWQCB, 2013). The presence of manmade flood control infrastructure is evident at various locations along Las Trampas Creek (see example, Figure 4.4), and present along upstream tributaries to Alhambra Creek.

Elevated water temperatures also occur during periods of elevated air temperatures, via the transfer of heat by conduction from higher temperature air to the surfaces of lower temperature stream water (NCRWQCB, 2013). The seasonal trend, as illustrated in Figure 4.2, suggests air temperature and solar radiation are contributing factors to water temperature exceedances in WY 2017. Conduction heating of creeks is apparent in all creeks, but may be the primary factor in such locations as Franklin Creek, where satellite imagery and field staff reconnaissance reveal upstream riparian habitat is abundant and channel-altering flood control infrastructure is absent. The effects of air temperature on stream temperature were likely enhanced in WY 2017, as the region experienced higher than normal air temperatures, as illustrated in Figure 4.5.

The effects of the factors described above can have either a more pronounced effect or a dampened effect, depending upon stream discharge. Lower flows can exacerbate the temperature-related effects of insufficient riparian vegetation, higher channel width-to-depth ratios, and increased air temperatures. During sonde deployments in Las Trampas Creek and Alhambra Creek, discharge rates were noted to be 5 to 20 cubic feet per second (cfs) and 1 to 5 cfs, respectively. Additional data would be needed to relate these flows to historical flow levels and water temperatures in these creeks.

The disruption of water temperature diurnal curves, as experienced in Alhambra Creek and Las Trampas Creek (Figure 4.6), also display data characteristic of possible anthropogenic activities affecting water temperature, similar to data recorded in West Branch Alamo Creek in WY 2015 (ADH, 2015). In WY 2015, the disruption of water temperature diurnal curves was potentially attributed to warmer water outflows off the surface of an artificial impoundment located upstream of the HOBO monitoring station. In WY 2017, the complete loss of the water temperature diurnal curve experienced at Alhambra Creek, as well as the attenuated diurnal curve at Las Trampas Creek (Figure 4.7), from the end of July through the first week of August, displays the possible influence of anthropogenic activities or other external factors on water temperature. However, for locations monitored in WY 2017, satellite image reconnaissance and contacts with officials from the Contra Costa County Public Works Department confirm there are no impoundments upstream of any locations monitored in WY 2017. In addition, illicit dry weather urban runoff discharges into the creeks were determined to not be a contributing factor in elevated stream temperatures, as no dry weather discharges have been identified in the upstream vicinity of the stations to date. Stage data recorded in Alhambra Creek during the deployment period also confirm the lack of anthropogenic activities, as no unusual or artificial rises in stage were recorded.[9] No gauging stations were available at monitoring locations along Las Trampas Creek or Franklin Creek.

Disruption of water temperature diurnal curves during August 1-4 may instead be attributed to a low pressure system associated with a southwest monsoon that tracked into the area during that period.[10] It is hypothesized that the resulting cloud cover associated with monsoonal conditions partially blocked the incident solar radiation, preventing stream water temperatures from following normal diurnal cycles (Figure 4.6). In addition, light rain was detected on the afternoon of August 4, resulting in denser cloud cover, higher humidity, and above-average evening air temperatures, all of which contributed to the anomalies seen in all creeks; however, not as pronounced in Las Trampas Creek due to higher stream discharge rates and greater stream depth.

[9] See http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=ACZ.

[10] See http://www.wpc.ncep.noaa.gov/dailywxmap/index_20170801.html, http://www.wpc.ncep.noaa.gov/dailywxmap/index_20170802.html, http://www.wpc.ncep.noaa.gov/dailywxmap/index_20170803.html, and http://www.wpc.ncep.noaa.gov/dailywxmap/index_20170804.html.

Figure 4.4 Overview and Channel Detail of Sites Monitored Along Las Trampas Creek

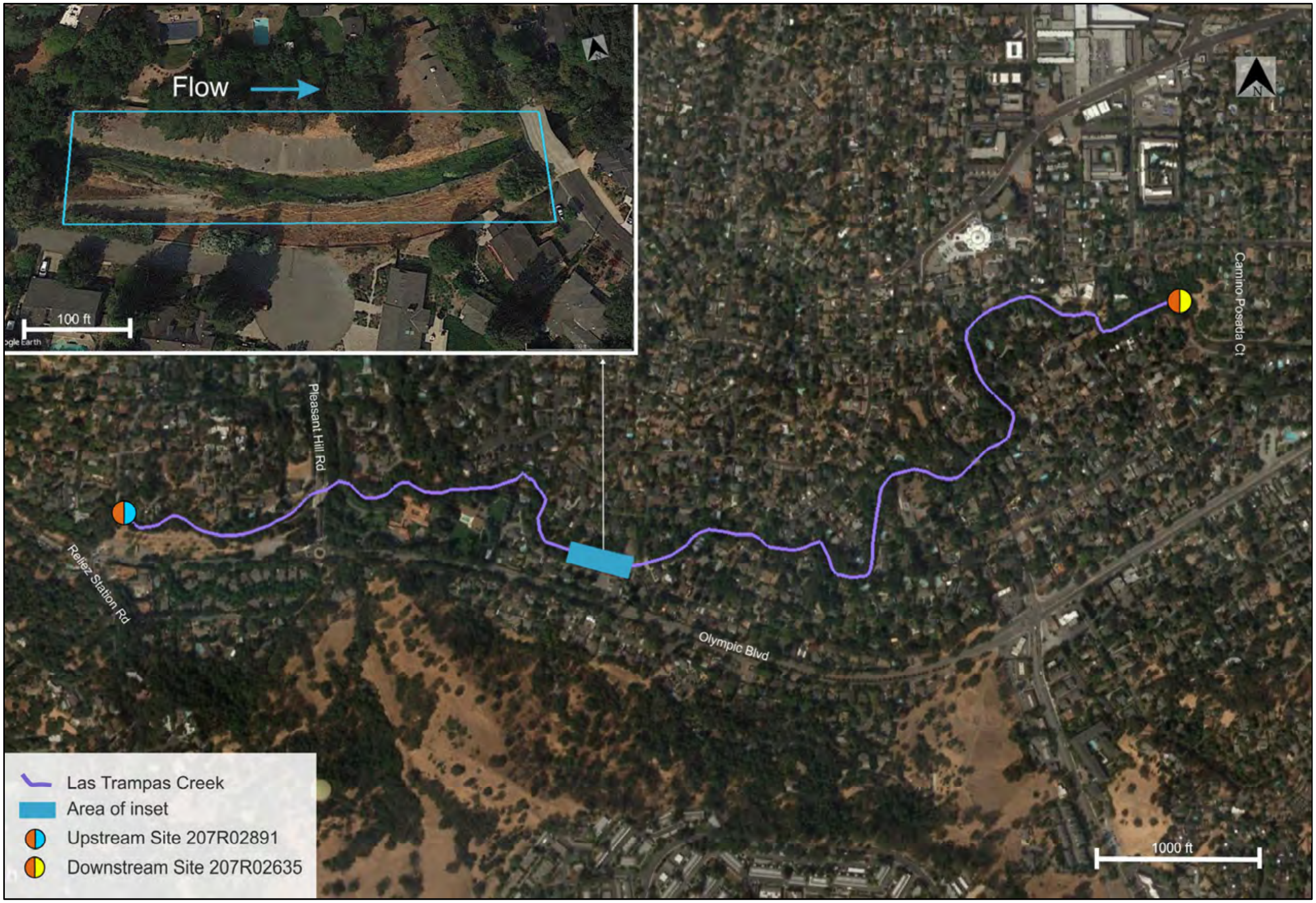
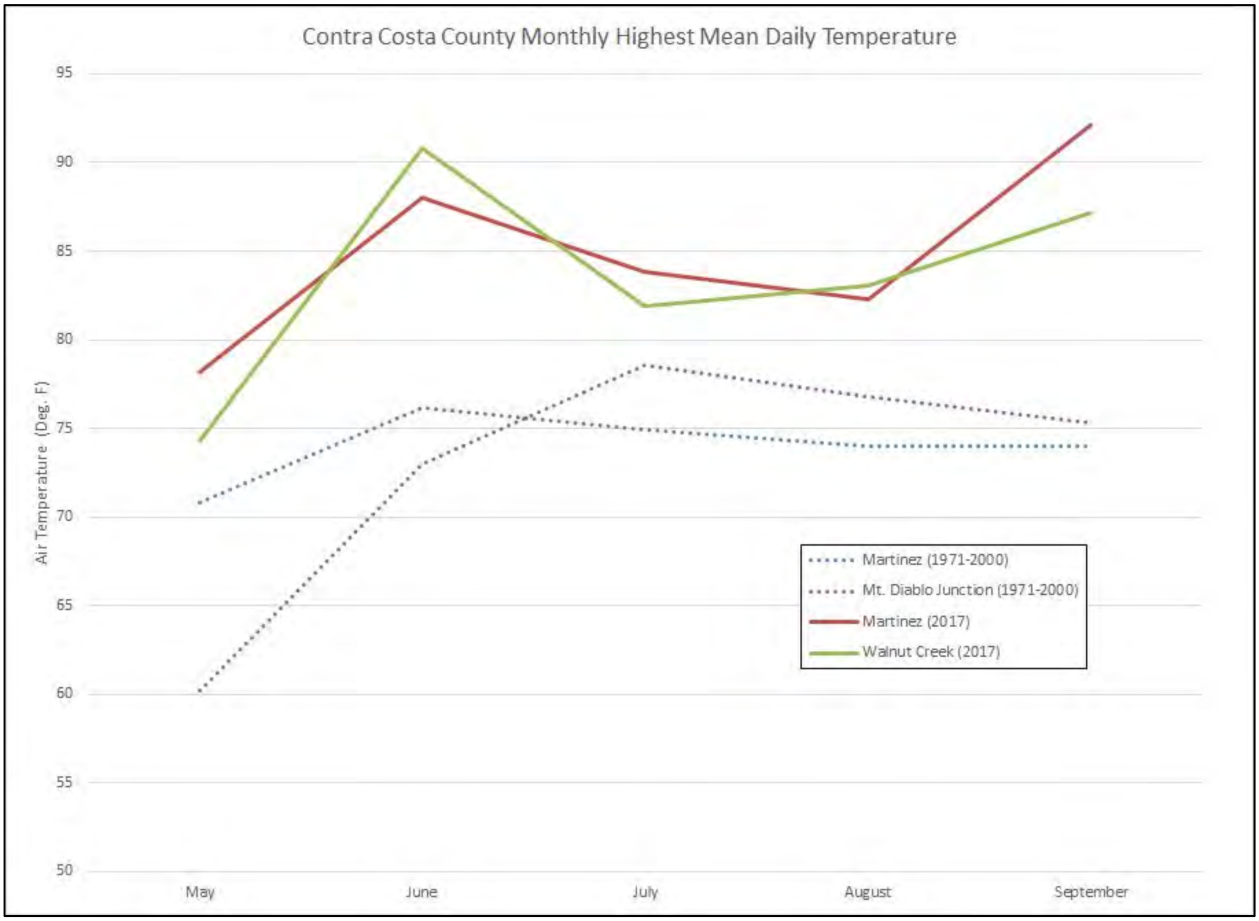


Figure 4.5 Historical Mean Daily Temperatures Plotted Against 2017 Mean Daily Temperature



Although evaluating the interaction of multiple drivers in the analysis of stream temperatures is complex, the absence of shading, presence of modified stream channel segments, increased exposure to solar radiation, and increased conduction heating, as indicated by record high air temperatures, suggest a combination of factors contributed to the level of exceedances in water temperature at locations monitored in WY 2017.

4.2.2. Continuous Water Quality

Summary statistics for continuous water quality measurements collected at stations on Las Trampas Creek and Alhambra Creek during two separate periods (once in May and once during late July into August) are shown in Table 4.4. WAT and MWAT for both stations over the same monitoring period are displayed in Table 4.5. Data collected during both periods, along with the required thresholds, are plotted in Figures 4.6 through 4.9.

Table 4.4 Descriptive Statistics for Daily and Monthly Continuous Water Quality Parameters (Temperature, Dissolved Oxygen, Conductivity and pH) Measured at Two Sites in Contra Costa County (Las Trampas Creek and Alhambra Creek), May 16-30 and July 31-August 11, 2017

Parameter		Site 207R02635 Las Trampas Creek		Site 207R04544 Alhambra Creek	
		May	July/August	May	July/August
Temperature (°C)	Minimum	13.39	18.19	13.54	17.78
	Median	16.63	20.63	15.94	18.59
	Mean	16.88	20.67	16.04	18.77
	Maximum	21.8	23.57	18.93	19.84
Dissolved oxygen (mg/l)	Minimum	7.63	5.91	8.1	1.3
	Median	9.00	7.29	9.04	5.34
	Mean	9.31	7.61	9.04	4.85
	Maximum	11.73	10.33	10.06	7.019
pH	Minimum	8.24	6.5	8.27	7.48
	Median	8.39	7.48	8.32	7.78
	Mean	8.39	7.39	8.32	7.75
	Maximum	8.59	7.85	8.41	7.92
Specific conductance (µS/cm)	Minimum	1022	391	1445	1741
	Median	1044	720	1475	1762
	Mean	1040	703	1471	1758
	Maximum	1057	924	1515	1772

Table 4.5 Maximum Weekly Average Temperatures of YSI Sondes at Two Sites (Las Trampas Creek and Alhambra Creek) for Both Events

Site Name	Creek Name	Monitoring Period	WAT	MWAT
207R02635	Las Trampas Creek	May 16-30, 2017	16.82, 16.94	16.94
		July 31-August 11, 2017	21.43	21.43
207R04544	Alhambra Creek	May 16-30, 2017	16.02, 16.01	16.02
		July 31-August 11, 2017	19.03	19.03

Values in **Bold** exceed MRP criterion of 17.0 °C for steelhead streams.

Figure 4.6 Continuous Water Quality Data (Continuous Temperature) Collected in Contra Costa County (Las Trampas Creek and Alhambra Creek), May 16-30 and July 31-August 11, 2017

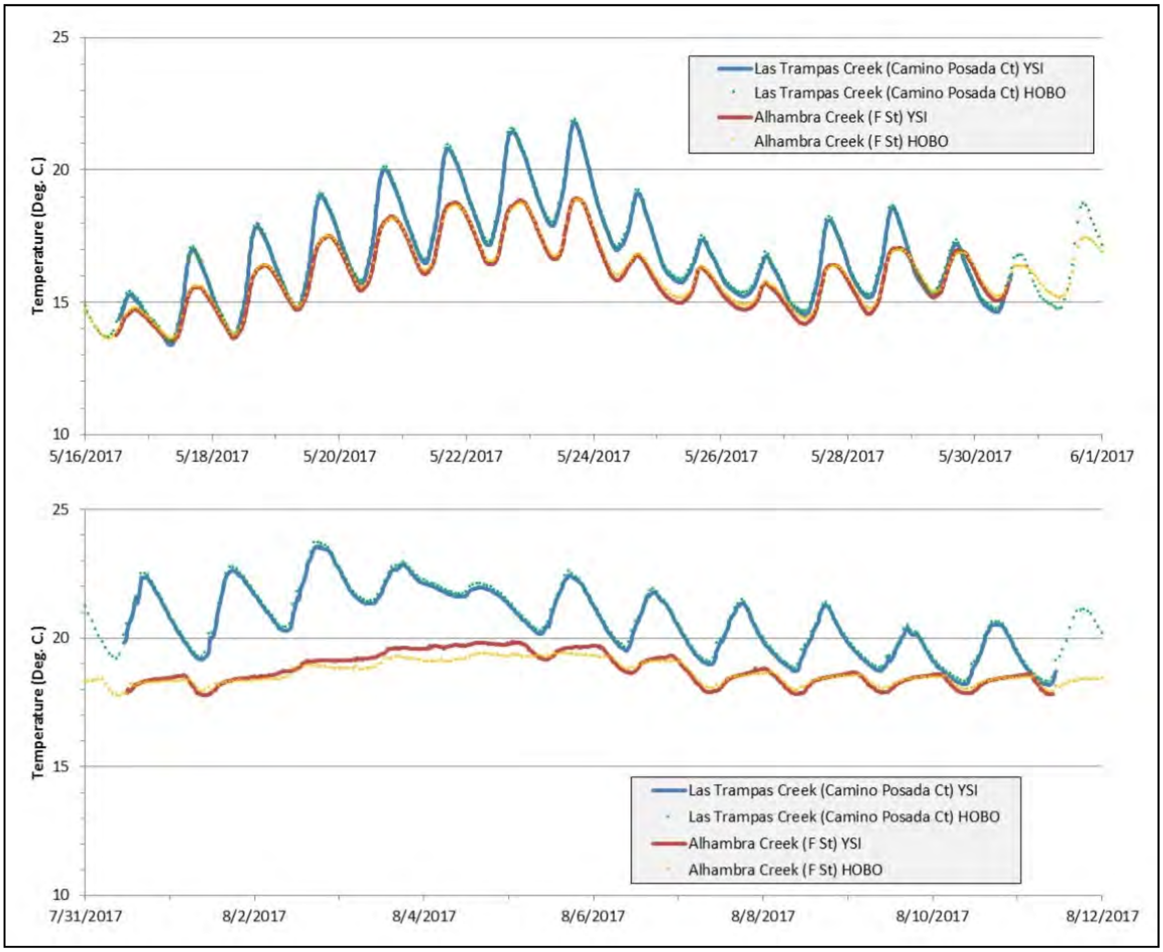


Figure 4.7 Continuous Water Quality Data (Continuous pH) Collected in Contra Costa County (Las Trampas Creek and Alhambra Creek), May 16-30 and July 31-August 11, 2017

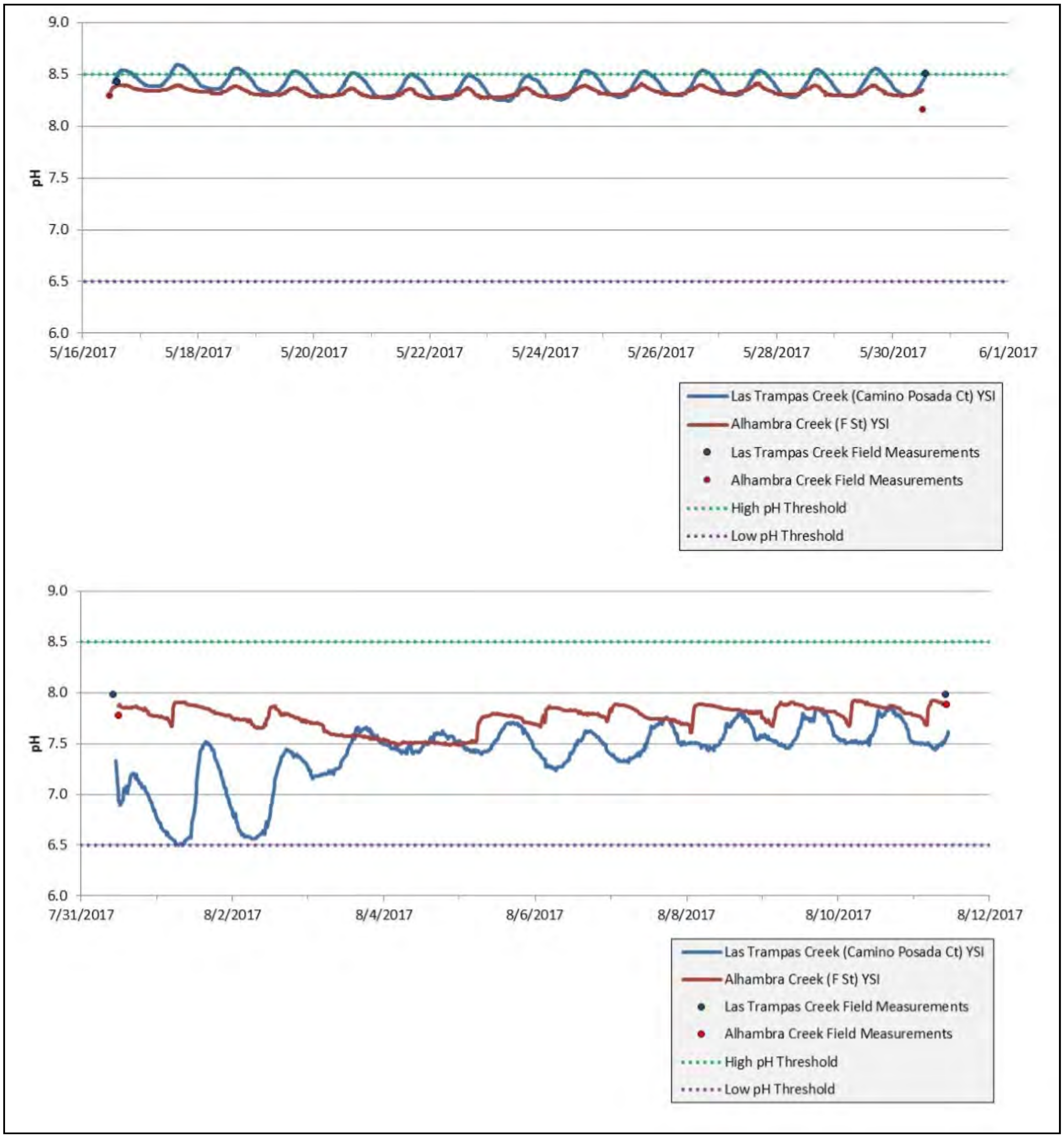


Figure 4.8 Continuous Water Quality Data (Continuous Dissolved Oxygen) Collected in Contra Costa County (Las Trampas Creek and Alhambra Creek), May 16-30 and July 31-August 11, 2017

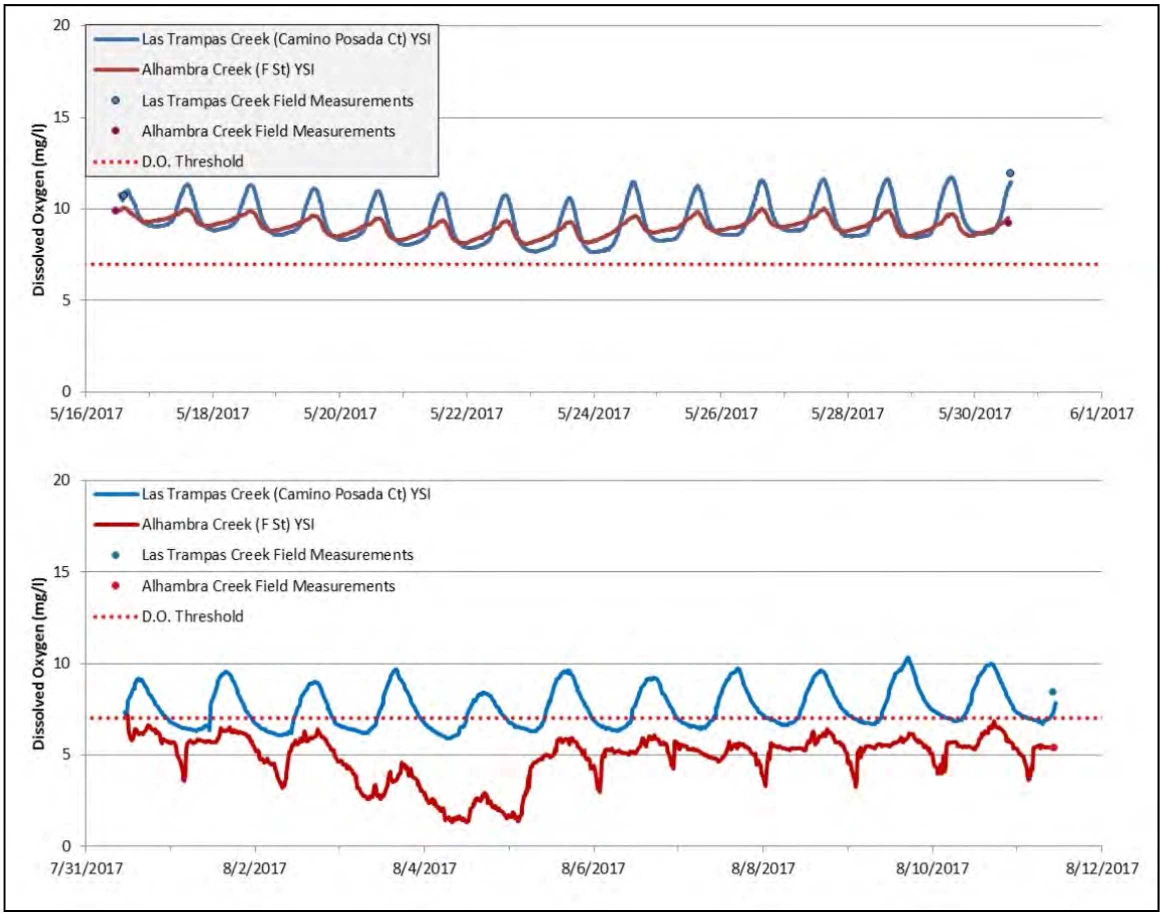
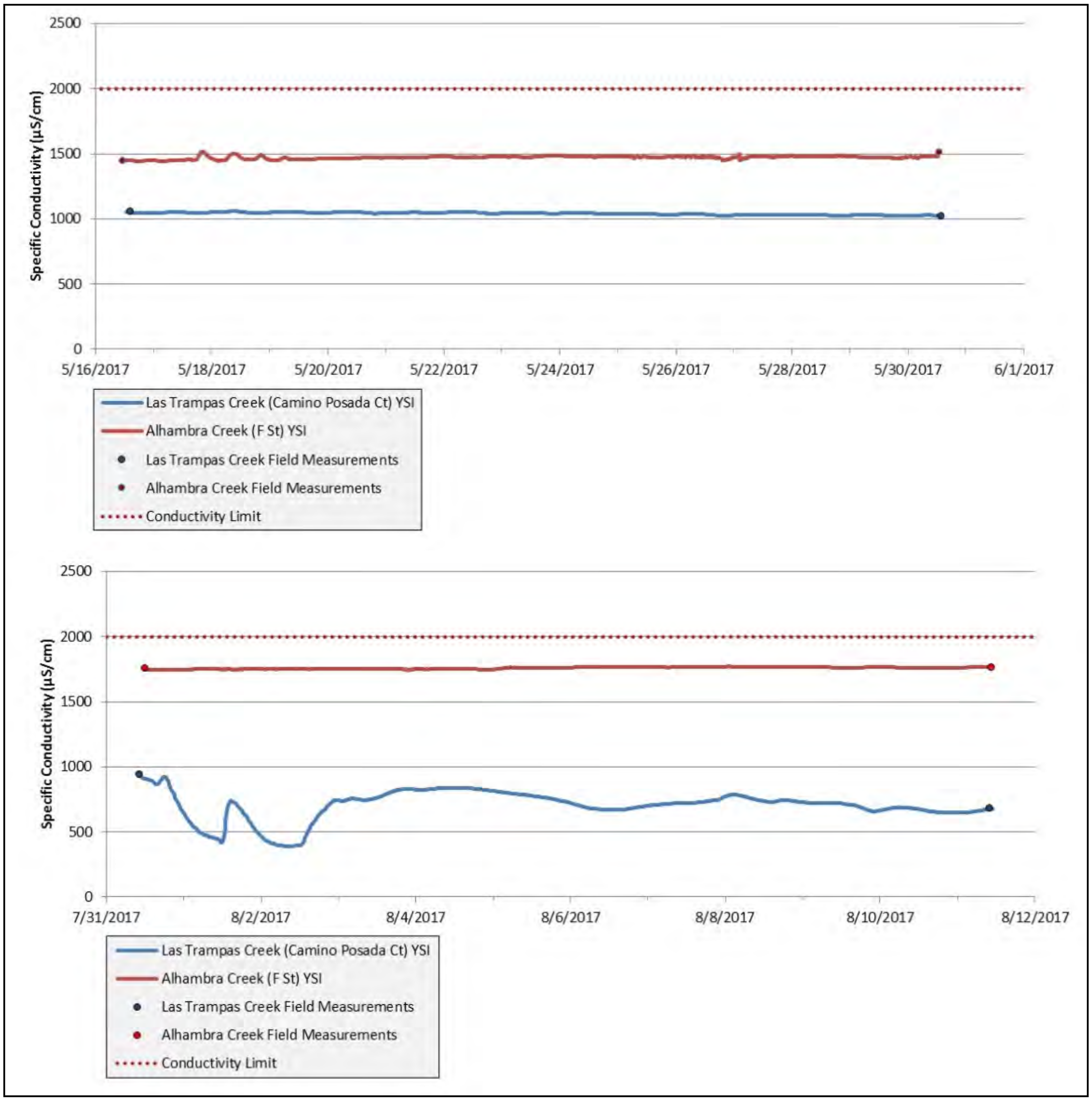


Figure 4.9 Continuous Water Quality Data (Continuous Specific Conductivity) Collected in Contra Costa County (Las Trampas Creek and Alhambra Creek), May 16-30 and July 31-August 11, 2017



During May, the WAT measured at both stations was below the MRP threshold of 17 °C for steelhead streams, but was above the temperature threshold measured at both stations during the July-August deployment (Table 4.5).

During May, none of the dissolved oxygen measurements fell below the 7 mg/L limit at either site, while during August 40 percent of the Las Trampas Creek measurements and 100 percent of the Alhambra Creek measurements fell below the limit, exceeding the MRP 2.0 percent threshold (Table 4.6). The lowest dissolved oxygen concentration (5.91 mg/l) at Las Trampas Creek occurred during August 2017. The lowest dissolved oxygen concentration (1.30 mg/l) at Alhambra Creek occurred in August 2017 as well. The minimum and maximum pH measurements for Las Trampas Creek during both deployment periods were 6.50 and 8.59, respectively. The minimum and maximum pH measurements at Alhambra Creek during both periods was 7.48 and 8.41, respectively.

For pH measurements, continuous water quality data at both Las Trampas Creek and Alhambra Creek generally met WQOs (Table 4.6). While 17 percent of pH measurements during the May deployment period at Las Trampas Creek were outside of the Basin Plan objectives, this did not exceed the 20 percent threshold criterion per MRP guidelines.

During the May deployment period, dissolved oxygen and pH in both Las Trampas Creek and Alhambra Creek show a diurnal cycle associated with primary production typical of the region. Continuous water temperature data at both locations display a diurnal cycle as well, as expected with oscillating air temperatures typical of the region. During the July-August deployment period, there is a noticeable change in the data displayed (Figures 4.5 through 4.8):

- A complete loss of the diurnal curve in water temperature at Alhambra Creek (Figure 4.6)
- A reduced variation of the diurnal curve in water temperature at Las Trampas Creek, specifically from August 2-4 (Figure 4.6)
- A complete loss of the diurnal curve in pH at Alhambra Creek from August 2-5 (Figure 4.7)
- A reduced variation of the diurnal curve in pH at Alhambra Creek, with slopes characterized by steep spikes, followed by gradual and vacillating decreases in pH (Figure 4.7)
- A variation in the normal range of the diurnal curve in pH at Las Trampas Creek, particularly from July 31-August 3, where pH readings fluctuate below normal oscillations (Figure 4.7)
- A decrease in dissolved oxygen at Alhambra Creek, particularly from August 3-5 (Figure 4.8)
- A pattern of sudden decrease and subsequent increase in conductivity at Las Trampas Creek (Figure 4.9, top)

The underlying causes of these phenomena need to be further investigated before comprehensive conclusions can be reported. At this time, the following preliminary conclusions can be suggested:

- Disruption of water temperature diurnal curves during August 1-4 may be attributed to a low pressure system associated with a southwest monsoon that tracked into the area during this period (See: http://www.wpc.ncep.noaa.gov/dailywxmap/index_20170731.html). It is hypothesized that the resulting cloud cover associated with monsoonal conditions partially blocked the incident solar radiation, preventing stream water temperatures from following normal diurnal cycles (Figure 4.6). In addition, light rain was detected the afternoon of August 4, resulting in denser cloud cover, higher humidity and above average evening air temperatures, all of which contributed to the anomalies seen in all creeks; however, not as pronounced in Las Trampas Creek due to higher stream discharge rates and greater stream depth.

- The decrease in dissolved oxygen at Alhambra Creek from August 3-5 is consistent with a warming of water temperature. The decrease in dissolved oxygen displays the reduced solubility of oxygen with increased water temperatures (Figure 4.6 and Figure 4.8).

- During the July-August deployment at Alhambra Creek, YSI sonde temperatures were recorded to be warmer during peak temperatures associated with local heat waves. Field crew observations suggest the YSI temperature measurements were subject to temperature stratification in the stream, resulting in the recording of warmer temperatures near the water's surface due to a shallower deployment depth in the water column (Figure 4.6).

- From July 31-August 3, pH and conductivity data at Las Trampas Creek suggest readings consistent with the influx of a new water mass (Figure 4.7 and Figure 4.9).

Continuous conductivity data display readings typical of the region. The median concentration of conductivity in Alhambra Creek between the two deployment periods increased from 1,475 µS/cm in May to 1,762 µS/cm in July-August. This increase can be attributed to a decrease in surface runoff, resulting in an increase of groundwater discharge. Groundwater discharges in this area percolate through old marine sediment layers, picking up ions and increasing the stream's conductivity.

Table 4.7 presents the percentages of continuous water quality data exceeding the selected water quality criteria for temperature, dissolved oxygen and pH, as measured at Las Trampas Creek and Alhambra Creek stations during both monitoring periods. The data are compared to water quality evaluation criteria specified in provision C.8.d of the MRP (Table 3.3).

Table 4.6 Percent of Dissolved Oxygen and pH Data Measured at Two Sites (Las Trampas and Alhambra Creek) for Both Events Exceeding Water Quality Evaluation Criteria Identified in Table 3.3

Site Name	Creek Name	Monitoring Period	Specific Conductance	DO Percent Results < 7.0 mg/L	pH Percent Results < 6.5 or > 8.5
207R02635	Las Trampas Creek	May 16-30, 2017	0%	0%	17%
		July 31-August 11, 2017	0%	40%	0%
207R04544	Alhambra Creek	May 16-30, 2017	0%	0%	0%
		July 31-August 11, 2017	0%	100%	0%

Following is a summary of water quality evaluation criteria exceedances occurring at either creek.

Las Trampas Creek

During the July-August 2017 deployments, dissolved oxygen fell below the steelhead stream threshold 40 percent of the time. Therefore, Las Trampas Creek exceeded MRP trigger thresholds for dissolved oxygen (20 percent or more of values exceed the applicable threshold; see Table 3.3) during the July-August measurement period.

Alhambra Creek

During the July-August 2017 deployment, dissolved oxygen fell below the steelhead stream threshold 100 percent of the time. Therefore, Alhambra Creek exceeded MRP trigger thresholds for dissolved oxygen

(20 percent or more of values exceed the applicable threshold; see Table 3.3) during the July-August measurement period.

4.2.3. Water Quality Data Evaluation for Steelhead Suitability

The potential responsive action to the analysis of water quality as it relates to fish habitat in Franklin Creek, Las Trampas Creek, and Alhambra Creek is discussed below. After a brief discussion of the site results, the potential responsive action to the analysis of water quality as it relates to fish habitat follows.

4.2.3.1. Franklin Creek (207R01447)

Water Temperature

At the HOBO monitoring station, the median water temperature in this stream was 17.43 °C and its MWAT was 18.99 °C (see Table 4.2). The 17 °C criterion was exceeded on 14 occasions, with all occasions during the 14-week period occurring from June 14-September 19.

Steelhead migrating up Alhambra Creek are assumed to also move up Franklin Creek to headwaters more suitable for spawning and rearing. Frequent exceedance of the WAT criterion indicates lower Franklin Creek provides migration passage habitat, but no or marginal summer rearing habitat for steelhead or anadromous salmonids (Cressey, 2017).

4.2.3.2. Las Trampas Creek – Camino Posada Court (204R02635)

Water Temperature

The HOBO monitoring station at this location is the downstream point of two monitoring locations on Las Trampas Creek. The median water temperature in this stream was 19.15 °C and the MWAT was 21.10 °C (see Table 4.2). The 17 °C criterion was exceeded on 17 occasions, with three separate instances taking course during the May index period, and the remaining exceedances spanning from June 14 to September19.

As shown in Table 4.4, at the YSI sonde monitoring station at Las Trampas Creek recorded a median temperature of 16.63 °C and 20.63 °C for the May and July-August deployments, respectively. The MWAT over the two deployment periods was 16.94 °C and 21.43 °C. The temperature criterion was exceeded at the YSI sonde monitoring location during the July-August deployment where the WAT exceeded 17 °C.

Although Las Trampas Creek probably once supported steelhead, as did most of the Walnut Creek drainage, construction of drop structures on Walnut Creek downstream of the City of Walnut Creek prevent steelhead access to the watershed at present. The upper watershed of Las Trampas Creek is thought to support resident rainbow trout, as determined by its proximity to resident rainbow trout located in Lafayette Creek (Cressey, 2017). As summer temperatures recorded in this portion of the creek consistently exceeded criterion on seventeen occasions, this location on Las Trampas Creek is thought to be marginal or prohibitive for steelhead rearing.

Dissolved Oxygen

Dissolved oxygen levels during May did not drop below the minimum steelhead stream criterion of 7.0 mg/L.

Dissolved oxygen levels in Las Trampas Creek during the July-August deployment failed to meet steelhead stream criterion of 7.0 mg/L for 40 percent of the recorded monitoring period.

pH

The pH during the May deployment period exceeded Basin Plan criterion during 17 percent of the monitoring period. As this does not exceed MRP trigger thresholds for pH (20 percent or more of values exceed the applicable threshold; see Table 3.3), pH met MRP criterion during the May monitoring period.

pH levels during July-August always met the Basin Plan criterion during the monitoring period (see Table 4.6).

Specific Conductance

The specific conductance of Las Trampas Creek always met MRP criterion during the monitoring period (see Table 4.6). The median specific conductance of 720 µS/cm to 1040 µS/cm is normal for this region.

4.2.3.3. Las Trampas Creek – Reliez Station Road (207R02891)

Water Temperature

The HOBO monitoring station at this location is the upstream point of two monitoring locations on Las Trampas Creek. The median water temperature in this stream was 18.69 °C and the MWAT was 21.10 °C (see Table 4.2). The 17 °C criterion was exceeded on 16 occasions, with two separate instances taking course during the May index period, and the remaining exceedances occurring during the June 14-September 19 index period.

Although located farther up the watershed, summer temperatures make this location of Las Trampas Creek marginal or prohibitive for steelhead rearing.

4.2.3.4. Alhambra Creek – (207R04544)

Water Temperature

At the HOBO monitoring station, the median water temperature was 18.05 °C and its MWAT was 19.62 °C (Table 4.2). The monitored water temperatures at this site in the City of Martinez exceeded the MRP criterion of 17 °C on 15 occasions, once during the week of May 31 and again during all weeks recorded during the June 14-September 19 index period.

As shown in Table 4.4, at the YSI sonde monitoring station, the median water temperature recorded for the May and July-August deployments was 15.94 °C and 18.59 °C, respectively. The maximum WAT over the two deployment periods was 16.02 °C and 19.03 °C, respectively. The temperature criterion was exceeded at the YSI sonde monitoring location during the July-August deployment where the WAT exceeded 17 °C.

Alhambra Creek historically supported steelhead and it is assumed a small number of steelhead still ascend the creek to spawn and rear young (Cressey, 2017). Due to the temperature criterion exceedances listed above, lower Alhambra Creek provides steelhead migration habitat, but no rearing habitat for salmonids during the summer months.

Dissolved Oxygen

Dissolved oxygen levels in Alhambra Creek during May did not drop below the minimum in-stream habitat criterion of 7.0 mg/L. During the July-August period, 100 percent of results failed to meet the minimum dissolved oxygen criterion, exceeding the MRP threshold of 20 percent of instantaneous results < 7.0 mg/L.

These dissolved oxygen results further suggest lower Alhambra Creek provides steelhead migration habitat, but no rearing habitat for salmonids during the summer. Depressed dissolved oxygen levels eliminate steelhead rearing habitat at this location (Cressey, 2017).

pH

The pH of Alhambra Creek always met MRP criterion during the monitoring period (see Table 4.6).

Specific Conductance

The specific conductance of Alhambra Creek always met MRP numeric WQOs during the monitoring period (see Table 4.6). As shown in Table 4.4, specific conductance medians for both May and July-August were within MRP criterion (1475-1762 µS/cm, respectively).

4.3. Pathogen Indicators

In compliance with MRP provision C.8.d and Central Valley Permit provision C.8.c, a set of pathogen indicator samples were collected on July 24, 2017 at five stations on creeks in Contra Costa County. They were analyzed for enterococci and *E. coli*. The sites were located along West Branch Alamo Creek, Sans Crainte Creek, Las Trampas Creek, Walnut Creek, and Alhambra Creek. The sites on Las Trampas Creek and Alhambra Creek also had continuous monitoring devices deployed. Due to their proximity to a public park, all locations were targeted to investigate if the water quality could be impacted by regular human recreational activity, such as off-leash dog parks or other activities (e.g., suspected illegal encampments). All sites were chosen based upon the likelihood of water contact recreation or to investigate areas of possible anthropogenically-induced contamination.

As described previously (Section 3.4.3), single sample maximum concentrations of 130 CFU/100ml enterococci and 410 CFU/100ml *E. coli* were used for evaluation, based on the most recently published recreational water quality criteria statistical threshold values for water contact recreation (EPA, 2012). Enterococci concentrations ranged from 93 to 2,419 CFU/100 ml and *E. coli* concentrations ranged from 280 to 800 CFU/100 ml. Four enterococci samples exceeded the applicable criterion, while three samples collected for *E. coli* exceeded the applicable EPA criterion. Samples collected at 207R01675 (Sans Crainte Creek), 207R02891 (Las Trampas Creek) and 207R04544 (Alhambra Creek) exceeded criteria for both enterococci and *E. coli,* while one sample collected at 204R01412 (West Branch Alamo Creek) exceeded only the enterococci criterion.

Table 4.7 Enterococci and *E. coli* Levels Measured From Water Samples Collected at Five Locations in Creeks in Contra Costa County, July 24, 2017

Site ID	Creek Name	Enterococci (CFU/100ml)	*E. coli* (CFU/100ml)
204R01412	West Branch Alamo Creek	172[1]	300
207R01675	Sans Crainte Creek	2419[1]	500[2]
207R02891	Las Trampas Creek	152[1]	800[2]
207R03403	Walnut Creek	93	280
207R04544	Alhambra Creek	365[1]	500[2]

1 Exceeded EPA criterion of 130 CFU/100ml enterococci

2 Exceeded EPA criterion of 410 CFU/100ml *E. coli*

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5. Next Steps

Under the requirements of provision C.8 in the MRP and the Central Valley Permit, the following next steps will be taken:

1. CCCWP will continue to conduct monitoring for local/targeted parameters in WY 2018.

2. All permit-related water quality threshold exceedances will be included in a compilation of water quality triggers for consideration by the RMC as potential SSID projects, as well as other potential follow-up investigations and/or monitoring. Based on the analysis of the local targeted data, the results exceeding the MRP trigger thresholds (Table 5.1) will be listed in the SSID data evaluation form as potential SSID projects.

Table 5.1 Summary of CCCWP Exceedances for Water Year 2017

Creek	Index Period	Parameter	Criterion Exceedance
Franklin Creek	June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Las Trampas Creek (at Camino Posada)	May 3-May 9, 2017 May 17-May 23, 2017 May 31-June 6, 2017 June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Las Trampas Creek (at Camino Posada)	July 31-August 11, 2017	Continuous Water Temperature (sonde)	When one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Las Trampas Creek (at Camino Posada)	July 31-August 11, 2017	Continuous Water Quality - DO	When 20 percent of instantaneous results drop below 7.0 mg/L
Las Trampas Creek (at Reliez Station Rd)	May 17-May 23, 2017 May 31-June 6, 2017 June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Alhambra Creek	May 31-June 6, 2017 June 14-September 19, 2017	Continuous Water Temperature (HOBO)	More than one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Alhambra Creek	July 31-August 11, 2017	Continuous Water Temperature (sonde)	When one WAT exceeds 17 °C or when 20 percent of instantaneous results > 24 °C
Alhambra Creek	July 31-August 11, 2017	Continuous Water Quality - DO	When 20 percent of instantaneous results drop below 7.0 mg/L
West Branch Alamo Creek	July 24, 2017	Enterococci	Single grab sample exceeded EPA criterion of 130 CFU/100ml
Sans Crainte Creek	July 24, 2017	Enterococci	Single grab sample exceeded EPA criterion of 130 CFU/100ml
Las Trampas Creek (at Reliez Station Rd)	July 24, 2017	Enterococci	Single grab sample exceeded EPA criterion of 130 CFU/100ml
Alhambra Creek	July 24, 2017	Enterococci	Single grab sample exceeded EPA criterion of 130 CFU/100ml
Sans Crainte Creek	July 24, 2017	*E. coli*	Single grab sample exceeded EPA criterion of 410 CFU/100ml
Las Trampas Creek (at Reliez Station Rd)	July 24, 2017	*E. coli*	Single grab sample exceeded EPA criterion of 410 CFU/100ml
Alhambra Creek	July 24, 2017	*E. coli*	Single grab sample exceeded EPA criterion of 410 CFU/100ml

WAT = weekly average temperature

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Appendix 3

BASMAA Regional Monitoring Coalition Stressor/Source Identification Studies Status Report

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BASMAA Regional Monitoring Coalition
Regional Stressor/Source Identification (SSID) Report, prepared in compliance with Municipal Regional Stormwater NPDES Permit (MRP; Order No. R2-2015-0049) Provision C.8.e.ii(1)
MRP 2.0 SSID Project Locations, Rationales, Status
Updated March 2018

SSID Project ID	Date Updated	Program	Creek Channel Name	Site Code(s) or Other Site ID	Project Title	Primary Indicator(s) Triggering Stressor/Source ID Project									Indicator Result Summary	Rationale for Proposing/Selecting Project	Status of SSID Project or Date Completed	EO Concurrence of Project Completion (per C.8.e.iii.(b))
						Bioassessment	General Water Quality	Chlorine	Temperature	Water Toxicity	Sediment Toxicity	Sediment Chemistry	Pathogen Indicators	Other				
AL-1	02/23/18	ACCWP	Palo Seco Creek		Exploring Unexpected CSCI Results and the Impacts of Restoration Activities	X									Sites where there is a substantial difference in CSCI score observed at a location relative to upstream or downstream sites, including sites on Palo Seco Creek upstream of the Sausal Creek restoration-related sites, that had substantial and unexpected differences in CSCI scores.	The project will provide additional data to aid consideration of unexpected and unexplained CSCI results from previous water year sampling on Palo Seco Creek, enable a more focused study of monitoring data collected over many years in a single watershed, and allow analysis of before and after data at sites upstream and downstream of previously completed restoration activities.	The work plan is under development. Completion planned June 2018.	
AL-2		ACCWP																
CC-1	02/01/18	CCCWP	Lower Marsh Creek		Stressor Source Identification Study of Marsh Creek Fish Kills					X					9 fish kills were documented in Marsh Creek between September 2005 and October 2017. A conclusive cause is not yet identified.	Fish kills are clear indicators that aquatic habitat beneficial uses are not attained in this reach of Marsh Creek. These events are of interest to the public as well as regulatory and resource agencies in SF Bay and Central Valley regions. Past monitoring data from CCCWP and other parties are being used to develop a phased work plan investigating multiple potential causes, including low dissolved oxygen, warm temperatures, daily pH swings, fluctuating flows, physical stranding, and pesticide exposure.	The work plan is under development. Completion planned June 2018.	
SC-1	01/22/18	SCVURPPP	Coyote Creek		Coyote Creek Toxicity SSID Project						X				The SWRCB recently added Coyote Creek to the 303(d) list for toxicity.	This SSID study will investigate sources of toxicity to Coyote Creek.	The work plan will be submitted with SCVURPPP's WY 2017 UCMR.	
SC-2		SCVURPPP																
SM-1	01/31/18	SMCWPPP	Pillar Point / Deer Creek / Denniston Creek		Pillar Point Harbor Bacteria SSID Project								X		FIB samples from 2008 and 2011-2012 exceeded WQOs.	The Pillar Point Harbor MST study conducted in 2008, 2011-2012 pointed to urban runoff as a primary contributor to bacteria at Capistrano Beach and Pillar Point Harbor. However, the specific urban locations were not identified nor were the contributing organisms established. This SSID project will investigate bacteria contributions from the urban areas within the watershed.	The work plan will be submitted with SMCWPPP's WY 2017 UCMR.	
FS-1		FSURMP																
TBD		RMC/TBD																

Appendix 4

Pollutants of Concern Monitoring Report:

Water Year 2017 Sampling and Analysis

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Contra Costa Clean Water Program

Pollutants of Concern Monitoring Report: Water Year 2017 Sampling and Analysis

February 1, 2018

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Contra Costa Clean Water Program

Pollutants of Concern Monitoring Report: Water Year 2017 Sampling and Analysis

February 1, 2018

Prepared for

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Contra Costa Clean Water Program Participants

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List of Acronyms and Abbreviations

ADH	ADH Environmental
AMS	Applied Marine Sciences
ASTM	American Society for Testing and Materials
BMP	best management practice
CCCWP	Contra Costa Clean Water Program
EPA	U.S. Environmental Protection Agency
MRP	municipal regional stormwater permit
MS4	municipal separate storm sewer system
PCB	polychlorinated biphenyl
POC	pollutants of concern
ppb	parts per billion
PSD	particle size distribution
QAPP	quality assurance project plan
RMP	Regional Monitoring Program
RWQCB	regional water quality control board
SM	Standard Methods for the Examination of Water and Wastewater
SSC	suspended sediment concentration
TOC	total organic carbon
WY	water year

1. INTRODUCTION

This report summarizes pollutants of concern (POC) monitoring conducted by the Contra Costa Clean Water Program (CCCWP) during water year (WY) 2017 (October 1, 2016 through September 30, 2017). This report fulfills provision C.8.h.iv of the Municipal Regional Stormwater Permit (MRP) 2.0, Order No. R2-2015-0049.

During WY 2017, the following monitoring activities were completed:

- Countywide street dirt sampling (Tier 1 approach) in urban landscape targeted for historic industrial land uses and halo extent from known areas of elevated PCB concentrations
- Stormwater sampling (Tier 3 approach) in the Rumrill Boulevard and Chesley Avenue areas in the cities of Richmond and San Pablo adjacent to suspected source properties for PCBs and mercury to confirm if elevated concentrations are present in runoff
- Copper and nutrients stormwater monitoring in lower Walnut Creek and lower Marsh Creek
- Mercury and methylmercury stormwater monitoring in lower Marsh Creek during upper watershed discharge; this monitoring also supports information needed for the methylmercury control study required by the Delta methylmercury TMDL
- Infiltration monitoring to native soil at six BMPs in the City of Pittsburg

All monitoring activities were performed in accordance with CCCWP's POC Sampling and Analysis Plan and Quality Assurance Project Plan, draft guidance documents (ADH and AMS, 2016a; ADH and AMS, 2016b). Each of these monitoring efforts is described in the following sections.

Additional monitoring information, background and context, including a discussion of permit-driven goals, can be found in the WY 2017 POCs report (CCCWP, 2017).

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2. STREET DIRT SAMPLING AND ANALYSIS (TIER 1 SCREENING FOR SOURCE ID)

In WY 2017, eight street dirt locations throughout the county were sampled and analyzed for PCBs, mercury, total organic carbon (TOC), and particle size distribution (PSD). Street dirt is surface material within the public right-of-way available for stormwater entrainment into the MS4. It is found in street gutters, on sidewalks and driveway aprons, or accumulated near an MS4 entry point (e.g., adjacent to a drop inlet grate). Water year 2017 sampling took place at sites known to have or suspected of having elevated levels of PCBs, or were sites requested for survey by CCCWP permittees.

Table 1 provides site IDs, sampling dates, position coordinates and site descriptions (rationale for selection) for each location. Table 2 provides analytical test methods, reporting limits and holding times. Table 3 provides results of PCBs, mercury, TOC and PSD testing. Refer to Figure 1 for the general locations of street dirt sampling.

Table 1. Street Dirt Sampling Locations and Selection Rationale (WY 2017)

Site ID [1]	Date Sampled	Latitude (decimal degrees)	Longitude (decimal degrees)	General Description and Selection Rationale
CCC-LBV-100-P1	08/23/17	38.03728	-122.17797	Sample collected near an off-line transformer station
CCC-LBV-101-P1	08/23/17	38.03741	-122.17609	Sample collected below an electrical pole with a transformer on the hillside
CCC-LBV-102-P1	08/23/17	38.03678	-122.17696	Sample collected at a low point in the dry local watercourse downstream of former industrial facility
CCC-PAC-100-P1	08/23/17	37.99732	-122.07687	Sampled trackout from an unpaved access road to several businesses
CCC-PAC-101-P1	08/23/17	38.00598	-122.08932	Sampled along a fence line in right-of-way
CCC-ALT-100-P1	08/23/17	37.99604	-122.34834	Adjacent to PG&E property and recommended for testing by CCCWP; sampled near drop inlet where runoff appears to flow from the substation
CCC-CHR-100-P1	08/23/17	37.95201	-122.36234	Sampled trackout from non-jurisdictional railroad property
CCC-GDN-100-P1	08/23/17	37.96307	-122.37623	Sampled at low point in channel before culvert which runs west to San Francisco Bay; previously identified as a hot spot

1 Site ID Key:

CCC	Contra Costa County	P1	Phase 1	ALT	Atlas Road	GDN	Garden Tract Road
LBV	Little Bull Valley	PAC	Pacheco Boulevard	CHR	Cherry Street		

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

Sediment Analytical Test	Method	Reporting Limit	Holding Time
Total PCBs (RMP 40 congeners) [1]	EPA 8082A	0.5 µg/kg	1 year
Total Mercury	EPA 7471B	5 µg/kg	1 year
Total Organic Carbon (TOC)	ASTM D4129-05M	0.05%	28 days
Particle Size Distribution (PSD) [2]	ASTM D422M	0.01%	28 days

1 San Francisco Bay RMP 40 PCB congeners include PCB-8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, 105, 110, 118, 128, 132, 138, 141, 149, 151, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, and 203.

2 Particle size distribution by the Wentworth scale; percent fines (slit and clay) are less than 62.5 microns.

Table 3. Street Dirt Sampling Results (WY 2017)

Sample ID	Total PCBs (µg/Kg) [1]	Total Hg (µg/Kg)	TOC (%)	Particle Size Distribution			
				Gravel (%)	Sand (%)	Silt (%)	Clay (%)
CCC-ALT-100-P1	21	63	0.545	18	64	17	1
CCC-CHR-100-P1	360	103	1.32	22	62	15	2
CCC-GDN-100-P1	46	235	2.70	19	39	36	6
CCC-LBV-100-P1	14	48	0.866	7	33	52	8
CCC-LBV-101-P1	0	50	0.660	3	40	46	10
CCC-LBV-102-P1	2	26	0.983	19	52	27	3
CCC-PAC-100-P1	31	181	3.07	29	49	21	2
CCC-PAC-101-P1	25	421	1.04	9	52	36	3

1 Sum of RMP 40 congeners.

3. STORMWATER SAMPLING AND ANALYSIS (TIER 3 SCREENING FOR SOURCE ID)

Water year 2017 stormwater samples were collected in the Rumrill Boulevard and Chesley Avenue areas in the cities of Richmond and San Pablo as a follow up to the determination of high PCBs and mercury concentrations found in street dirt samples and drop inlet samples collected in WYs 2015 and 2016. Stormwater sampling results correlated positively with street dirt sampling results and indicated runoff to the MS4 is relatively high in PCBs in the following areas:

- West end of Sutro Avenue
- Kelsey Street, immediately east of railroad tracks
- South of Chesley Avenue, immediately east of railroad tracks

Street dirt and stormwater sampling data may be compiled and evaluated for PCB congener fingerprints to determine if common source areas can be identified, and to understand the degree of weathering sampled PCBs have undergone. If evaluated, pertinent findings will be reported in the main body of future urban creeks monitoring report(s).

Refer to Table 4 for test methods and reporting limits, and Table 5 for position coordinates of the sampling points and analytical results.

Table 4. Stormwater Analytical Tests, Methods, Reporting Limits, and Holding Times

Sediment Analytical Test	Method	Reporting Limit	Holding Time
Total PCBs (RMP 40 congeners) [1]	EPA 1668C	0.1 µg/kg	1 year
Total Mercury	EPA 1631E	0.5 ng/L	28 days
Total Methylmercury	EPA 1630	0.1 ng/L	28 days
Suspended Sediment Concentration	ASTM D 3977-97	1.5 mg/L	7 days
Total Organic Carbon (TOC)	EPA 9060	0.50 mg/L	28 days

1 San Francisco Bay RMP 40 PCB congeners include PCB-8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, 105, 110, 118, 128, 132, 138, 141, 149, 151, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, and 203.

Table 5. Stormwater Sampling Results – Rumrill Boulevard and Chesley Avenue Areas (WY 2017)

Site ID [1]	CCC-MKT-100-SW	CCC-RUM-101-SW	CCC-CHS-102-SW	CCC-CHS-103-SW	CCC-CHS-104-SW	CCC-KEL-105-SW	CCC-CHS-106-SW	CCC-SUT-107-SW	CCC-RUM-108-SW	CCC-RUM-109-SW
Date Sampled	01/08/17	01/08/17	01/08/17	01/08/17	01/08/17	01/08/17	01/08/17	01/08/17	01/08/17	01/08/17
Latitude	37.95898	37.956605	37.954699	37.954598	37.954212	37.951034	37.954707	37.953363	37.95298	37.954081
Longitude	-122.357749	122.356936	122.357417	122.358093	122.358118	122.363521	122.359882	122.357754	122.357131	122.357083
Total PCBs [2] (ng/L)	5.20	2.58	6.53	4.39	8.37	20.2	5.37	1.98	3.28	30.4
Total Hg (ng/L)	12.1	10.2	5.53	13.8	20.1	21.1	38.6	6.28	2.23	13.5
Total MeHg (ng/L)	0.12	0.38	0.12	0.25	0.58	0.28	0.76	0.08	0.19	0.41
MeHg/Hg Ratio (%)	9.9	37.3	21.7	18.1	28.9	13.3	19.7	12.7	85.2	30.4
SSC (mg/L)	33.2	9.3	14.0	13.7	7.6	15.1	8.3	2.4	43.2	215
TOC (mg/L)	1.7	2.71	1.48	7.6	18.8	5.9	9.9	1.19	2.4	1.9
PCBs/SSC Ratio (ppb) [3]	157	278	466	320	1101	1338	647	825	76	141

1 Site ID Key: MKT Market Avenue RUM Rumrill Boulevard CHS Chesley Avenue KEL Kelsey Street SUT Sutro Avenue

2 PCBs in stormwater matrix analyzed by method EPA 1668

3 Values in bold italics indicate a likely high source area for PCBs

4. COPPER AND NUTRIENTS MONITORING

Copper and nutrients samples were collected during one storm at both Walnut Creek and Marsh Creek. The sampling sites were in the lower reach of each creek, but upstream of tidal influences, and represent discharge to the Bay/Delta from the two largest watersheds in the county. For Marsh Creek, the site was co-located with the fixed sampling stations for WYs 2012, 2013 and 2014, which is immediately upstream of the City of Brentwood's waste water treatment plant discharge. This site was selected because past data for copper and nutrients can be compared to current results to address trends. For Walnut Creek, the site was co-located with an MRP provision C.8.d probabilistic creek status monitoring site which is yet to be sampled; this site was selected because future monitoring efforts under the creek status program may provide an opportunity for trends assessment.

Two sets of grab samples were collected at each creek during the storm of March 24, 2017. At each site, the first set of samples were collected on the rising hydrograph of the storm, and the second set of samples were collected near peak flow. Samples were field filtered within 15 minutes of collection for dissolved copper, ammonia, nitrate, nitrite, and orthophosphate. Refer to Table 6 for test methods and reporting limits. Refer to Table 7 for position coordinates and analytical results.

Table 6. Watershed Characterization Analytical Tests, Methods and Reporting Limits – Copper and Nutrients

Analytical Test	Method	Reporting Limit
Suspended Sediment Concentration (SSC)	ASTM D 3977-97B	3 mg/L
Copper, total recoverable and dissolved	EPA 200.8	0.5 µg/L
Hardness	SM 2340C (titration)	5 mg/L
Ammonium	SM 4500 NH3-C	0.02 mg/L
Nitrate	EPA 300.0	0.05 mg/L
Nitrite	EPA 300.0	0.05 mg/L
Total Kjeldahl Nitrogen	SM 4500 NH3-C	0.1 mg/L
Dissolved Orthophosphate	SM 4500P-E	0.01 mg/L
Total Phosphorus	SM 4500P-E	0.01 mg/L

Table 7. Copper and Nutrients Monitoring Results – Lower Marsh Creek and Lower Walnut Creek (WY 2017)

Site ID [1]	LMC		WAL	
Sample Date	03/24/17		03/24/17	
Sample Time	1215 [2]	1330 [3]	1100 [2]	1400 [3]
Latitude	37.96264		37.97271	
Longitude	-121.68794		-122.05305	
Copper, Dissolved (µg/L)	1.4	1.4	1.7	2.2
Copper, Total (µg/L)	2.3	2.3	3.0	4.4
Hardness (mg/L)	340	340	360	340
Ammonium (mg/L)	0.088	0.099	<0.04	<0.066
Nitrate (mg/L)	0.71	0.67	0.69	0.61
Nitrite (mg/L)	0.011	0.01	0.006	0.007
Total Kjeldahl Nitrogen (mg/L)	0.53	0.66	0.48	0.75
Dissolved Orthophosphate (mg/L)	0.007	0.009	0.17	0.17
Phosphorus (mg/L)	0.041	0.039	0.22	0.24

1 Site ID Key: LMC Lower Marsh Creek WAL Lower Walnut Creek
2 Rising hydrocurve
3 Near peak of hydrocurve

5. MERCURY AND METHYLMERCURY MONITORING IN MARSH CREEK DURING UPPER WATERSHED DISCHARGE

To help fill data gaps in the Marsh Creek watershed monitoring effort (performed in water years 2012, 2013 and 2014), upper watershed discharge samples were collected during one storm in WY 2017. Samples were collected at the site of the former fixed monitoring station on lower Marsh Creek immediately upstream of discharge from the City of Brentwood's waste water treatment plant. Approximately six miles upstream of the sampling point lies the Marsh Creek Reservoir, which captures runoff from the upper watershed, including the former Mount Diablo Mercury Mine. The reservoir discharges through the primary spillway only during periods of extreme runoff; otherwise, the reservoir is successful at impounding water from most rain events.

The storm event of January 8, 2017 produced runoff rates high enough to discharge through the reservoir's primary spillway and conveyed upper watershed runoff through lower Marsh Creek and to the Delta. Four grab samples were collected over a span of eight hours as the initial pulse of reservoir discharge passed through the sampling location. See Table 4 for analytical test methods and reporting limits. Analytical results for SSC, mercury, and methylmercury are presented in Table 8.

Table 8. Mercury and Methylmercury Monitoring – Marsh Creek Upper Watershed Discharge (WY 2017)

Site ID	LMC			
Sample Date	01/08/17			
Sample Time	0920	1220	1445	1745
Latitude	37.96264			
Longitude	-121.68794			
Mercury (µg/L)	0.015	0.023	0.047	0.080
Methylmercury (ng/L)	0.09	0.11	0.23	0.30
SSC (mg/L)	48	57	174	236
MeHg/Hg Ratio (%)	0.6	0.5	0.5	0.4
Hg/SSC Ratio (ppb)	312	404	270	339

LMC Lower Marsh Creek
SSC Suspended sediment concentration
MeHg Methylmercury

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6. BMP EFFECTIVENESS – INFILTRATION MONITORING

Monitoring was conducted at six bioretention BMPs to help inform management decisions regarding the efficacy of infiltration as a means of reducing or eliminating discharge of pollutants. Three existing BMPs were monitored at the Fire Prevention Bureau in Pittsburg, and three newly constructed BMPs were monitored at a commercial gas station, also in Pittsburg. The typical configuration of a bioretention/ infiltration BMP is depicted in Figure 2.

Fire Prevention Bureau, Pittsburg

During the period of late February to late April 2017, water levels were monitored in subsurface gravel storage layers in three of six bioretention facilities at the Fire Prevention Bureau building and parking lot at 2331 Loveridge Road in Pittsburg, California. These hydromodification BMPs were installed in 2011, as required by MRP 1.0 permit provision C.3.g. They were initially monitored in 2011-2013 for the purposes of model calibration and verification, and to determine their flow-control effectiveness (CCCWP, 2013). The purpose of the most recent monitoring was to determine if stormwater infiltration rates into the surrounding subsurface native soils from the bioretention facilities were the same as reported in 2013.

Each of the three BMPs was constructed in the same general manner: after rilling of the subsurface soil, a layer of gravel and 18 inches of sand/compost mix were placed. The monitoring wells were composed of sections of 3-inch-diameter PVC pipe mounted vertically through the sand/compost and gravel layers with their lowest ends resting at the bottom of the gravel layer. In the 2011-2013 study, the three wells were designated as Integrated Management Practice or IMP 2, IMP 4, and IMP 6. During the WY 2017 study, the wells were designated as Stations A-2, A-4, and A-6, and the water levels were recorded by OnSet® Corporation HOBO® U-220 data loggers.

Over the course of the WY 2017 monitoring period, only Station A-2 had consistently measurable water levels above the bottom of its gravel layer during storms. Station A-4 had little or no measurable water during the entire sampling period, and Station A-6 had a slight response to the largest storm, which occurred on March 22, 2017. Similar responses were noted and recorded in the 2011-2013 study.

The 2011-2013 study (CCCWP, 2013) reported that, following significant storms, accumulated water infiltrated into the native soil at a rate of 0.21 to 0.71 inches per hour at Station A-2, and 0.32 inches per hour at Station A-6. Whereas during the WY 2017 study infiltration rates were much greater, ranging from 1.46 to 1.98 at Station A-2, and 2.42 inches per hour at Station A-6. It is not clear why this difference in infiltration rates exists.

Arco Gas Station, Pittsburg

During the period of late February to late April 2017, the water levels were monitored in subsurface storage layer monitoring wells at three BMPs at the Arco Gas Station at 2102 West Leland Road in Pittsburg, California. These hydromodification BMPs were newly implemented in early 2017. The purpose of this monitoring was to determine the rate of stormwater infiltration into the surrounding subsurface native soils.

Each of the three BMPs was constructed in a similar manner: after rilling of the subsurface soil, 12 inches of gravel and then 18 inches of sand/compost mix were placed in layers. The monitoring wells were composed of sections of 8-inch diameter PVC pipe mounted vertically through the sand/compost and gravel layers with their lowest ends resting at the bottom of the gravel layer. The monitoring wells were designated as Arco 1, Arco 2, and Arco 3, with the water levels recorded by OnSet® Corporation HOBO® U-220 data loggers.

Infiltration rates varied substantially among the three BMPs and among storms. For Arco 1, rates ranged from 0.02 to 0.05 inches per hour; for Arco 2, rates ranged from 0.19 to 0.56 inches per hour; and for Arco 3, rates ranged from 0.17 to 0.72 inches per hour.

Table 9 summarizes the infiltration rates for Fire Prevention Bureau Stations A-2 and A-6, and for Arco Stations 1 through 3. Note that the infiltration rates are equivalent to the recession rates multiplied by an estimated porosity factor of 0.4.

Table 9. Summary of Infiltration Rates

BMP Location	Station ID	Date	Infiltration Rate (in/hr) [1]
Fire Prevention Bureau	A-2	03/16/12	0.27
	A-2	03/17/12	0.21
	A-2	11/28/12	0.33
	A-2	11/30/12	0.71
	A-6	11/30/12	0.32
	A-2	03/04/17	1.46
	A-2	03/22/17	1.98
	A-6	03/22/17	2.42
Arco Gas Station	Arco 1	03/04/17	0.05
	Arco 2	03/04/17	0.21
	Arco 3	03/04/17	0.17
	Arco 2	03/05/17	0.56
	Arco 3	03/05/17	0.72
	Arco 1	03/22/17	0.02
	Arco 2	03/22/17	0.26
	Arco 3	03/22/17	0.55
	Arco 2	03/23/17	0.19

1 The porosity of a gravel layer in BMPs like these is generally estimated at 0.4. This factor was applied to the recession rates derived through regression to estimate the rate at which water is infiltrated to the surrounding soils.

7. SUMMARY OF MONITORING COMPLETED IN WATER YEAR 2017

Water year 2017 monitoring is summarized in Table 10. The table lists the total number of tests completed for each pollutant class, and the corresponding targets outlined in MRP 2.0.

The number of samples collected and analyzed in WY 2017 met or exceeded the minimum annual requirements of the MRP in all pollutant categories, except for emerging contaminants which will be sampled and analyzed in one special study before the end of the five-year permit term.

Table 10. Summary of Monitoring Completed in WY 2017 by Pollutant Class, Analyte, and MRP Targets

Pollutant Class / Type of Monitoring	Analyte									Agency or Organization Performing the Monitoring	Number of Samples Collected and Analyzed in WY 2017	Cumulative Number of Samples Collected and Analyzed in WYs 2016 and 2017	Annual Minimum Number of Samples Required by the MRP	Total Number of Samples Required by the MRP Over 5 Year Term
	PCBs	Mercury	Methylmercury	SSC	PSD	TOC	Copper [1]	Hardness	Nutrients [2]					
PCBs - water	✓			✓		✓				CCCWP	10	27	8	80
PCBs - water	✓			✓		✓				RMP (SFEI)	4			
PCBs - sediment	✓				✓	✓				CCCWP	8	35	8	80
PCBs - sediment	✓				✓	✓				City of San Pablo	5			
Mercury - water		✓	✓	✓		✓				CCCWP	14	46	8	80
Mercury - water		✓	✓	✓		✓				RMP (SFEI)	4			
Mercury - sediment		✓			✓	✓				CCCWP	8	30	8	80
Copper - water							✓	✓		CCCWP	4	4	2	20
Nutrients – water									✓	CCCWP	4	4	2	20
Emerging Contaminants[3]										-	0	0	3	3
BMP Infiltration										CCCWP	6 [a]	6 [a]	0	0

1 Total and dissolved fractions of copper
2 Nutrients include ammonia, nitrate, nitrite, total Kjeldahl nitrogen, orthophosphate and total phosphorus
3 Emerging contaminants (alternative flame retardants) need only be tested during one special study over the 5-year term of the permit
a Infiltration monitoring was performed at 6 bioretention/infiltration BMPs in water year 2017
SSC suspended sediment concentration
PSD particle size distribution
TOC total organic carbon

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Figure 1. Location of WY 2017 Sampling Points and Monitoring Activities

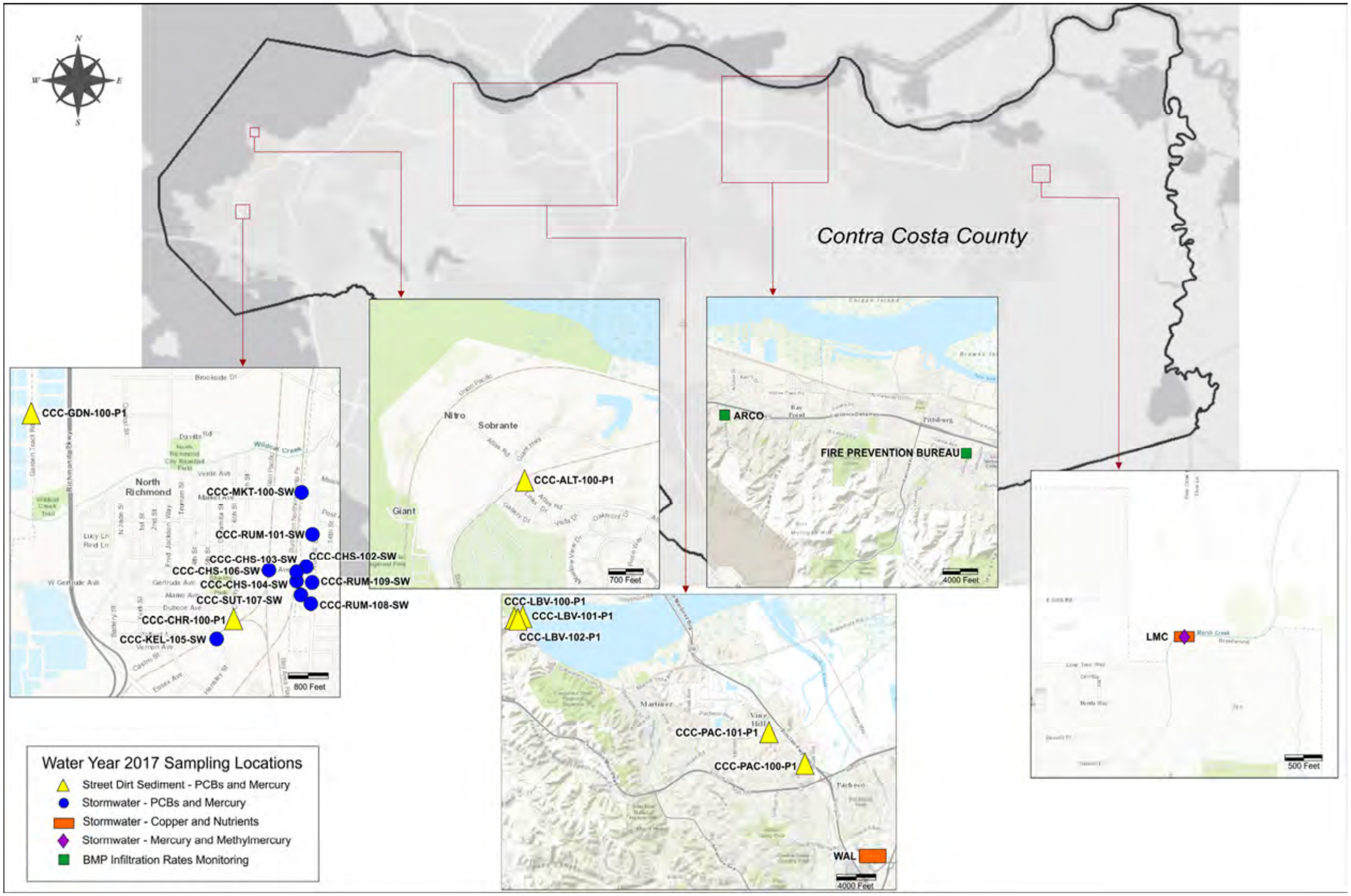
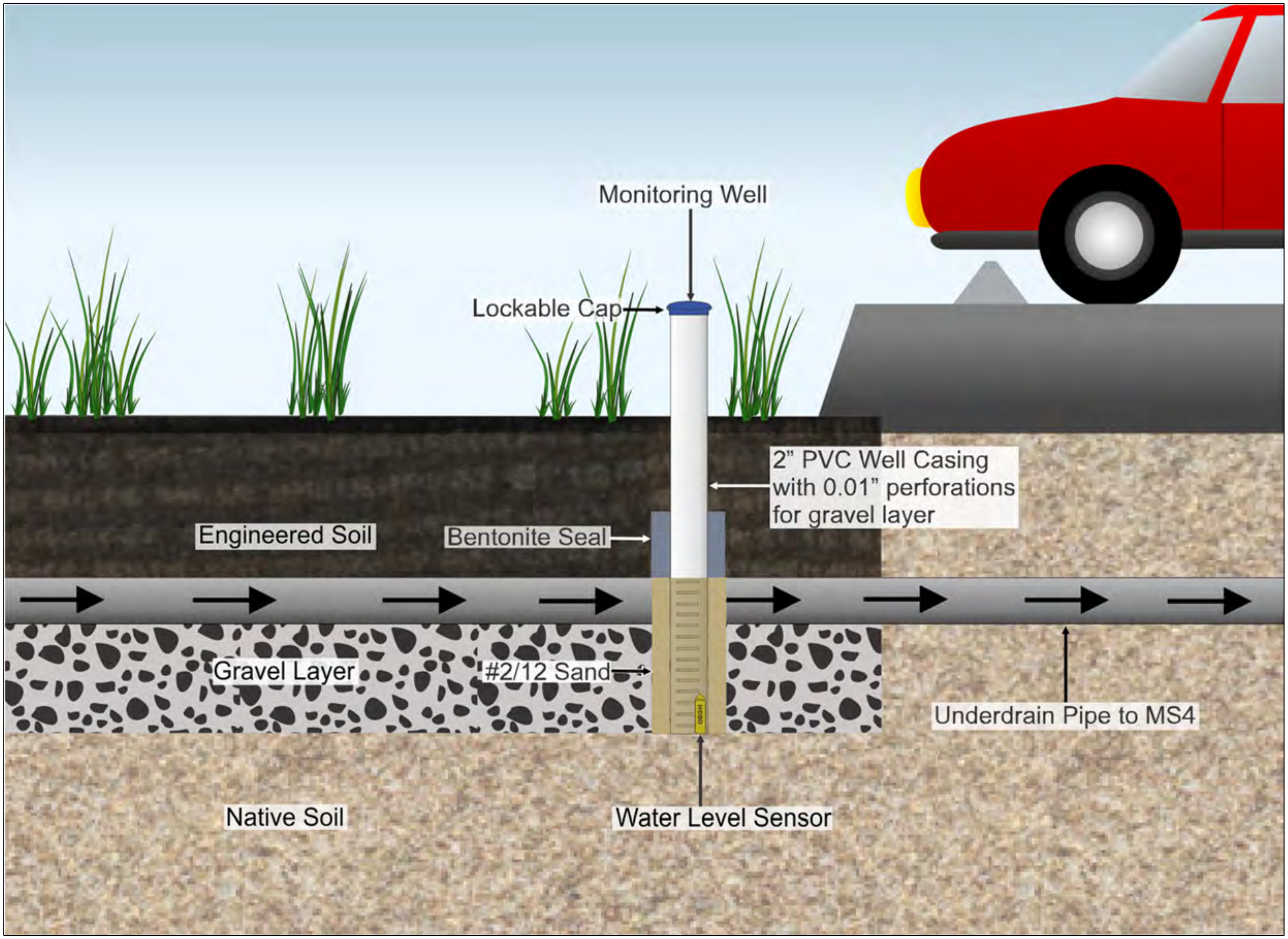


Figure 2. Typical Configuration of Bioretention/Infiltration BMP and Monitoring Well Placement



8. QUALITY ASSURANCE / QUALITY CONTROL ANALYSIS

ADH performed verification and validation of all laboratory data per the project draft QAPP and consistent with SWAMP 2013 measurement quality objectives (MQOs).

Of the nine sediment samples collected overall, one was a blind field duplicate sample (LBV-150-P1). The relative percent difference (RPD) for the sum of PCB congeners of this duplicate sample and the related field sample was 3 percent; the RPD for mercury was 8 percent; and the RPDs for total organic carbon and total solids were both 0.1 percent. All these RPDs are well within the acceptable maximum of 25 percent.

Of the 20 stormwater samples collected overall, one was a blind field duplicate sample (LMC-201703241330-03 FILTERED). Nine analytes (various nutrients, plus copper, total and dissolved) were analyzed from each sample. Of these, eight had RPDs relative to their related field sample results that were less than 10 percent, well below the 25 percent limit. The RPD for dissolved ammonia (as N) was 40 percent. However, in keeping with the MQOs for conventional analytes in water specified in the project QAPP, Table 26-5, the 25 percent limit was not applicable in this case because both the duplicate and field sample results were less than their reporting limits.

All samples for all analyses met quality control objectives, except for instances shown in Table 11 below. Given that all the quality control issues described in Table 11 show the issues were of relatively minor consequence, the data from these samples are of acceptable quality and have been included in the data set for this annual report.

Table 11. Quality Control Issues and Analysis in the WY 2017 Project Data Set

Sample ID & Type	Issue	Analysis
Batch MS Sample in service request K1610489 (Sediment)	The matrix spike recovery of mercury for the batch QC sample was outside control criteria.	Recovery in the batch Laboratory Control Sample (LCS) was acceptable, which indicated the analytical batch was in control. The matrix spike outlier suggested a potential low bias in this matrix. No further corrective action was appropriate.
CCC-PAC-100-PI (Sediment)	The RPDs of matrix spike duplicate samples of mercury and several PCB congeners were above 25 percent.	The variability in the results was attributed to the heterogeneous character of the sample. Standard mixing techniques were used but were not sufficient for complete homogenization of this sample. The results were flagged to indicate this.
CCC-PAC-100-PI (Sediment)	The recovery of a few PCB congeners in a matrix spike sample was outside the project control limits because of the heterogeneous character of the sample.	The RPDs for the related matrix spike duplicate results supports this. Since the unspiked samples contained high analyte concentrations relative to the amount spiked, the variability between the matrix spike samples was sufficient to bias the percent recoveries about the project MQO. Recovery in the laboratory control sample was acceptable, which indicated the analytical batch was in control. No further corrective action was appropriate other than flagging the affected results.
CCC-PAC-100-PI (Sediment)	The matrix spike recoveries of the congeners PCB 132 and PCB 194 were outside of project control limits.	The control criteria for the matrix spike recovery of these analytes was not applicable. The chromatogram indicated non-target matrix background components contributed to the reported matrix spike concentrations. Thus, the reported recoveries contained a high bias. Based on the magnitude of background contribution, the interference appeared to be minimal. These results were flagged to indicate matrix interference.
Laboratory Control Sample KWG1707623-5	The recovery of PCB congeners 18 and 49 were outside the project control limits.	Based on the method and historic data, the recoveries observed were in the range expected for this procedure. No further corrective action was taken other than flagging the results.
Samples in service request K1700258 (Stormwater)	The ion abundance ratios did not meet the acceptance criteria for some PCB congeners in some samples.	Reported value is an estimated maximum.

9. REFERENCES

ADH and AMS. 2016a. Contra Cost County Clean Water Program, Sampling and Analysis Plan DRAFT, Pollutants of Concern Monitoring; Pesticides and Toxicity Monitoring. ADH Environmental and Applied Marine Sciences. January 21, 2016.

ADH and AMS. 2016b. Contra Costa County Clean Water Program, Quality Assurance Project Plan DRAFT, Pollutants of Concern Monitoring; Pesticides and Toxicity Monitoring. ADH Environmental and Applied Marine Sciences. January 26, 2016.

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CCCWP. 2017. Pollutants of Concern Report: Accomplishments in Water Year 2017 and Allocation of Effort for Water Year 2018. Contra Costa Clean Water Program. October 2017.

Appendix 5

Pollutants of Concern

Reconnaissance Monitoring

Water Years 2015, 2016 and 2017

Draft Progress Report

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RMP
REGIONAL MONITORING PROGRAM FOR WATER QUALITY IN SAN FRANCISCO BAY

sfei.org/rmp

Pollutants of Concern Reconnaissance Monitoring Water Years 2015, 2016, and 2017

Draft Progress Report

Prepared by

Alicia Gilbreath, Jing Wu, Jennifer Hunt and Lester McKee

SFEI

CONTRIBUTION NO. 840 / JANUARY 2018

Preface

Reconnaissance monitoring for water years 2015, 2016, and 2017 was completed with funding provided by the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). This report is designed to be updated each year until completion of the study. At least one additional water year (2018) is planned for this study. This initial full draft report was prepared for BASMAA in support of materials submitted on or before March 31st 2018 in compliance with the Municipal Regional Stormwater Permit (MRP) Order No. R2-2015-0049. Changes are likely after further RMP review and prior to the final report being made available on the RMP website in early summer 2018.

Acknowledgements

We appreciate the support and guidance from members of the Sources, Pathways, and Loadings Workgroup of the RMP. The detailed work plan behind this study was developed by the Small Tributaries Loading Strategy (STLS) Team during a series of meetings in the summer of 2014, with slight modifications made during the summers of 2015, 2016, and 2017. Local members on the STLS Team at that time were Arleen Feng (Alameda Countywide Clean Water Program), Bonnie de Berry (San Mateo Countywide Water Pollution Prevention Program), Lucile Paquette (Contra Costa Clean Water Program), Chris Sommers and Lisa Sabin (Santa Clara Valley Urban Runoff Pollution Prevention Program), and Richard Looker and Jan O'Hara (Regional Water Board). San Francisco Estuary Institute (SFEI) field and logistical support over the first year of the project was provided by Patrick Kim, Carolyn Doehring, and Phil Trowbridge, in the second year of the project by Patrick Kim, Amy Richey, and Jennifer Sun, and in the winter of WY 2017 by Ila Shimabuku, Amy Richey, Steven Hagerty, Diana Lin, Margaret Sedlak, Jennifer Sun, Katie McKnight, Emily Clark, Don Yee, and Jennifer Hunt. SFEI's data management team is acknowledged for their diligent delivery of quality-assured well-managed data. This team was comprised of Amy Franz, Adam Wong, Michael Weaver, John Ross, and Don Yee in WYs 2015, 2016, and 2017. Helpful written reviews of this report were provided by members of BASMAA (Bonnie DeBerry, EOA Inc.; Lucile Paquette, Contra Costa Clean Water Program; Jim Scanlin, Alameda Countywide Clean Water Program).

Suggested citation:

Gilbreath, A.N., Wu, J., Hunt, J.A., and McKee, L.J., in preparation. Pollutants of concern reconnaissance monitoring final progress report, water years 2015, 2016, and 2017. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). Contribution No. 840. San Francisco Estuary Institute, Richmond, California.

Executive Summary

The San Francisco Bay polychlorinated biphenyl (PCB) and mercury (Hg) total maximum daily loads (TMDLs) called for implementation of control measures to reduce PCB and Hg loads entering the Bay via stormwater. Subsequently, in 2009, the San Francisco Bay Regional Water Quality Control Board (Regional Water Board) issued the first combined Municipal Regional Stormwater Permit (MRP). This first MRP contained provisions aimed at improving information on stormwater pollutant loads in selected watersheds (Provision C.8.) and piloted a number of management techniques to reduce PCB and Hg loading to the Bay from smaller urbanized tributaries (Provisions C.11. and C.12.). In 2015, the Regional Water Board issued the second iteration of the MRP. "MRP 2.0" placed an increased focus on identifying those watersheds, source areas, and source properties that are potentially most polluted and are therefore most likely to be cost-effective areas for addressing load reduction requirements through implementation of control measures.

To support this increased focus, a stormwater screening monitoring program was developed and implemented in water years (WYs) 2015, 2016, and 2017. Most of the sites monitored were in Alameda, Santa Clara, and San Mateo Counties, with a few sites in Contra Costa County. At the 55 sampling sites, time-weighted composite water samples collected during individual storm events were analyzed for 40 PCB congeners, total Hg (HgT), suspended sediment concentration (SSC), selected trace metals, organic carbon (OC), and grain size. Where possible, sampling efficiency was increased by sampling two sites during a single storm that were near enough to one another that alternating between the two sites was safe and rapid. This same design is being implemented in the winter of WY 2018 by the RMP. The San Mateo Countywide Water Pollution Prevention Program and the Santa Clara Valley Urban Runoff Pollution Prevention Program are also implementing the design with their own funding.

During this study, the RMP began piloting the use of un-manned "remote" suspended sediment samplers (i.e., Hamlin samplers and Walling tube samplers). These remote samplers are designed to enhance settling and capture of suspended sediment from the water column. At nine of the manual sampling sites, a sample was collected in parallel using a Hamlin remote suspended sediment sampler, and at seven sites a sample was collected in parallel using a Walling tube suspended sediment sampler.

Key Findings

Based on this monitoring, a number of sites with elevated PCB and Hg concentrations in stormwater and estimated particle concentrations were identified. Total PCB concentrations measured in the composite water samples collected from the 55 sites ranged 300-fold, from 533 to 160,000 pg/L (excluding one sample where PCBs were below the detection level). The three highest ranking sites for PCB whole water concentrations from WYs 2015-2017 were Industrial Rd Ditch in San Carlos (160,000 pg/L), Line 12H at Coliseum Way in Oakland (156,000 pg/L), and the Outfall at Gilman St. in Berkeley (65,700 pg/L). When normalized by SSC to generate estimated particle concentrations, the three sites with highest estimated particle concentrations were slightly different: Industrial Rd Ditch in San Carlos (6,139 ng/g), Line 12H at Coliseum Way in Oakland (2,601 ng/g), and Gull Dr. SD in South San Francisco (859 ng/g). Estimated particle concentrations of this magnitude are among the highest observed in the Bay Area. Prior to this reconnaissance study, maximum concentrations were measured at Pulgas Pump Station-

South (8,222 ng/g), Santa Fe Channel (1,295 ng/g), Pulgas Pump Station-North (893 ng/g) and Ettie St. Pump Station (759 ng/g).[1]

Total Hg concentrations in composite water samples collected during WYs 2015-2017 ranged over 78-fold, from 5.6 to 439 ng/L. The lower variation in HgT concentrations as compared to PCBs is consistent with conceptual models for these substances (McKee et al., 2015). HgT is expected to be more uniformly distributed than PCBs because it has more widespread sources in the urban environment and a larger influence of atmospheric redistribution in the global mercury cycle. The greatest HgT concentrations were measured at the Outfall at Gilman St. in Berkeley (439 ng/L), Line 12K at the Coliseum Entrance in Oakland (288 ng/L), and Rodeo Creek at Seacliff Ct. Pedestrian Bridge in Rodeo (119 ng/L). For the estimated particle concentrations, the highest ranked site was the same, Outfall at Gilman St. in Berkeley (5.3 µg/g), but the second and third ranked sites were different, Meeker Slough in Richmond (1.3 µg/g), and Line 3A-M at 3A-D in Union City (1.2 µg/g). Estimated particle concentrations of this magnitude are similar to the upper range of those observed previously (mainly in WY 2011).

The sites with the highest particle concentrations for PCBs were typically not the sites with the highest concentrations for HgT. The ten highest ranking sites for PCBs based on estimated particle concentrations only ranked 18th, 12th, 15th, 1st, 48th, 26th, 6th, 10th, 37th, and 52nd, respectively, in relation to estimated HgT particle concentrations.

Remote Suspended Sediment Samplers

Results from the two remote suspended sediment sampler types used (Walling tube sampler and Hamlin sampler) generally characterized sites similarly to the composite stormwater sampling methods. Sites with higher concentrations with the remote samplers lined up with sites with higher concentrations in the composite samples and vice versa. The match appears to be better for PCBs (R^2 = 0.69) than for HgT (R^2 = -0.22), and the results suggest that the Walling tube sampler (R^2 = 0.84 for PCBs) performs better than the Hamlin (R^2 = 0.64 for PCBs). These results indicate that one option to consider is using Walling tube samplers to do preliminary screening of sites before doing a more thorough sampling of the water column during multiple storms at selected higher priority sites. However, further testing is needed to determine the overall reliability and practicality of deploying these remote instruments instead of, or to augment, manual composite stormwater sampling.

Further Data Interpretations

Relationships between the PCB and HgT estimated particle concentrations, watershed characteristics, and other water quality measurements were evaluated using Spearman Rank correlation analysis. Based on data collected by SFEI since WY 2003, PCB particle concentrations positively correlate with

[1]Note, these estimated particle concentrations do not all match those reported in McKee et al. (2012) because of the slightly different method of computing the central tendency of the data (see the Methods section of this report above) and, in the case of Pulgas Pump Station – South, because of the extensive additional sampling that has occurred since McKee et al. (2012) reported the reconnaissance results from the WY 2011 field season.

impervious cover (r_s = 0.56), old industrial land use (r_s = 0.58), and HgT particle concentrations (r_s = 0.43). PCB particle concentrations inversely correlate with watershed area and trace metal particle concentrations (other than Hg, i.e., As, Cu, Cd, Pb, and Zn). HgT particle concentrations do not correlate with any of the other trace metals and showed similar but weaker relationships to impervious cover, old industrial land use, and watershed area than did PCBs. In contrast, the trace metals other than HgT (i.e., As, Cd, Cu, Pb, and Zn) all correlate with one another more generally. Overall, the data collected to date do not support the use of any of the trace metals analyzed as a tracer for either PCB or HgT pollution sources.

Old industrial land use is believed to yield the greatest mass of PCB loads in the region. The watersheds for the 79 sites that have been sampled by SFEI since WY 2003 cover about 34% of the old industrial land use in the region. The largest proportion of old industrial area sampled so far in each county has occurred in Santa Clara (96% of old industrial area in this county is in the watershed of a sampling site), followed by San Mateo (51%), Alameda (41%), and Contra Costa (11%). The higher coverage in Santa Clara County is due to sampling of a number of large watersheds and the prevalence of older industrial areas upstream in the Coyote Creek and Guadalupe River watersheds. Of the remaining areas in the region with older industrial land use yet to be sampled in the region (~100 km^2), 46% of it lies within 1 km of the Bay and 67% of it is within 2 km of the Bay. These areas are more likely to be tidal, include heavy industrial areas that were historically serviced by rail and ship based transport, and are often very difficult to sample due to a lack of public rights of way. A different sampling strategy may be needed to effectively determine what pollution levels might be associated with these areas. In the short term, this study will continue into WY 2018 and possibly beyond in the attempt to continue to identify areas for follow up investigation and possible management action. The focus will continue to be on finding new areas of concern, although follow up sampling may occur at some sites in order to verify initial sampling results, and there will also be effort towards continuing the remote sampler pilot study.

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Introduction

The San Francisco Bay polychlorinated biphenyl (PCB) and mercury total maximum daily loads (TMDLs) (SFBRWQCB, 2006; 2007) called for implementation of control measures to reduce stormwater polychlorinated biphenyl (PCB) loads from an estimated annual baseline load of 20 kg to 2 kg by 2030 and total mercury (HgT) loads from about 160 kg to 80 kg by 2028. Shortly after adoption of the TMDLs, in 2009, the San Francisco Bay Regional Water Quality Control Board (Regional Water Board) issued the first combined Municipal Regional Stormwater Permit (MRP) for MS4 phase I stormwater agencies (SFBRWQCB, 2009; 2011). In support of the TMDLs, MRP 1.0, as it came to be known, contained a provision for improved information on stormwater loads for pollutants of concern (POCs) in selected watersheds (Provision C.8.) as well as specific provisions for Hg, methylmercury and PCBs (Provisions C.11 and C.12) that called for reducing Hg and PCB loads from smaller urbanized tributaries. To help address these permit requirements, a Small Tributaries Loading Strategy (STLS) was developed that outlined four key management questions (MQs) as well as a general plan to address these questions (SFEI, 2009).

MQ1. Which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from POCs?

MQ2. What are the annual loads or concentrations of POCs from tributaries to the Bay?

MQ3. What are the decadal-scale loading or concentration trends of POCs from small tributaries to the Bay?

MQ4. What are the projected impacts of management actions (including control measures) on tributaries and where should these management actions be implemented to have the greatest beneficial impact?

During the first MRP term (2009-15), the majority of STLS effort was focused on refining pollutant loading estimates and finding and prioritizing potential “high leverage” watersheds and subwatersheds which contribute disproportionately high concentrations or loads to sensitive Bay margins, through the funding from both RMP and Bay Area Stormwater Management Agencies Association (BASMAA)[2]. As a result of these efforts, sufficient pollutant data were collected at 11 urban sites, making it possible to estimate pollutant loads from these sites with varying degrees of certainty (McKee et al. 2015, Gilbreath et al. 2015a). During the first MRP term, a Regional Watershed Spreadsheet Model (RWSM) was also developed as a regional-scale planning tool primarily to estimate long-term pollutant loads from the small tributaries, and secondarily to provide supporting information for prioritizing watersheds or sub-watershed areas for management (Wu et al., 2016; Wu et al., 2017).

In November 2015, the Regional Water Board issued the second iteration of the MRP (SFBRWQCB, 2015). MRP “2.0” places an increased focus on finding high leverage watersheds, source areas, and

[2] BASMAA is made up of a number of programs which represent Permittees and other local agencies

source properties that are more polluted, and that are located upstream of sensitive Bay margin areas. Specifically, the permit adds a new stipulation that calls for the identification of sources or watershed source areas that provide the greatest opportunities for reductions of PCBs and Hg in urban stormwater runoff. To help support this focus and also refine information to address Management Questions, the Sources, Pathways and Loadings Work Group (SPLWG) and the Small Tributaries Loading Strategy (STLS) Team developed and implemented a stormwater reconnaissance screening monitoring program in WYs 2015, 2016, and 2017 to provide data, as part of multiple lines of evidence, for the identification of potential high leverage areas. The monitoring program was adapted from the one first implemented in WY 2011 (McKee et al., 2012) and benefited from lessons learned from that effort. This same design was also implemented in WYs 2016 and 2017 by the San Mateo Countywide Water Pollution Prevention Program and the Santa Clara Valley Urban Runoff Pollution Prevention Program (EOA, 2017a and 2017b).

This report summarizes and provides a preliminary interpretation of data collected during WYs 2015, 2016, and 2017. The data collected and presented here are contributing to a broad effort of identifying potential management areas for pollutant reduction. During Calendar Year (CY) 2018, the RMP is funding a data analysis project that aims to mine and analyze all the existing stormwater data. The primary goals of that analysis are to develop an improved method for identifying and ranking watersheds of management interest for further screening or investigation, and to guide future sampling design. In addition, the STLS team is evaluating sampling programs for monitoring stormwater loading trends in response to management efforts (Melwani et al., 2017 in preparation). Reconnaissance data collected in WYs 2011, 2015, 2016, and 2017 may provide baseline data for identifying concentration or particle concentration trends over time.

The report is designed to be updated annually and will be updated again in approximately 12 months to include the WY 2018 sampling data that is currently being collected.

Sampling Methods

Sampling locations

Four objectives were used as bases for site selection.

1. Identifying potential high leverage watersheds and subwatersheds
    a. Watersheds with suspected high pollution
    b. Sites with ongoing or planned management actions
    c. Source identification within a larger watershed of known concern (nested sampling design)
2. Sampling strategic large watersheds with USGS gauges to provide first-order loading estimates and to support calibration of the Regional Watershed Spreadsheet Model (RWSM)
3. Validating unexpected low (potential false negative) concentrations (to address the possibility of a single storm composite poorly characterizing a sampling location)
4. Filling gaps along environmental gradients or source areas (to support the RWSM)

The majority of samples each year (60-70% of the effort) were dedicated to identifying potential high leverage watersheds and subwatersheds. The remaining resources were allocated to address the other three objectives. SFEI worked with the respective Countywide Clean Water Programs to identify priority drainages for monitoring including storm drains, ditches/culverts, tidally influenced areas, and natural areas. During the summers of 2014, 2015, and 2016, a large number of sites were visited, and each of them was surveyed for safety, logistical constraints, and feasible drainage-line entry points. From this larger set, a final set of about 25 sites was selected each year to form the pool from which field staff would select sampling locations for each storm depending on logistics.

Watershed sites with a wide variety of characteristics were sampled in WYs 2015, 2016, and 2017 (Figure 1 and Table 1). Of these sites, 17 were in Santa Clara County, 17 in San Mateo County, 15 in Alameda County, five in Contra Costa County[3] and one site in Solano County. The drainage area for each sampling location ranged from 0.09 km^2 to 233 km^2 and typically was characterized by a high degree of imperviousness (2%-88%: mean = 64%; dataset used is the National Land Cover Database). The percentage of the watersheds designated as old industrial[4] ranged from 0% to 87% (mean 24%) (dataset used included the land use dataset input to the Regional Watershed Spreadsheet Model (in prep; estimated 2018 release to public)). While the majority of sampling sites were selected to primarily identify potential high leverage watersheds and subwatersheds, Lower Penitencia Creek was resampled to verify whether the first sample collected there (WY 2011) was a false negative (unexpectedly low concentration). Guadalupe River at Hwy 101 was also resampled in WY 2017 during a large and rare storm to assess trends for mercury (McKee et al., in prep). A matrix of site characteristics for sampling strategic larger watersheds was also developed (Table 2), but none of them were sampled in WYs 2015 or 2016 because the sampling trigger criteria for rainfall and flow were not met and only one (Colma Creek) was sampled in WY 2017. Trigger criteria were met in January and February 2017 for other strategic larger watersheds under consideration (Alameda Creek, Dry Creek at Arizona Street, San Francisquito Creek at University Avenue, Matadero Creek at Waverly Street, and Colma Creek at West Orange Avenue), but none were sampled because staff and budgetary resources were allocated elsewhere.

[3] Given the long history of industrial zoning along much of the Contra Costa County waterfront relative to other counties, still more sampling is needed to characterize these areas.

[4] Note the definition of "old Industrial" land use used here is based on definitions developed by the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) building on GIS development work completed during the development of the RWSM (Wu et al., 2016; 2017).

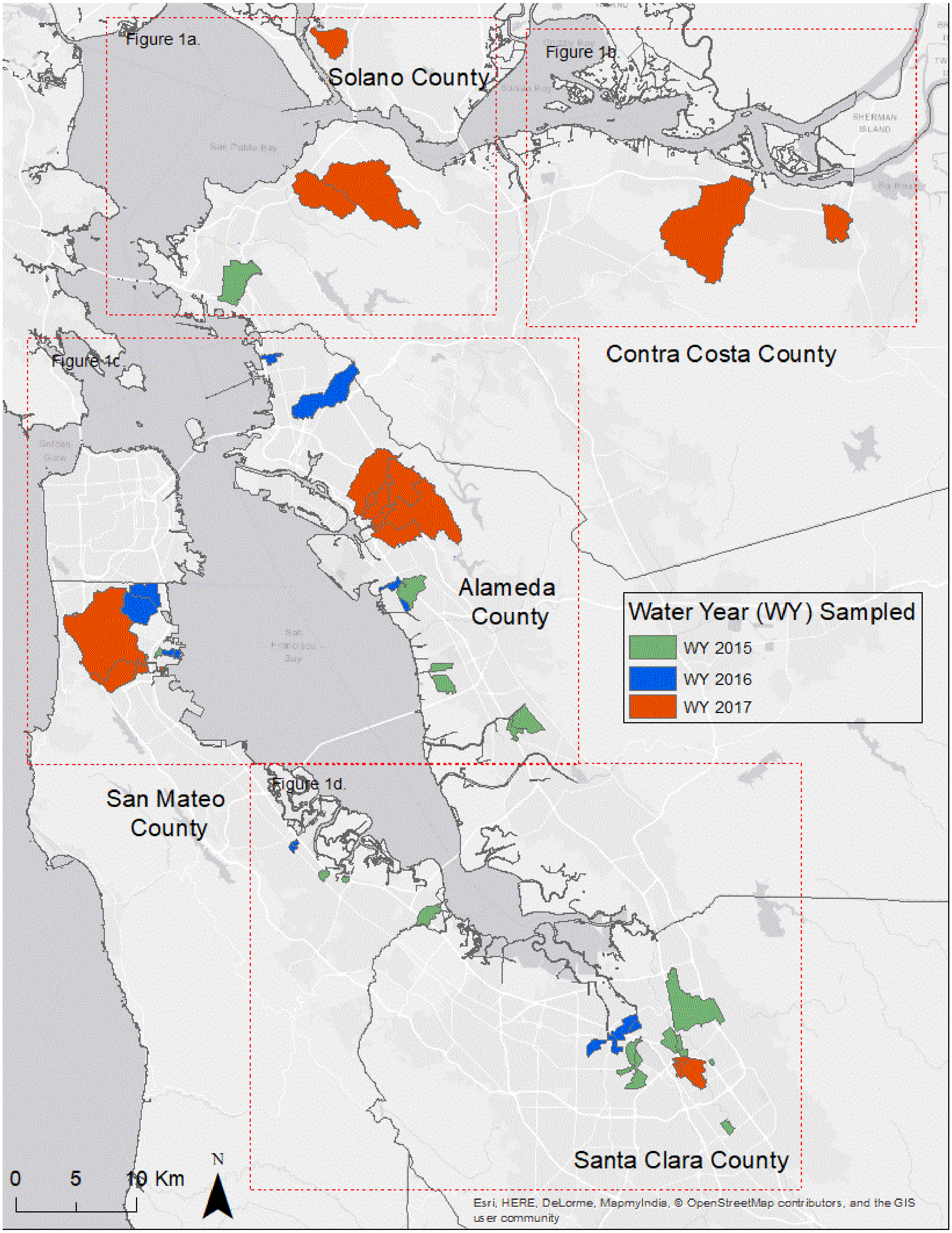

Figure 1. Watersheds sampled in water years 2015, 2016, and 2017.

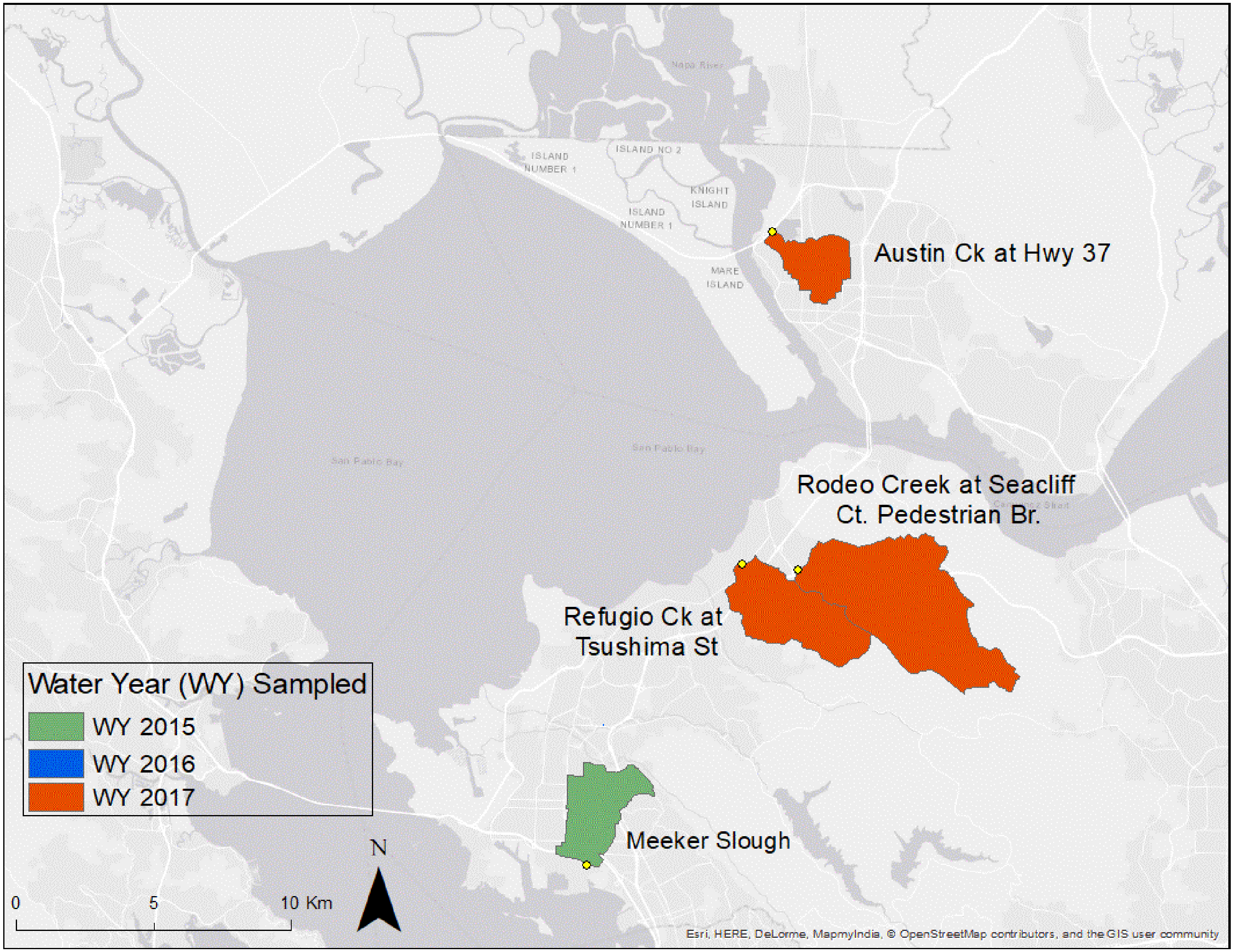

Figure 1a. Sampling locations (marked by yellow dots) and watershed boundaries in western Contra Costa County and Solano County.

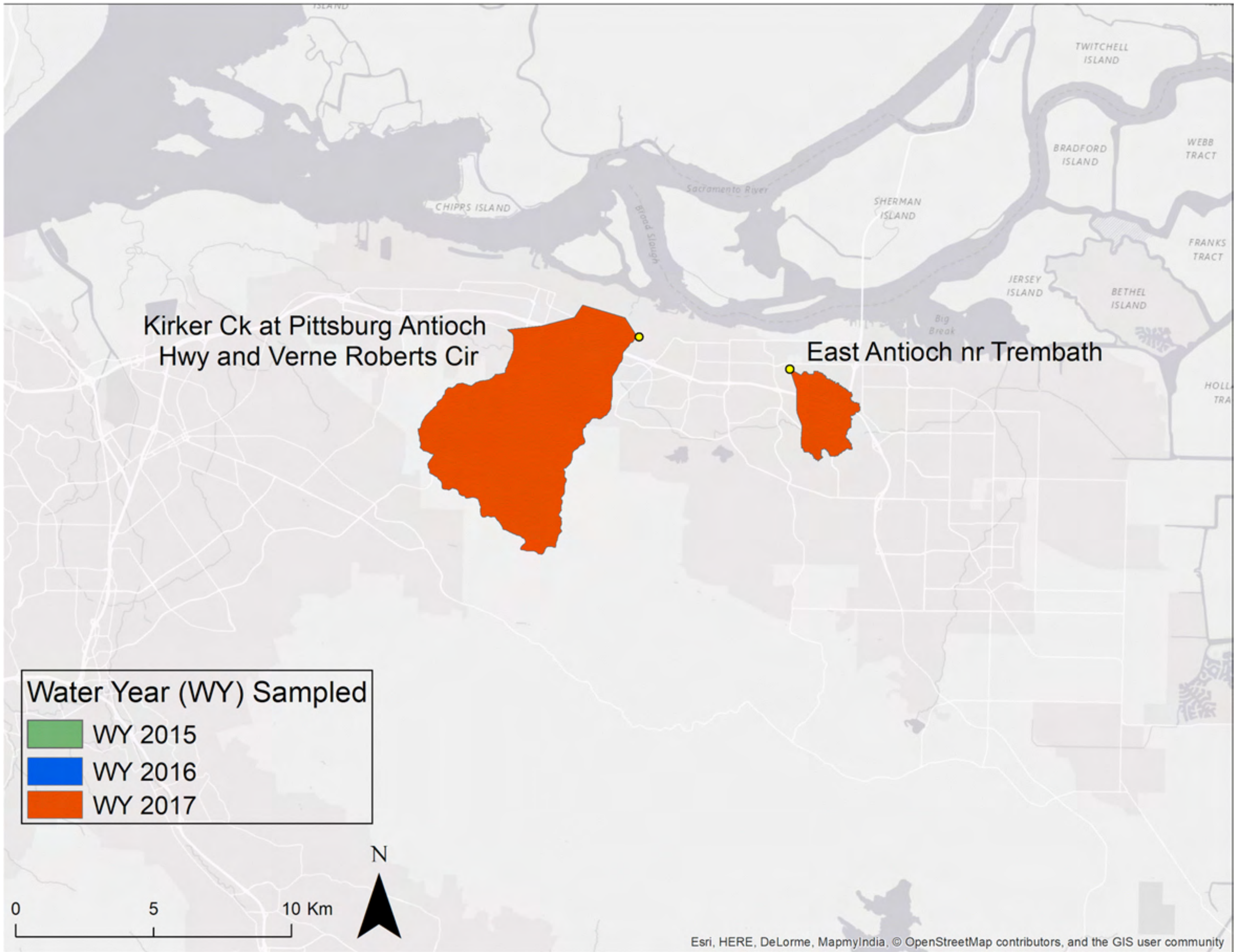

Figure 1b. Sampling locations (marked by yellow dots) and watershed boundaries in eastern Contra Costa County.

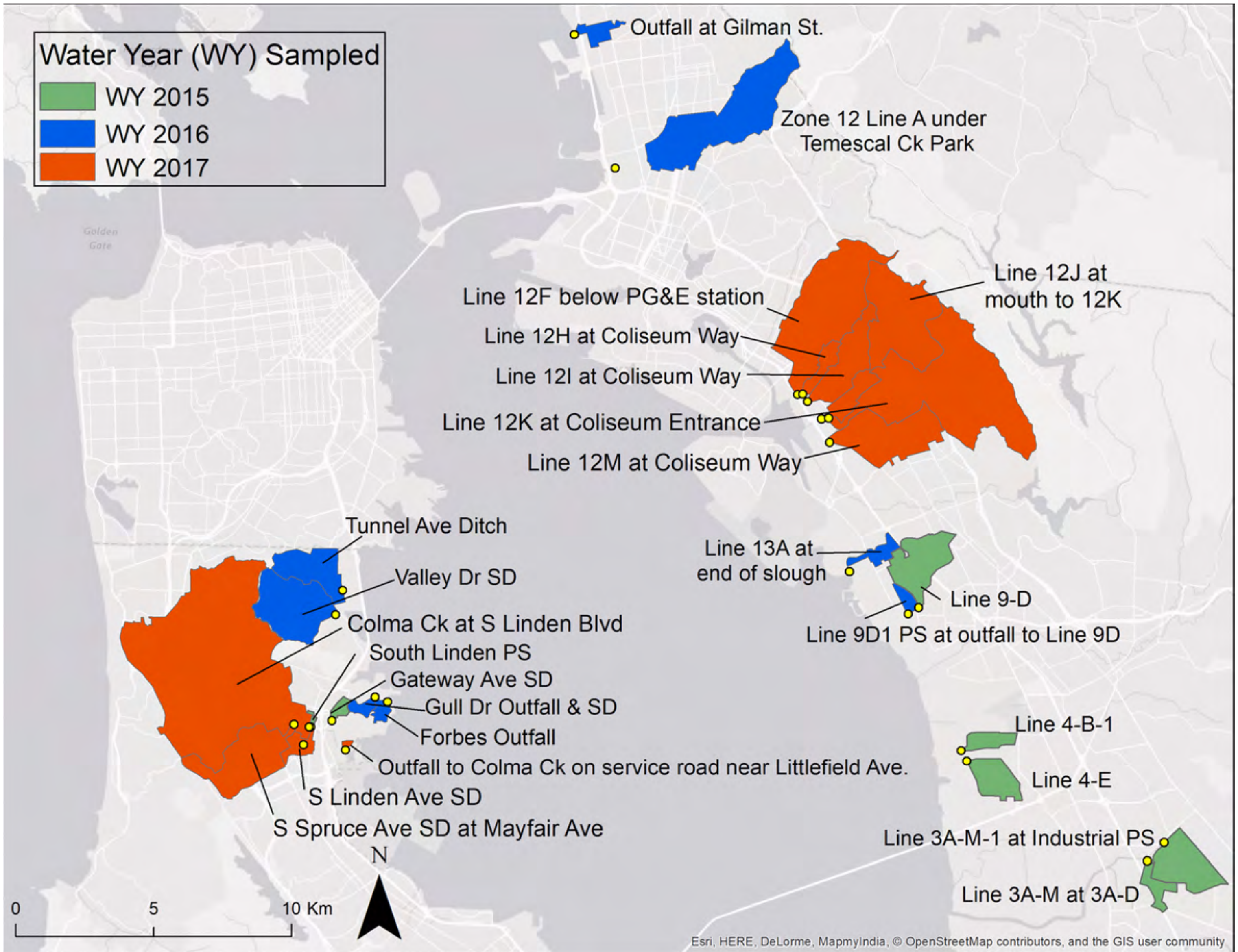

Figure 1c. Sampling locations (marked by yellow dots) and watershed boundaries in Alameda County and northern San Mateo County.

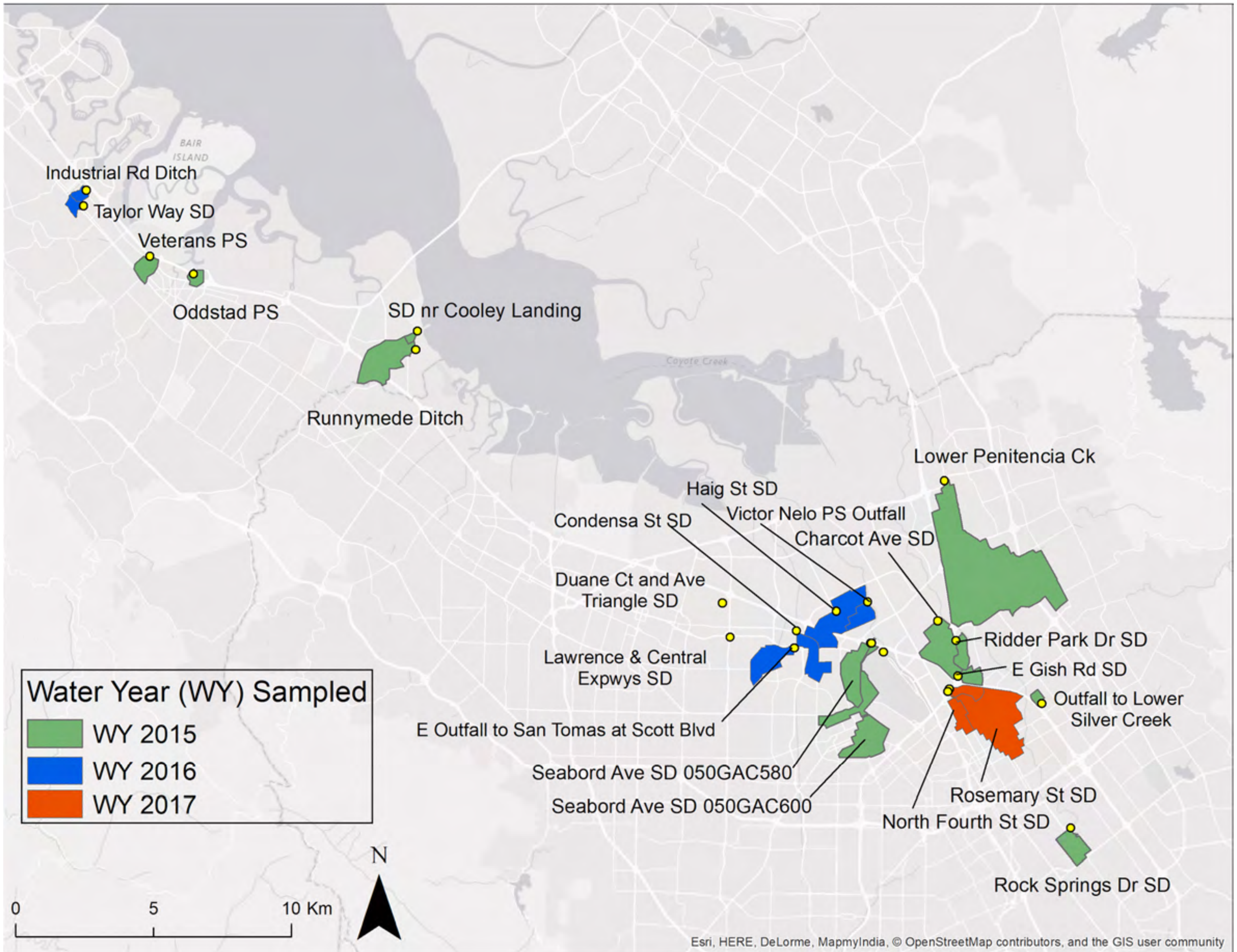

Figure 1d. Sampling locations (marked by yellow dots) and watershed boundaries in northern San Mateo County and Santa Clara County.

Table 1. Key characteristics of water years 2015, 2016, and 2017 sampling locations.

County	City	Watershed Name	Catchment Code	MS4 or Receiving Water	Latitude	Longitude	Sample Date	Area (sq km)	Impervious Cover (%)	Old Industrial (%)
Alameda	Union City	Line 3A-M-1 at Industrial PS	AC-Line 3A-M-1	MS4	37.61893	-122.05949	12/11/14	3.44	78%	26%
Alameda	Union City	Line 3A-M at 3A-D	AC-Line 3A-M	MS4	37.61285	-122.06629	12/11/14	0.88	73%	12%
Alameda	Hayward	Line 4-B-1	AC-Line 4-B-1	MS4	37.64752	-122.14362	12/16/14	0.96	85%	28%
Alameda	Hayward	Line 4-E	AC-Line 4-E	MS4	37.64415	-122.14127	12/16/14	2.00	81%	27%
Alameda	San Leandro	Line 9-D	AC-Line 9-D	MS4	37.69383	-122.16248	4/7/15	3.59	78%	46%
Alameda	Berkeley	Outfall at Gilman St.	AC-2016-1	MS4	37.87761	-122.30984	12/21/15	0.84	76%	32%
Alameda	San Leandro	Line 9-D-1 PS at outfall to Line 9-D	AC-2016-15	MS4	37.69168	-122.16679	1/5/16	0.48	88%	62%
Alameda	Emeryville	Zone 12 Line A under Temescal Ck Park	AC-2016-3	MS4	37.83450	-122.29159	1/6/16	17.47	30%	4%
Alameda	San Leandro	Line 13-A at end of slough	AC-2016-14	MS4	37.70497	-122.19137	3/10/16	0.83	84%	68%
Alameda	Oakland	Line 12F below PG&E station	Line12F	MS4	37.76218	-122.21431	12/15/16	10.18	56%	3%
Alameda	Oakland	Line 12H at Coliseum Way	Line12H	MS4	37.76238	-122.21217	12/15/16	0.97	71%	10%
Alameda	Oakland	Line 12I at Coliseum Way	Line12I	MS4	37.75998	-122.21020	12/15/16	3.41	63%	9%
Alameda	Oakland	Line 12J at mouth to 12K	Line12J	MS4	37.75474	-122.20136	12/15/16	8.81	30%	2%
Alameda	Oakland	Line 12K at Coliseum Entrance	Line12KEntrance	MS4	37.75446	-122.20431	2/9/17	16.40	31%	1%
Alameda	Oakland	Line 12M at Coliseum Way	Line12MColWay	MS4	37.74689	-122.20069	2/9/17	5.30	69%	22%
Contra Costa	Richmond	Meeker Slough	Meeker Slough	Receiving Water	37.91786	-122.33838	12/3/14	7.34	64%	6%
Contra Costa	Pittsburg	Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir	KirkerCk	Receiving Water	38.01275	-121.84345	1/8/17	36.67	18%	5%
Contra Costa	Antioch	East Antioch nr Trembath	EAntioch	Receiving Water	38.00333	-121.78106	1/8/17	5.26	26%	3%
Contra Costa	Hercules	Refugio Ck at Tsushima St	RefugioCk	Receiving Water	38.01775	-122.27710	1/18/17	10.73	23%	0%
Contra Costa	Rodeo	Rodeo Creek at Seacliff Ct. Pedestrian Br.	RodeoCk	Receiving Water	38.01604	-122.25381	1/18/17	23.41	2%	3%
San Mateo	Redwood City	Oddstad PS	SM-267	MS4	37.49172	-122.21886	12/2/14	0.28	74%	11%
San Mateo	Redwood City	Veterans PS	SM-337	MS4	37.49723	-122.23693	12/15/14	0.52	67%	7%
San Mateo	South San Francisco	Gateway Ave SD	SM-293	MS4	37.65244	-122.40257	2/6/15	0.36	69%	52%
San Mateo	South San Francisco	South Linden PS	SM-306	MS4	37.65018	-122.41127	2/6/15	0.14	83%	22%

San Mateo	East Palo Alto	Runnymede Ditch	SM-70	MS4	37.46883	-122.12701	2/6/15	2.05	53%	2%
San Mateo	East Palo Alto	SD near Cooley Landing	SM-72	MS4	37.47492	-122.12640	2/6/15	0.11	73%	39%
San Mateo	South San Francisco	Forbes Blvd Outfall	SM-319	MS4	37.65889	-122.37996	3/5/16	0.40	79%	0%
San Mateo	South San Francisco	Gull Dr Outfall	SM-315	MS4	37.66033	-122.38502	3/5/16	0.43	75%	42%
San Mateo	South San Francisco	Gull Dr SD	SM-314	MS4	37.66033	-122.38510	3/5/16	0.30	78%	54%
San Mateo	Brisbane	Tunnel Ave Ditch	SM-350/368/more	Receiving Water	37.69490	-122.39946	3/5/16	3.02	47%	8%
San Mateo	Brisbane	Valley Dr SD	SM-17	MS4	37.68694	-122.40215	3/5/16	5.22	21%	7%
San Mateo	San Carlos	Industrial Rd Ditch	SM-75	MS4	37.51831	-122.26371	3/11/16	0.23	85%	79%
San Mateo	San Carlos	Taylor Way SD	SM-32	MS4	37.51320	-122.26466	3/11/16	0.27	67%	11%
San Mateo	South San Francisco	S Linden Ave SD (291)	SLinden	MS4	37.64420	-122.41390	1/8/17	0.78	88%	57%
San Mateo	South San Francisco	S Spruce Ave SD at Mayfair Ave (296)	SSpruce	MS4	37.65084	-122.41811	1/8/17	5.15	39%	1%
San Mateo	South San Francisco	Colma Ck at S. Linden Blvd	ColmaCk	MS4	37.65017	-122.41189	2/7/17	35.07	41%	3%
San Mateo	South San Francisco	Outfall to Colma Ck on service rd nr Littlefield Ave. (359)	ColmaCkOut	MS4	37.64290	-122.39677	2/7/17	0.09	88%	87%
Santa Clara	Milpitas	Lower Penitencia Ck	Lower Penitencia	Receiving Water	37.42985	-121.90913	12/11/14	11.50	65%	2%
Santa Clara	Santa Clara	Seabord Ave SD SC-050GAC580	SC-050GAC580	MS4	37.37637	-121.93793	12/11/14	1.35	81%	68%
Santa Clara	Santa Clara	Seabord Ave SD SC-050GAC600	SC-050GAC600	MS4	37.37636	-121.93767	12/11/14	2.80	62%	18%
Santa Clara	San Jose	E. Gish Rd SD	SC-066GAC550	MS4	37.36632	-121.90203	12/11/14	0.44	84%	71%
Santa Clara	San Jose	Ridder Park Dr SD	SC-051CTC400	MS4	37.37784	-121.90302	12/15/14	0.50	72%	57%
Santa Clara	San Jose	Outfall to Lower Silver Ck	SC-067SCL080	MS4	37.35789	-121.86741	2/6/15	0.17	79%	78%
Santa Clara	San Jose	Rock Springs Dr SD	SC-084CTC625	MS4	37.31751	-121.85459	2/6/15	0.83	80%	10%
Santa Clara	San Jose	Charcot Ave SD	SC-051CTC275	MS4	37.38413	-121.91076	4/7/15	1.79	79%	25%
Santa Clara	Santa Clara	Lawrence & Central Expwys SD	SC-049CZC800	MS4	37.37742	-121.99566	1/6/16	1.20	66%	1%
Santa Clara	Santa Clara	Condensa St SD	SC-049STA710	MS4	37.37426	-121.96918	1/19/16	0.24	70%	32%
Santa Clara	San Jose	Victor Nelo PS Outfall	SC-050GAC190	MS4	37.38991	-121.93952	1/19/16	0.58	87%	4%
Santa Clara	Santa Clara	E Outfall to San Tomas at Scott Blvd	SC-049STA550	MS4	37.37991	-121.96842	3/6/16	0.67	66%	31%
Santa Clara	San Jose	Haig St SD	SC-050GAC030	MS4	37.38664	-121.95223	3/6/16	2.12	72%	10%

Santa Clara	San Jose	North Fourth St SD 066GAC550B	NFourth	MS4	37.36196	-121.90535	1/8/17	1.01	68%	27%
Santa Clara	San Jose	Rosemary St SD 066GAC550C	Rosemary	MS4	37.36118	-121.90594	1/8/17	3.67	64%	11%
Santa Clara	San Jose	Guadalupe River at Hwy 101	Guad 101	Receiving Water	37.37355	-121.93269	1/8/17	233.00	39%	3%
Santa Clara	Santa Clara	Duane Ct and Ave Triangle SD	SC-049CZC200	MS4	37.38852	-121.99901	12/13/15 and 1/6/2016	1.00	79%	23%
Solano	Vallejo	Austin Ck at Hwy 37	AustinCk	Receiving Water	38.12670	-122.26791	3/24/17	4.88	61%	2%

Table 2. Characteristics of larger watersheds to be monitored, proposed sampling location, and proposed sampling trigger criteria. None of these watersheds were sampled during water years 2015 or 2016 because sampling trigger criteria for flow and rainfall were not met, and in WY 2017 large watershed sampling was focused on the Guadalupe River rather than the watersheds in this list.

Proposed sampling location							Relevant USGS gauge fo 1st order loads computations	
Watershed system	**Watershed Area (km^2)**	**Impervious Surface (%)**	**Industrial (%)**	**Sampling Objective**	**Commentary**	**Proposed Sampling Triggers**	**Gauge number**	**Area at USGS Gauge (sq^2)**
Alameda Creek at EBRPD Bridge at Quarry Lakes	913	8.5	2.3	2, 4	Operating flow and sediment gauge at Niles just upstream will allow the computation of 1st order loads to support the calibration of the RWSM for a large, urbanizing type watershed.	7” of antecedent rainfall in Livermore (reliable web published rain gauge), after at least an annual storm has already occurred (~2000 cfs at the Niles gauge), and a forecast for the East Bay interior valleys of 2-3” over 12 hrs.	11179000	906
Dry Creek at Arizona Street (purposely downstream from historic industrial influences)	25.3	3.5	0.3	2, 4	Operating flow gauge at Union City just upstream will allow the computation of 1st order loads to support the calibration of the RWSM for mostly undeveloped land use type watersheds.	7” of antecedent rainfall in Union City, after at least a common annual storm has already occurred (~200 cfs at the Union City gauge), and a forecast for the East Bay Hills of 2-3” over 12 hrs.	11180500	24.3
San Francisquito Creek at University Avenue (as far down as possible to capture urban influence upstream from tide)	81.8	11.9	0.5	2, 4	Operating flow gauge at Stanford upstream will allow the computation of 1st order loads to support the calibration of the RWSM for larger mixed land use type watersheds. Sample pair with Matadero Ck.	7” of antecedent rainfall in Palo Alto, after at least a common annual storm has already occurred (~1000 cfs at the Stanford gauge), and a forecast for the Peninsula Hills of 3-4” over 12 hrs.	11164500	61.1
Matadero Creek at Waverly Street (purposely downstream from the railroad)	25.3	22.4	3.7	2, 4	Operating flow gauge at Palo Alto upstream will allow the computation of 1st order loads to support the calibration of the RWSM for mixed land use type watersheds. Sample pair with San Francisquito Ck.	7” of antecedent rainfall in Palo Alto, after at least a common annual storm has already occurred (~200 cfs at the Palo Alto gauge), and a forecast for the Peninsula Hills of 3-4” over 12 hrs.	11166000	18.8
Colma Creek at West Orange Avenue or further downstream (as far down as possible to capture urban and historic influence upstream from tide)	27.5	38	0.8	2, 4 (possibly 1)	Historic flow gauge (ending 1996) in the park a few hundred feet upstream will allow the computation of 1st order loads estimates to support the calibration of the RWSM for mixed land use type watersheds.	Since this is a very urban watershed, precursor conditions are more relaxed: 4” of antecedent rainfall, and a forecast for South San Francisco of 2-3” over 12 hrs. Measurement of discharge and manual staff plate readings during sampling will verify the historic rating.	11162720	27.5

Field methods

Mobilization and preparing to sample

The mobilization for sampling was typically triggered by storm forecast. When a minimum rainfall of at least one-quarter inch[5] over 6 hours was forecasted, sampling teams were deployed, ideally reaching the sampling site about 1 hour before the onset of rainfall[6]. When possible, one team sampled two sites close to one another to increase efficiency and reduce staffing costs. Upon arrival, the team assembled equipment and carried out final safety checks. Sampling equipment used at a site depended on the accessibility of drainage lines. Some sites were sampled by attaching laboratory-prepared trace-metal-clean Teflon sampling tubing to a painter's pole and a peristaltic pump with laboratory-cleaned silicone pump-roller tubing (Figure 2a). During sampling, the tube was dipped into the channel or drainage line at mid-channel mid-depth (if shallow) or depth integrating if the depth was more than 0.5 m. In other cases, a DH 84 (Teflon) sampler was used without a pump.

Manual time-paced composite stormwater sampling procedures

At each site, a time-paced composite sample was collected with a variable number of sub-samples, or aliquots. Based on the weather forecast, prevailing on-site conditions, and radar imagery, field staff estimated the duration of the storm and selected an aliquot size for each analyte (0.1-0.5 L) and number of aliquots (minimum=2; mode=5) to ensure the minimum volume requirements for each analyte (Hg, 0.25L; SSC, 0.3L; PCBs, 1L; Grain Size, 1L; TOC, 0.25L) would be reached before the storm's end. Because the minimum volume requirements were less than the size of sample bottles, there was flexibility to add aliquots in the event when a storm continued longer than predicted. The final volume of the aliquots was determined just before the first aliquot was taken and remained fixed for the sampling event. All aliquots for a storm were collected into the same bottle, which was kept in a cooler on ice and/or refrigerated at 4 °C before transport to a lab (see Yee et al. (2017)) for information about bottles, preservatives and hold times).

Remote suspended sediment sampling procedures

Two remote samplers, the Hamlin (Lubliner, 2012) and the Walling tube (Phillips et al., 2000), were deployed approximately at mid-channel/ storm drain to collect suspended sediment samples. To date, 9 locations have been sampled with the Hamlin and 7 locations with the Walling tube sampler (Table 3). During each deployment, the Hamlin sampler[7] was stabilized on the bed of stormdrain or concrete channel either by its own weight (approximately 25 lbs) or additionally by attaching barbell weight plates to the bottom of the sampler (Figure 2b). The Walling tube could not be deployed in storm drains due to its size and the need for staying horizontal, and therefore was secured in open channels either by barbell weights secured with hose clamps to a concrete bed, or to a natural bed with hose clamps

[5] Note, this was relaxed due to a lack of larger storms. Ideally, mobilization would only proceed with a minimum forecast of at least 0.5".

[6] Antecedent dry-weather was not considered prior to deployment. Antecedent conditions can have impacts on the concentration of certain build-up/wash-off pollutants like metals. For PCBs, however, antecedent dry-weather may be less important than the mobilization of in-situ legacy sources.

[7] In future years, if the Hamlin is deployed within a natural bed channel, elevating the sampler more off the bed may be considered but was not done in WYs 2015 or 2016.

attached to temporarily installed rebar (Figure 2c). To minimize the chances of sampler loss, both samplers were secured by a stainless steel cable to a temporary rebar anchor or another object such as a tree or fencepost.

The remote samplers were deployed for the duration of the manual sampling, and removed from the channel bed/storm drain bottom shortly after the last water quality sample aliquot was collected. Water and sediment collected in the samplers were decanted into one or two large glass bottles. When additional water was needed to flush the settled sediments from the remote samplers into the collecting bottles, site water from the sampled channel was used. The collected samples were split and placed into laboratory containers and then shipped to the laboratory for analysis. Most samples were analyzed as whole water samples (due to insufficient solid mass to analyze as a sediment sample), and only one location was analyzed as a sediment sample. Between sampling sites, the remote samplers were thoroughly cleaned using a brush and Alconox detergent, followed by a DI rinse.

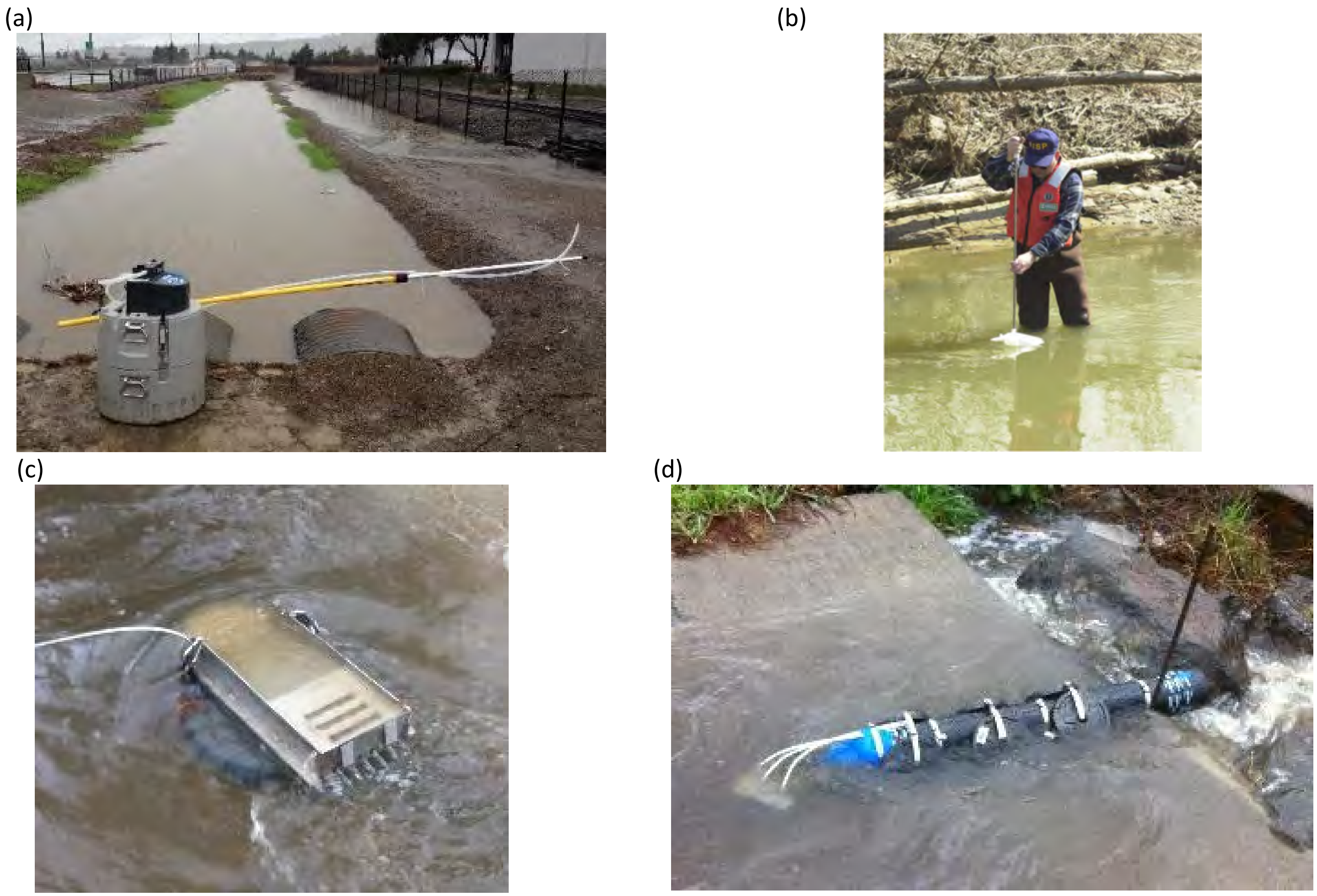

Figure 2. Sampling equipment used in the field. (a) Painter's pole, Teflon tubing and an ISCO used as a slave pump; (b) Teflon bottle attached to the end of a DH81 sampling pole; (c) a Hamlin suspended sediment sampler secured atop a 45 lb plate; and (d) a Walling tube suspended sediment sampler secured by 5 lb weights along the body of the tube (because it is sitting atop a concrete bed) and rebar driven into the natural bed at the back of the sampler.

Table 3. Locations where remote sediment samplers were pilot tested.

Site	Date	Sampler(s) deployed	Comments
Meeker Slough	11/2015	Hamlin and Walling	Sampling effort was unsuccessful due to very high velocities. Both samplers washed downstream because they were not weighted down enough and debris caught on the securing lines.
Outfall to Lower Silver Creek	2/06/15	Hamlin and Walling	Sampling effort was successful. This sample was analyzed as a water sample.
Charcot Ave Storm Drain	4/07/15	Hamlin	Sampling effort was successful. This sample was analyzed as a sediment sample.
Cooley Landing Storm Drain	2/06/15	Hamlin	Sampling effort was successful. This sample was analyzed as a water sample.
Duane Ct and Ave Triangle SD	1/6/2016	Hamlin	Sampling effort was successful. This sample was analyzed as a water sample.
Victor Nelo PS Outfall	1/19/2016	Hamlin and Walling	Sampling effort was successful. This sample was analyzed as a water sample.
Forbes Blvd Outfall	3/5/2016	Hamlin	Sampling effort was successful. This sample was analyzed as a water sample.
Tunnel Ave Ditch	3/5/2016	Hamlin and Walling	Sampling effort was successful. This sample was analyzed as a water sample.
Taylor Way SD	3/11/2016	Hamlin	Sampling effort was successful. This sample was analyzed as a water sample.
Colma Creek Outfall	2/7/2017	Walling	Sampling effort was successful; however, sampler became submerged for several hours during a high tide cycle and was retrieved afterwards. We hypothesize that this may have had the effect of adding cleaner sediment into the sampler and therefore the result may be biased low. This sample was analyzed as a water sample.
Austin Creek	3/24/2017	Hamlin and Walling	Sampling effort was successful. This sample was analyzed as a water sample.
Refugio Creek	1/18/2017	Walling	Sampling effort was successful. This sample was analyzed as a water sample.
Rodeo Creek	1/18/2017	Walling	Sampling effort was successful. This sample was analyzed as a water sample.

Laboratory analytical methods

The target analytes for this study are listed in Table 4. The analytical methods and quality control tests are further described in the RMP Quality Assurance Program Plan (Yee et al., 2017). Laboratory methods were chosen based on a combination of factors of method detection limits, accuracy and precision, and costs (BASMAA, 2011; 2012) (Table 4). For some sites where the remote samplers were deployed, Hg, PCBs and organic carbon (OC) were analyzed for both particulate and dissolved phases to be compared with total water concentrations and particulate-only concentrations from manually collected water samples.

Table 4. Laboratory analysis methods.

Analysis	Matrix	Analytical Method	Lab	Filtered	Field Preservation	Contract Lab / Preservation Hold Time
PCBs (40)[8]-Dissolved	Water	EPA 1668	AXYS	Yes	NA	NA
PCBs (40)[8]-Total	Water	EPA 1668	AXYS	No	NA	NA
SSC	Water	ASTM D3977	USGS	No	NA	NA
Grain size	Water	USGS GS method	USGS	No	NA	NA
Mercury-Total	Water	EPA 1631E	BRL	No	BrCl	BRL preservation within 28 days
Metals-Total (As, Cd, Pb, Cu, Zn)	Water	EPA 1638 mod	BRL	No	HNO_3	BRL preservation with Nitric acid within 14 days
Mercury-Dissolved	Water	EPA 1631E	BRL	Yes	BrCl	BRL preservation within 28 days
Organic carbon-Total (WY 2015)	Water	5310 C	EBMUD	No	HCL	NA
Organic carbon-Dissolved (WY 2015)	Water	5310 C	EBMUD	Yes	HCL	NA
Organic carbon-Total (WY 2016, 2017)	Water	EPA 9060A	ALS	No	HCL	NA
Organic carbon-Dissolved (WY 2016, 2017)	Water	EPA 9060A	ALS	Yes	HCL	NA
Mercury	Particulate	EPA 1631E, Appendix	BRL	NA	NA	
PCBs (40)[8]	Particulate	EPA 1668	AXYS	NA	NA	NA
Organic carbon (WY 2016, 2017)	Particulate	EPA 440.0	ALS	NA	NA	NA

[8] Samples were analyzed for 40 PCB congeners (PCB-8, PCB-18, PCB-28, PCB-31, PCB-33, PCB-44, PCB-49, PCB-52, PCB-56, PCB-60, PCB-66, PCB-70, PCB-74, PCB-87, PCB-95, PCB-97, PCB-99, PCB-101, PCB-105, PCB-110, PCB-118, PCB-128, PCB-132, PCB-138, PCB-141, PCB-149, PCB-151, PCB-153, PCB-156, PCB-158, PCB-170, PCB-174, PCB-177, PCB-180, PCB-183, PCB-187, PCB-194, PCB-195, PCB-201, PCB-203).

Interpretive methods

Estimated particle concentrations

The reconnaissance monitoring is designed to collect only one composite sample during a single storm at each site to provide "screening level" information. Measured PCB and Hg concentrations from this single sample could exhibit large inter-storm variability associated with storm size and intensity, as observed from previous studies when a large number of storms were sampled (Gilbreath et al., 2015a). However, this variability can be reduced when the concentrations are normalized to SSC, which produces an estimate of the pollutant concentration on particles in the sample. It was therefore reasoned that the estimated particle concentration (EPC) is likely a better characterization of water quality for a site, and therefore a better metric for comparison between sites (McKee et al., 2012; Rügner et al., 2013; McKee et al., 2015). For each analyte the estimated particle concentration (mass of a given pollutant of concern in relation to mass of suspended sediment) was computed for each composite water sample (Equation 1) at each site:

$$EPC\ (ng/mg) = \ (pollutant\ concentration\ (ng/L))/(SSC\ (mg/L)\ ) \qquad (1)$$

where SSC is the suspended sediment concentration in the sample in units of mg/L. These EPCs were used as the primary index to compare sites without regard to climate or rainfall intensity.

While normalizing PCB and Hg concentrations with SSC provides an improved metric to compare sites, climatic conditions can influence relative ranking based on EPCs. The absolute nature of that influence may differ between watershed locations depending on source characteristics. For example, dry years or lower storm intensity might result in a greater estimated particle concentration for some watersheds if transport of the polluted sediment is triggered but the sediment is less diluted by erosion of less contaminated particles from other parts of the watershed. This is most likely to occur in mixed land use watersheds with large amounts of pervious area. For other watersheds, the source may be a patch of polluted soil that can only be eroded and transported when antecedent conditions and/or rainfall intensity reach some threshold. In this instance, a false negative could occur during a dry year. Only with many years of data during many types of storms can such processes be teased out.

Therefore, relative ranking of sites based on EPC data from one or two storms should be interpreted with caution. Such comparisons may be sufficient for providing evidence to differentiate a group of sites with higher pollutant concentrations from a contrasting group with lower pollutant concentrations (acknowledging the risk that some data for watersheds in this group will be false negatives). However, to generate information on the absolute relative ranking between individual sites, a much more rigorous sampling campaign targeting many storms over many years would be required (c.f. the Guadalupe River study: McKee et al., 2006, or the Zone 4 Line A study: Gilbreath et al., 2012a), or a more advanced data analysis would need to be performed that that takes into account a variety of parameters (PCB and suspended sediment sources and mobilization processes, PCB congeners, rainfall intensity, rainfall antecedence, flow production and volume) in the normalization and ranking procedure. As mentioned above, the RMP has funded in project in CY 2018 to complete this type of investigation.

Derivations of central tendency for comparisons with past data

Mean, median, geometric mean, time-weighted mean, or flow-weighted mean can be used as measures of a dataset's central tendency. Most of these measures have been used to summarize data from RMP studies with discrete stormwater samples. To best compare composite data from WY 2015, 2016, and 2017 monitoring with previously collected discrete sample data, a slightly different approach was used to re-compute the central tendency of the discrete stormwater samples. For older data which were collected as multiple discrete samples within a storm, it was reasoned that a water composite collected over a single storm with timed intervals is equivalent to mixing all discrete samples collected during a storm into a single bottle. Mathematically, this is done by taking the sum of all PCB or HgT concentrations in discrete samples and dividing that by the sum of SSCs from the same samples collected within the same storm event (Equation 2):

$$EPCd\ (ng/mg) = (\Sigma POCd\ (ng/L))/(\Sigma SSCd\ (mg/L)) \qquad (2)$$

where *EPCd* is the estimated particle concentration for a site with discrete sampling, *POCd* is the pollutant concentration of the discrete sample at a site, and *SSCd* is suspended sediment concentration of a discrete sample at a site.

Note that this method is mathematically not equivalent to averaging together the EPCs of each discrete PCB:SSC or HgT:SSC pair. Because of the use of this alternative method, EPCs reported here differ slightly from those reported previously for some sites (McKee et al., 2012; McKee et al., 2014; Wu et al., 2016).

Results and Discussion

The data collected in WYs 2015, 2016 and 2017 were presented in the context of two key questions.

a) What are the concentrations and EPCs observed at each of the sites based on the composite water samples?
b) How do the EPCs measured at each of the sites from the composite water samples compare to EPCs derived from the remote suspended-sediment samplers?

These data contribute to a broad effort to identify potential management areas, and the rankings based on either stormwater concentration or EPCs are part of a weight-of-evidence approach for locating and prioritizing areas that may be disproportionately impacting downstream water quality. As the number of sample sites has increased over time, the relative rankings of particular sites have been changing, but the highest-ranking sites have generally remained in the top quarter of sites.

PCBs stormwater concentrations and estimated particle concentrations

Total PCB concentrations from composite water samples across the 55 sampling sites ranged from 533 to 159,606 pg/L excluding one <MDL (Table 5). The highest concentration was measured at Industrial Rd Ditch in San Carlos, located downstream of a known PCB contamination site (Delta Star) with 85% of impervious cover and 79% of old industrial within its drainage area. The second highest concentration (156,060 pg/L) was measured at Line 12H at Coliseum Way in Oakland, with 71% of its watershed

impervious but only 10% classified as old industrial. Sediment and soil samples upstream from this sampling location indicated the existence of some localized sources (Geosyntec, 2011). We often associate high PCB concentrations with old industrial land use, but these results suggest there is not a perfect correlation. Rather, localized sources are likely the most important factor, and these sources tend to be located within old industrial areas. These two highest concentrations are 3 times higher than the concentrations measured at the third and fourth highest sites: Outfall at Gilman Street (65,370 pg/L) and Ridder Park Dr SD location (55,503 pg/L), as well as measurements of PCBs in Bay Area stormwater taken prior to this study[9] (Gilbreath et al., 2012a; McKee et al., 2012).

There was good correspondence between the highest-ranking sites based on stormwater concentrations and those based on EPCs. The four highest ranking sites based on EPCs (Table 5) were the Industrial Rd Ditch in San Carlos (6,140 ng/g), Line 12H at Coliseum Way (2,601 ng/g), Gull Dr Storm Drain in South San Francisco (859 ng/g), and the Outfall at Gilman St. in Berkeley (794 ng/g). These EPCs are of similar magnitude to high values from previous studies in the Bay Area (McKee et al., 2012; Gilbreath et al., 2016)[10]. The repeat sample collected at Lower Penitencia Creek in WY 2015 was consistent with a previous measurement in WY 2011 (McKee et al., 2012). Similarly, two samples taken at the Duane Ct and Ave Triangle SD site during separate storm events on December 2015 and January 2016 showed relatively consistent and low EPCs (24.6 ng/g and 17.3 ng/g, respectively). Overall, the EPCs from WY 2015, 2016, and 2017 sampling were higher than those from WY 2011 (McKee et al., 2012), probably because the sites selected in the more recent study have a much greater proportion of old industrial in their drainage areas, and thereby a higher likelihood of PCB discharge to stormwater.

[9] E.g. Zone 4 Line A FWMC = 14,500 pg/L: Gilbreath et al., 2012a; Ettie Street Pump Station mean = 59,000 pg/L; Pulgas Pump Station-North: 60,300 pg/L: McKee et al., 2012.

[10] Note, Pulgas Pump Station-South (8,222 ng/g), Santa Fe Channel (1,295 ng/g), Pulgas Pump Station-North (893 ng/g), Ettie St. Pump Station (759 ng/g). Inconsistencies between the EPCs reported herein and those reported in McKee et al. (2012) stem from the slightly different method of computing the central tendency of the data (see the methods section of this report above) and, in the case of Pulgas Pump Station – South, because of the extensive additional sampling that has occurred since McKee et al. (2012) reported the reconnaissance results from the WY 2011 field season.

Table 5. Concentrations of total mercury, sum of PCBs and ancillary constituents measured at each of the sites during winter storms of water years 2015, 2016, and 2017. The sum of PCBs and total mercury are also expressed as an estimated particle concentration (mass of pollutant divided by mass of suspended sediment). The table is sorted from high to low PCB estimated particle concentrations.

Watershed/Catchment	County	City	Sample Date	Number of Aliquots Collected	SSC	DOC	TOC	PCBs				Total Hg			
					(mg/L)	(mg/L)	(mg/L)	(pg/L)	Rank	(ng/g)	Rank	(ng/L)	Rank	(µg/g)	Rank
Industrial Rd Ditch	San Mateo	San Carlos	3/11/16	4	26			160,000	1	6,140	1	13.9	40	0.535	18
Line 12H at Coliseum Way	Alameda	Oakland	12/15/16	3	60			156,000	2	2601	2	36.1	24	0.602	12
Gull Dr SD	San Mateo	South San Francisco	3/5/16	5	10			8,590	30	859	3	5.62	55	0.562	15
Outfall at Gilman St.	Alameda	Berkeley	12/21/15	9	83			65,700	3	794	4	439	1	5.31	1
Outfall to Colma Ck on service rd nr Littlefield Ave. (359)	San Mateo	South San Francisco	2/7/17	2	43	1.7	1.4	33,900	9	788	5	9.05	51	0.210	48
Outfall to Lower Silver Ck	Santa Clara	San Jose	2/6/15	5	57	8.6	8.3	44,600	5	783	6	24.1	33	0.423	26
S Linden Ave SD (291)	San Mateo	South San Francisco	1/8/17	7	16			11,800	22	736	7	12.4	46	0.775	6
Austin Ck at Hwy 37	Solano	Vallejo	3/24/17	6	20		6.3	11,500	23	573	8	12.8	45	0.640	10
Ridder Park Dr SD	Santa Clara	San Jose	12/15/14	5	114	7.7	8.8	55,500	4	488	9	37.1	23	0.326	37
Line 12I at Coliseum Way	Alameda	Oakland	12/15/16	3	93			37,000	7	398	10	12.0	48	0.129	52
Line 3A-M at 3A-D	Alameda	Union City	12/11/14	5	74	9.5	7.3	24,800	13	337	11	85.9	6	1.17	3
Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir	Contra Costa	Pittsburg	1/8/17	4	23			6,530	34	284	12	5.98	53	0.260	44

Watershed/Catchment	County	City	Sample Date	Number of Aliquots Collected	SSC	DOC	TOC	PCBs				Total Hg			
					(mg/L)	(mg/L)	(mg/L)	(pg/L)	Rank	(ng/g)	Rank	(ng/L)	Rank	(µg/g)	Rank
Seabord Ave SD SC-050GAC580	Santa Clara	Santa Clara	12/11/14	5	85	9.5	10	19,900	16	236	13	46.7	15	0.553	17
Line 12M at Coliseum Way	Alameda	Oakland	2/9/17	4	109			24,100	14	222	14	39.6	19	0.365	30
Line 4-E	Alameda	Hayward	12/16/14	6	170	2.8	3.6	37,400	6	219	15	59.0	12	0.346	33
Seabord Ave SD SC-050GAC600	Santa Clara	Santa Clara	12/11/14	5	73	7.9	8.6	13,472	21	186	16	38.3	21	0.528	19
Line 12F below PG&E station	Alameda	Oakland	12/15/16	3	114			21,000	15	184	17	42.5	17	0.373	28
South Linden PS	San Mateo	South San Francisco	2/6/15	5	43	7.4	7.4	7,810	32	182	18	29.2	28	0.679	9
Gull Dr Outfall	San Mateo	South San Francisco	3/5/16	5	33			5,760	37	174	19	10.4	50	0.315	38
Taylor Way SD	San Mateo	San Carlos	3/11/16	5	25	4.5	9.1	4,230	41	169	20	28.9	30	1.16	4
Line 9-D	Alameda	San Leandro	4/7/15	8	69	5	4.6	10,500	25	153	21	16.6	36	0.242	45
Meeker Slough	Contra Costa	Richmond	12/3/14	6	60	4.4	5.3	8,560	31	142	22	76.4	8	1.27	2
Rock Springs Dr SD	Santa Clara	San Jose	2/6/15	5	41	11	11	5,250	38	128	23	38	22	0.927	5
Charcot Ave SD	Santa Clara	San Jose	4/7/15	6	121	20	20	14,900	18	123	24	67.4	11	0.557	16
Veterans PS	San Mateo	Redwood City	12/15/14	5	29	5.9	6.3	3,520	44	121	25	13.7	41	0.469	22
Gateway Ave SD	San Mateo	South San Francisco	2/6/15	6	45	9.9	10	5,240	39	117	26	19.6	35	0.436	23

Watershed/Catchment	County	City	Sample Date	Number of Aliquots Collected	SSC	DOC	TOC	PCBs				Total Hg			
					(mg/L)	(mg/L)	(mg/L)	(pg/L)	Rank	(ng/g)	Rank	(ng/L)	Rank	(µg/g)	Rank
Line 9-D-1 PS at outfall to Line 9-D	Alameda	San Leandro	1/5/16	8	164			18,100	17	110	27	118	4.5	0.720	8
Tunnel Ave Ditch	San Mateo	Brisbane	3/5/16	6	96	5.8	11.3	10,500	24	109	28	73.0	10	0.760	7
Valley Dr SD	San Mateo	Brisbane	3/5/16	6	96			10,400	26	109	29	26.5	32	0.276	42
Runnymede Ditch	San Mateo	East Palo Alto	2/6/15	6	265	16	16	28,500	12	108	30	51.5	14	0.194	51
E. Gish Rd SD	Santa Clara	San Jose	12/11/14	5	145	12	13	14,400	19	99.2	31	84.7	7	0.585	14
Line 13-A at end of slough	Alameda	San Leandro	3/10/16	7	357			34,300	8	96.0	32	118	4.5	0.331	35
Line 3A-M-1 at Industrial PS	Alameda	Union City	12/11/14	6	93	4.2	4.5	8,920	28	95.8	33	31.2	26	0.335	34
Rosemary St SD 066GAC550C	Santa Clara	San Jose	1/8/17	5	46			4,110	43	89.4	34	27.2	31	0.591	13
North Fourth St SD 066GAC550B	Santa Clara	San Jose	1/8/17	5	48			4,170	42	87.0	35	22.9	34	0.477	21
Forbes Blvd Outfall	San Mateo	South San Francisco	3/5/16	5	23	3.4	7.9	1,840	52	80.0	36	14.7	39	0.637	11
SD near Cooley Landing	San Mateo	East Palo Alto	2/6/15	6	82	13	13	6,470	36	78.9	37	35.0	25	0.427	25
Lawrence & Central Expwys SD	Santa Clara	Santa Clara	1/6/16	3	58			4,510	40	77.7	38	13.1	42.5	0.226	46
Condensa St SD	Santa Clara	Santa Clara	1/19/16	6	35			2,600	48	74.4	39	11.5	49	0.329	36
Oddstad PS	San Mateo	Redwood City	12/2/14	6	148	8	7.5	9,200	27	62.4	40	54.8	13	0.372	29

Watershed/Catchment	County	City	Sample Date	Number of Aliquots Collected	SSC	DOC	TOC	PCBs				Total Hg			
					(mg/L)	(mg/L)	(mg/L)	(pg/L)	Rank	(ng/g)	Rank	(ng/L)	Rank	(µg/g)	Rank
Guadalupe River at Hwy 101	Santa Clara	San Jose	1/8/17	7	560			32,700	10	58.4	41	NR		NR	
Line 4-B-1	Alameda	Hayward	12/16/14	5	152	2.8	3.1	8,670	29	57	42	43.0	16	0.282	41
Zone 12 Line A under Temescal Ck Park	Alameda	Emeryville	1/6/16	8	143			7,800	33	54.4	43	41.5	18	0.290	40
Victor Nelo PS Outfall	Santa Clara	San Jose	1/19/16	9	45	4.0	11	2,290	49	50.9	44	15.8	37	0.351	31
Line 12K at Coliseum Entrance	Alameda	Oakland	2/9/17	4	671			32,000	11	47.6	45	288	2	0.429	24
Haig St SD	Santa Clara	San Jose	3/6/16	6	34			1,450	53	42.8	46	6.61	52	0.194	50
Colma Ck at S. Linden Blvd	San Mateo	South San Francisco	2/7/17	5	71			2,650	47	37.3	47	15.3	38	0.215	47
Line 12J at mouth to 12K	Alameda	Oakland	12/15/16	3	183			6,480	35	35.4	48	73.4	9	0.401	27
S Spruce Ave SD at Mayfair Ave (296)	San Mateo	South San Francisco	1/8/17	8	111			3,360	45	30.3	49	38.9	20	0.350	32
E Outfall to San Tomas at Scott Blvd	Santa Clara	Santa Clara	3/6/16	6	103			2,800	46	27.2	50	13.1	42.5	0.127	53
Duane Ct and Ave Triangle SD	Santa Clara	Santa Clara	12/13/15 and 1/6/2016	5	79			1,950	51	24.6	51	5.91	54	0.0748	54
Duane Ct and Ave Triangle SD	Santa Clara	Santa Clara	12/13/15 and 1/6/2016	3	48	4.2	12	832	54	17.3	52	12.9	44	0.268	43
Lower Penitencia Ck	Santa Clara	Milpitas	12/11/14	7	144	5.9	6.1	2,030	50	14.1	53	29.0	29	0.202	49
Refugio Ck at Tsushima St	Contra Costa	Hercules	1/18/17	6	59	5.5		533	55	9.04	54	30.0	27	0.509	20

Watershed/Catchment	County	City	Sample Date	Number of Aliquots Collected	SSC	DOC	TOC	PCBs				Total Hg			
					(mg/L)	(mg/L)	(mg/L)	(pg/L)	Rank	(ng/g)	Rank	(ng/L)	Rank	(µg/g)	Rank
Rodeo Creek at Seacliff Ct. Pedestrian Br.	Contra Costa	Rodeo	1/18/17	7	2630		11	13,900	20	5.28	55	119	3	0.0453	55
East Antioch nr Trembath	Contra Costa	Antioch	1/8/17	6	39			<MDL		NA		12.2	47	0.313	39
Minimum				2	10	1.7	1.4	533		5.28		5.62		0.0453	
Median				5	73.1	5.90	8.45	8923		109		29.2		0.373	
Maximum				9	2630	20	20	160,000		6140		439		5.31	

Mercury stormwater concentrations and estimated particle concentrations

Total mercury concentrations in composite water samples ranged from 5.62 to 439 ng/L, a variation of 78-fold, among the 55 catchment sampling sites sampled so far (Table 5). This relatively large range among sites is similar to that from a previous reconnaissance effort in WY 2011, when mean HgT concentrations ranged from 13.9 to 503 ng/L among sites (McKee et al., 2012). The highest HgT concentration measured was at the Outfall at Gilman Street (439 ng/L), which has 32% old industrial upstream from the sampling point. Other sites with high HgT concentrations were Line 12K at the Coliseum Entrance in Oakland (0.9% old industrial), Rodeo Creek at Seacliff Ct. Pedestrian Br. in Rodeo (2.6% old industrial), Line 9-D-1 PS at outfall to Line 9-D, and Line 13-A at end of the slough, both in San Leandro (62% and 68% old industrial respectively). These results suggest that there is no direct or strong relationship between mercury concentrations and old industrial land use, in contrast to the weak and positive relationship between concentrations measured in water and industrial land use for PCBs, after the addition of WY 2017 data to the dataset.

Based on estimated particle concentrations, the highest site was the same but the rest of the high-ranking sites were different than the ranking based on water concentration. The five most highly ranked sites were Outfall at Gilman Street (32% old industrial), Meeker Slough in Richmond (6% old industrial), Line-3A-M at 3A-D in Hayward (12% old industrial), Taylor Way Storm Drain in San Carlos (11% Old Industrial), and Rock Springs Dr. Storm Drain in San Jose (10% old industrial). Estimated particle concentrations at these sites were 5.3, 1.3, 1.2, 1.2, and 1.0 µg/g, respectively, exceeding the upper range of those measured during the WY 2011 sampling campaign[11] (McKee et al., 2012). On a regional basis, there is no discernible relationship between old industrial land use and HgT EPCs.

Co-occurrence of elevated PCBs and total mercury at the same locations

Another important issue during the ranking process is to consider the combined ranks of PCBs and HgT to determine whether management effort might address both pollutants together. There are few areas where both pollutants are elevated, notably the Gilman Street site in Berkeley and the area around the Coliseum in Oakland. However, in general, only a weak positive relationship exists between PCB and HgT concentrations. The six highest ranking sites for PCBs based on EPCs ranked 14th, 11th, 1st, 19th, 26th, and 3rd for HgT. There is one obvious location where both HgT and PCBs are high: Gilman Street. It shows up in the top five for both pollutants in stormwater and EPCs. The other area (not a site) that shows up high for both is around the Coliseum in Oakland. Line 12H is high for PCBs EPC. Line 12K is high for HgT in stormwater. They are not the same site but they are the same area. This observation contrasts with the conclusions drawn from the WY 2011 dataset, where there appeared to be more of a general correlation between the two contaminants (McKee et al., 2012). This difference might reflect a stronger focus on PCBs during the WY 2015-2017 sampling drainage-line outfalls to creeks with higher imperviousness and old industrial land use, or perhaps it might still be an artifact of small datasets without sample representation along all environmental gradients. This observation is explored further in later sections.

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[11] Pulgas Pump Station-South: 0.83 µg/g, San Leandro Creek: 0.80 µg/g, Ettie Street Pump Station: 0.78 µg/g, and Santa Fe Channel: 0.68 µg/g (McKee et al., 2012).

Trace metal (As, Cd, Cu, Mg, Pb, Se and Zn) concentrations

Trace metal concentrations (for As, Cd, Cu, Pb and Zn) measured in select watersheds during WYs 2015, 2016, and 2017 were all similar in range to those previously measured in the Bay Area.

- Arsenic (As): Measured As concentrations ranged from less than the reporting limit (RL)-2.66 µg/L (Table 6). Total As concentrations of this magnitude have been measured in the Bay Area before (Guadalupe River at Hwy 101: mean=1.9 µg/L; Zone 4 Line A: mean=1.6 µg/L) but are much lower than what was measured at the North Richmond Pump Station (mean=11 µg/L) (Appendix A3 in McKee et al., 2015).
- Cadmium (Cd): Cadmium concentrations were 0.023-0.55 µg/L (Table 6). These Cd concentrations are similar to mean concentrations measured at Guadalupe River at Hwy 101 (0.23 µg/L), North Richmond Pump Station (0.32 µg/L), and Zone 4 Line A (0.25 µg/L) (Appendix A3 in McKee et al., 2015).
- Copper (Cu): Concentrations for Cu ranged from 3.63-52.7 µg/L (Table 6). These concentrations are typical of those measured in other Bay Area watersheds (Guadalupe River at Hwy 101: 19 µg/L; Lower Marsh Creek: 14 µg/L; North Richmond Pump Station: Cu 16 µg/L; Pulgas Pump Station-South: Cu 44 µg/L; San Leandro Creek: Cu 16 µg/L; Sunnyvale East Channel: Cu 18 µg/L; and Zone 4 Line A: Cu 16 µg/L) (Appendix A3 in McKee et al., 2015).
- Lead (Pb): Measured Pb concentrations ranged from 0.910-21.3 µg/L (Table 6). Total Pb concentrations of this magnitude have been measured in the Bay Area before (Guadalupe River at Hwy 101: 14 µg/L; North Richmond Pump Station: Pb 1.8 µg/L; and Zone 4 Line A: 12 µg/L) (Appendix A3 in McKee et al., 2015).
- Zinc (Zn): Zinc concentrations measured 39.4-337 µg/L (Table 6). Zinc measurements at 26 of the sites sampled during WYs 2015, 2016, and 2017 were comparable to the mean concentrations measured in the Bay Area previously (Zone 4 Line A: 105 µg/L; Guadalupe River at Hwy 101: 72 µg/L) (see Appendix A3 in McKee et al., 2015).

In WY 2016, measurements of Mg (528-7350 µg/L) and Se (<RL-0.39 µg/L) were added to the analytical list. Both of these analytes largely reflect geologic sources in watersheds. No measurements of Mg have been previously reported in the Bay Area. The measured concentrations of Se are on the lower side of previously reported values (North Richmond Pump Station: 2.7 µg/L; Walnut Creek: 2.7 µg/L; Lower Marsh Creek: 1.5 µg/L; Guadalupe River at Hwy 101: 1.3 µg/L; Pulgas Creek Pump Station - South: 0.93 µg/L; Sunnyvale East Channel: 0.62 µg/L; Zone 4 Line A: 0.48 µg/L; Mallard Island: 0.46 µg/L; Santa Fe Channel - Richmond: 0.28 µg/L; San Leandro Creek: 0.22 µg/L) (Table A3: McKee et al., 2015). Given the high proportion of Se transported in the dissolved phase and inversely correlated with flow (David et al., 2012; Gilbreath et al., 2012a), it is reasonable that the current sampling design, with a focus on high flow, most likely measured lower concentrations than those measured with sampling designs that included low flow and baseflow samples (North Richmond Pump Station: 2.7 µg/L; Guadalupe River at Hwy 101: 1.3 µg/L; Zone 4 Line A: 0.48 µg/L; Mallard Island: 0.46 µg/). Therefore, Se concentrations reported from this study should not be used to estimate regional loads due to this sampling bias.

Table 6. Concentrations of selected trace elements measured during winter storms of water years 2015, 2016, and 2017. The highest and lowest concentration for each trace element is bolded.

Watershed/Catchment	Sample Date	As (µg/L)	Cd (µg/L)	Cu (µg/L)	Pb (µg/L)	Mg (µg/L)	Se (µg/L)	Zn (µg/L)
Charcot Ave SD	4/7/2015	0.623	0.0825	16.1	2.02			115
Condensa St SD	1/19/2016	1.07	0.055	6.66	3.37	3,650	0.39	54.3
E. Gish Rd SD	12/11/2014	1.52	**0.552**	23.3	19.4			152
East Antioch nr Trembath	1/8/2017	1.57	0.119	**3.53**	1.68	5,363	0.53	**36.3**
Forbes Blvd Outfall	3/5/2016	1.5	0.093	31.7	3.22	7,350	**0**	246
Gateway Ave SD	2/6/2015	1.18	0.053	24.3	1.04			78.8
Gull Dr SD	3/5/2016	**0**	**0.023**	3.63	1.18	**528**	**0**	39.4
Line 9-D-1 PS at outfall to Line 9-D	1/5/2016	1.07	0.524	22.5	20.9	2,822	0.2	217
Line 3A-M at 3A-D	12/11/2014	2.08	0.423	19.9	17.3			118
Line 3A-M-1 at Industrial PS	12/11/2014	1.07	0.176	14.8	7.78			105
Line 4-B-1	12/16/2014	1.46	0.225	17.7	8.95			108
Line 4-E	12/16/2014	2.12	0.246	20.6	13.3			144
Line 9-D	4/7/2015	0.47	0.053	6.24	**0.91**			67
Lower Penitencia Ck	12/11/2014	2.39	0.113	16.4	4.71			64.6
Meeker Slough	12/3/2014	1.75	0.152	13.6	14.0			85.1
North Fourth St SD 066GAC550B	1/8/2017	1.15	0.125	14.0	5.70	**11,100**	**0.67**	75.7
Oddstad PS	12/2/2014	2.45	0.205	23.8	5.65			117
Outfall to Lower Silver Ck	2/6/2015	2.11	0.267	21.8	5.43			**337**
Ridder Park Dr SD	12/15/2014	**2.66**	0.335	19.6	11.0			116
Rock Springs Dr SD	2/6/2015	0.749	0.096	20.4	2.14			99.2
Runnymede Ditch	2/6/2015	1.84	0.202	**52.7**	**21.3**			128
S Spruce Ave SD at Mayfair Ave (296)	1/8/2017	2.2	0.079	9.87	5.31	3,850	0.13	54.8
SD near Cooley Landing	2/6/2015	1.74	0.100	9.66	1.94			48.4
Seabord Ave SD SC-050GAC580	12/11/2014	1.29	0.295	27.6	10.2			168
Seabord Ave SD SC-050GAC600	12/11/2014	1.11	0.187	21	8.76			132
South Linden PS	2/6/2015	0.792	0.145	16.7	3.98			141
Taylor Way SD	3/11/2016	1.47	0.0955	10.0	4.19	5,482	**0**	61.6
Veterans PS	12/15/2014	1.32	0.093	8.83	3.86			41.7
Victor Nelo PS Outfall	1/19/2016	0.83	0.140	16.3	3.63	1,110	0.04	118
Minimum		0	0.0233	3.53	0.91	528	0	36.3
Maximum		2.66	0.552	52.7	21.3	11,100	0.67	337

Comparison between composite and remote sampling methods

The results from remote suspended-sediment samplers were compared to those from the water composite samples collected in parallel (Table 7a and Table 7b).

Grain sizes were analyzed for a select number of sites and the results show that the grain size distribution for the Hamlin samplers was typically coarser than for the Walling tube samples, and the grain size distribution for the Walling tube samples better approximated the grain size distribution for the manual water composite samples (Figure 3).

The EPCs for the samples from the remote samplers and manual water composites were evaluated to compare the measurement techniques. Following the Bland-Altman approach (Bland and Altman, 1986; and explained in Dallal, 2012), results were first plotted against one another for a basic visual inspection of scatter about the 1:1 line, and then the differences between the methods were plotted against the mean of the two measurements to evaluate symmetric grouping around zero and systematic variation of the differences with the mean.

Results for Hg showed that much of the remote sampler data had lower EPCs than those obtained from the composited stormwater samples (Figure 4A, B). However, the Walling tube samples are much closer to the 1:1 line than the Hamlin samples, and have no obvious bias (four samples are lower than the 1:1 line and two are higher). The mean and standard deviation of the paired sample differences (remote samples minus the water composite samples) for the Hamlin sampler were -240 ng/g (mean) and 292 (standard deviation), whereas the mean for the Walling tube sampler was -77 ng/g with a standard deviation of 148. The smallest difference in Hg EPCs between the remote samplers and the composite water samples was at Rodeo Creek at Seacliff Ct. Pedestrian Br (RPD 10%), which could be a result of subsampling and analytical variation. However, at other sites the differences could be up to 5-fold and cannot be easily explained by subsampling or analytical variation, as both the composite sample (time paced with just 2 to 9 sub-samples) and remote sampler methods collect time-integrated samples which reduce the influence of momentary spikes in concentrations. That the Hg EPCs from the remote sampler are typically lower than those from the manual composites is conceptually in concordance with the findings in Yee and McKee (2010). This study found that composited samples often have lower sediment content and thus a greater proportion of Hg in the dissolved phase or on fine particles and, hence, a higher EPC.

For PCBs, there is better agreement between the remote and manual sampling methods (Figure 4C,D). For sites with high EPCs from composite samples, consistently high EPCs were measured from remote samples. The EPCs from remote samples were higher than those from the manual samples, a result that is conceptually reasonable but somewhat surprising, since the manual composite EPCs also included a dissolved proportion (mean 15%, median 12%; Table 7) that would elevate the manual composite EPC versus a remote sample that has an insignificant dissolved phase contribution. Additional sampling in future years is expected to allow for more definitive interpretation. There was one interesting outlier from the Hamlin remote sampler with EPC (1767 ng/g) elevated well above the manual water composite EPC (783 ng/g). A Walling tube was also deployed at this location during the same storm and resulted with an EPC (956 ng/g) much closer to the manual water composite EPC (783 ng/g). One hypothesis is

Table 7a. Remote suspended-sediment sampler PCB data and comparison with manually collected composite water data. Note: EPC = estimated particle concentration.

Site	Remote Sampler Used	Manual Water Composite Data								Remote Sampler Data	
		SSC (manual composite) (mg/L)	PCBs Total (pg/L)	PCBs Particulate (pg/L)	PCBs Dissolved (pg/L)	% Dissolved	PCB particle concentration (lab measured on filter) (ng/g)	PCB EPC (ng/g)	Bias (EPC: lab measured)	PCB EPC (remote) (ng/g)	Comparative Ratio between Remote Sampler and Manual Water Composites
Duane Ct and Ave Triangle SD (Jan 6)	Hamlin	48	832	550	282	34%	11	17	151%	43	246%
Victor Nelo PS Outfall	Hamlin	45	2,289	2,007	283	12%	45	51	114%	70	137%
Taylor Way SD	Hamlin	25	4,227	3,463	764	18%	139	169	122%	237	140%
Tunnel Ave Ditch	Hamlin	96	10,491	9,889	602	6%	103	109	106%	150	137%
Forbes Blvd Outfall	Hamlin	23	1,840	1,794	47	3%	78	80	103%	42	53%
Charcot Ave SD	Hamlin	121	14,927	No data				123	No data	142	115%
Outfall to Lower Silver Ck	Hamlin	57	44,643					783		1767	226%
SD near Cooley Landing	Hamlin	82	6,473					79		68	87%
Austin Ck at Hwy 37	Hamlin	20	11,450					573		700	122%
Outfall to Lower Silver Ck	Walling	57	44,643					783		956	122%
Austin Ck at Hwy 37	Walling	20	11,450					573		362	63%
Rodeo Creek at Seacliff Ct. Pedestrian Br.	Walling	2626	13,863					5		10	195%
Victor Nelo PS Outfall	Walling	45	2,289	2,007	283	12%	45	50.9	114%	100	197%
Tunnel Ave Ditch	Walling	96	10,491	9,889	602	6%	103	109	106%	96	88%
Refugio Ck at Tsushima St	Walling	59	533	533	<MDL	0%	9	9	100%	8	86%
Outfall to Colma Ck on service rd nr Littlefield Ave. (359)	Walling	43	33,875	37,461	1045	3%	871	788	90%	1172	149%
Median						6%			106%		130%
Mean						11%			112%		135%

Table 7b. Remote suspended-sediment sampler Hg data and comparison with manually collected composite water data. Note: EPC = estimated particle concentration.

Site	Remote Sampler Used	Manual Water Composite Data								Remote Sampler Data	
		SSC (manual composite)	Hg Total (ng/L)	Hg Particulate (ng/L)	Hg Dissolved (ng/L)	% Dissolved	Hg particle concentration (lab measured on filter) (ng/g)	Hg EPC (ng/g)	Bias (EPC: lab measured)	Hg EPC (remote) (ng/g)	Comparative Ratio between Remote Sampler and Manual Water Composites
Duane Ct and Ave Triangle SD (Jan 6)	Hamlin	48	13	11	1.88	15%	229	268	117%	99	37%
Victor Nelo PS Outfall	Hamlin	45	16	12.1	3.71	23%	269	351	131%	447	127%
Taylor Way SD	Hamlin	25	29	17.9	11	38%	716	1156	161%	386	33%
Tunnel Ave Ditch	Hamlin	96	73	65.8	7.23	10%	685	760	111%	530	70%
Forbes Blvd Outfall	Hamlin	23	15	12.2	2.45	17%	530	637	120%	125	20%
Charcot Ave SD	Hamlin	121	67	No data				557	No data	761	137%
Outfall to Lower Silver Ck	Hamlin	57	24					423		150	36%
SD near Cooley Landing	Hamlin	82	35					427		101	24%
Austin Ck at Hwy 37	Hamlin	20	13					640		459	72%
Outfall to Lower Silver Ck	Walling	57	24					423		255	60%
Austin Ck at Hwy 37	Walling	20	13					640		548	86%
Rodeo Creek at Seacliff Ct. Pedestrian	Walling	2626	119					45		50	110%
Victor Nelo PS Outfall	Walling	45	16	12.1	3.71	23%	269	351	131%	483	138%
Tunnel Ave Ditch	Walling	96	73	65.8	7.23	10%	685	760	111%	577	76%
Refugio Ck at Tsushima St	Walling	59	30	21.6	8.44	28%	366	509	139%	223	44%
Outfall to Colma Ck on service rd nr Littlefield Ave. (359)	Walling	43	9	9.7	4.9	54%	225	210	93%	264	125%
Median						23%			120%		71%
Mean						26%			125%		75%

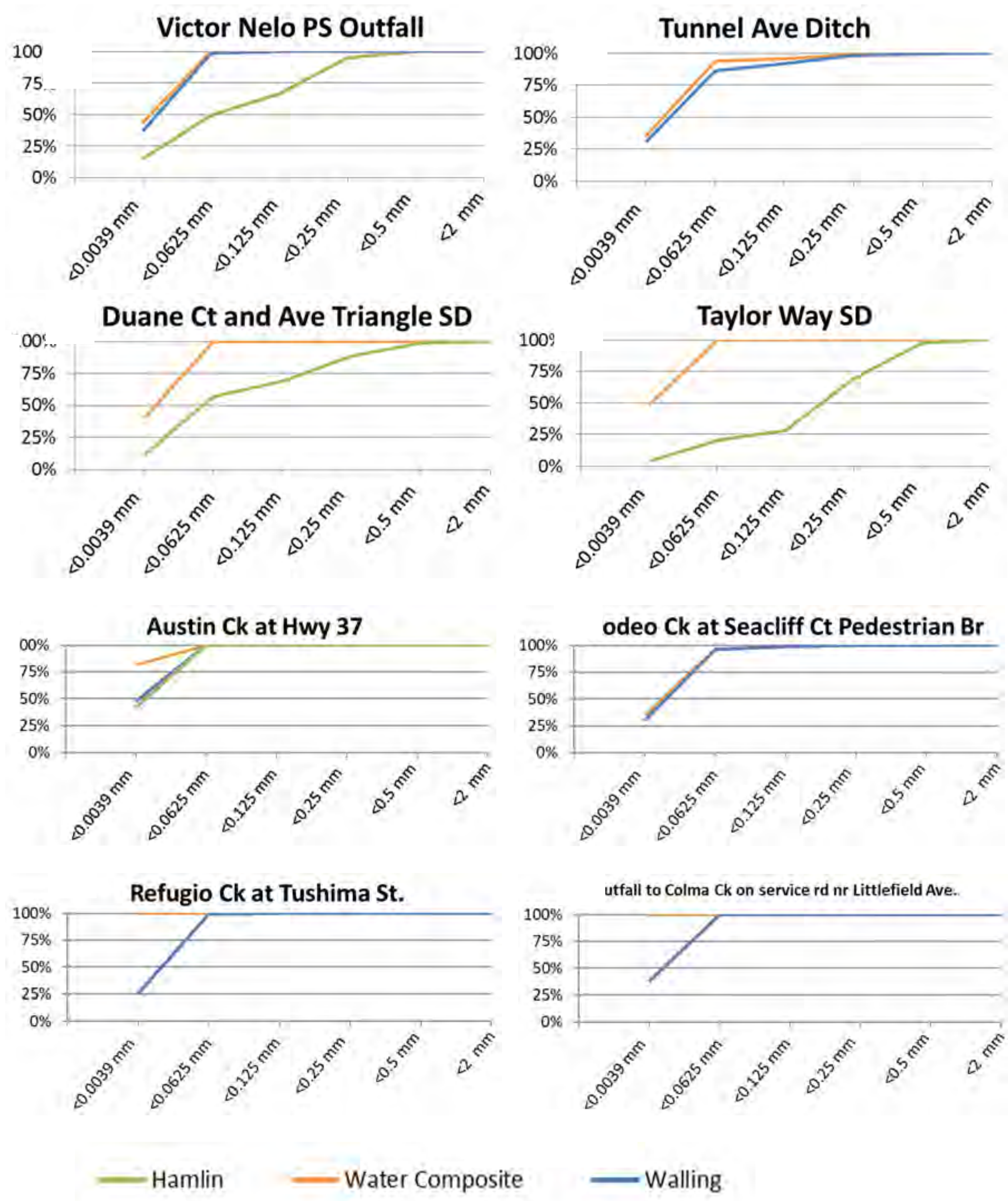

Figure 3. Cumulative grain size distribution in the Hamlin suspended-sediment sampler, Walling tube suspended-sediment sampler, and water composite samples at eight of the sampling locations. Note that both samplers were only used at two of these eight sites.

that the remote samplers captured a time-limited pulse of PCBs during the storm but the manual composite subsampling missed the pulse. This hypothesis may not entirely explain the high concentration in the Hamlin, however, since the EPC from the Walling tube sampler was only slightly elevated above the manual composite EPC. A key difference between the Hamlin sampler and the other two methods is that it disproportionately captures heavier and larger particles. These two ideas, taken together, may explain the very high Hamlin concentration – there may have been a time-limited pulse between manual samples causing both remote samplers to have relatively elevated concentrations, and a substantial portion of the PCBs flowing through this catchment may have been associated with larger particles, which the Hamlin is more likely to capture than the Walling tube.

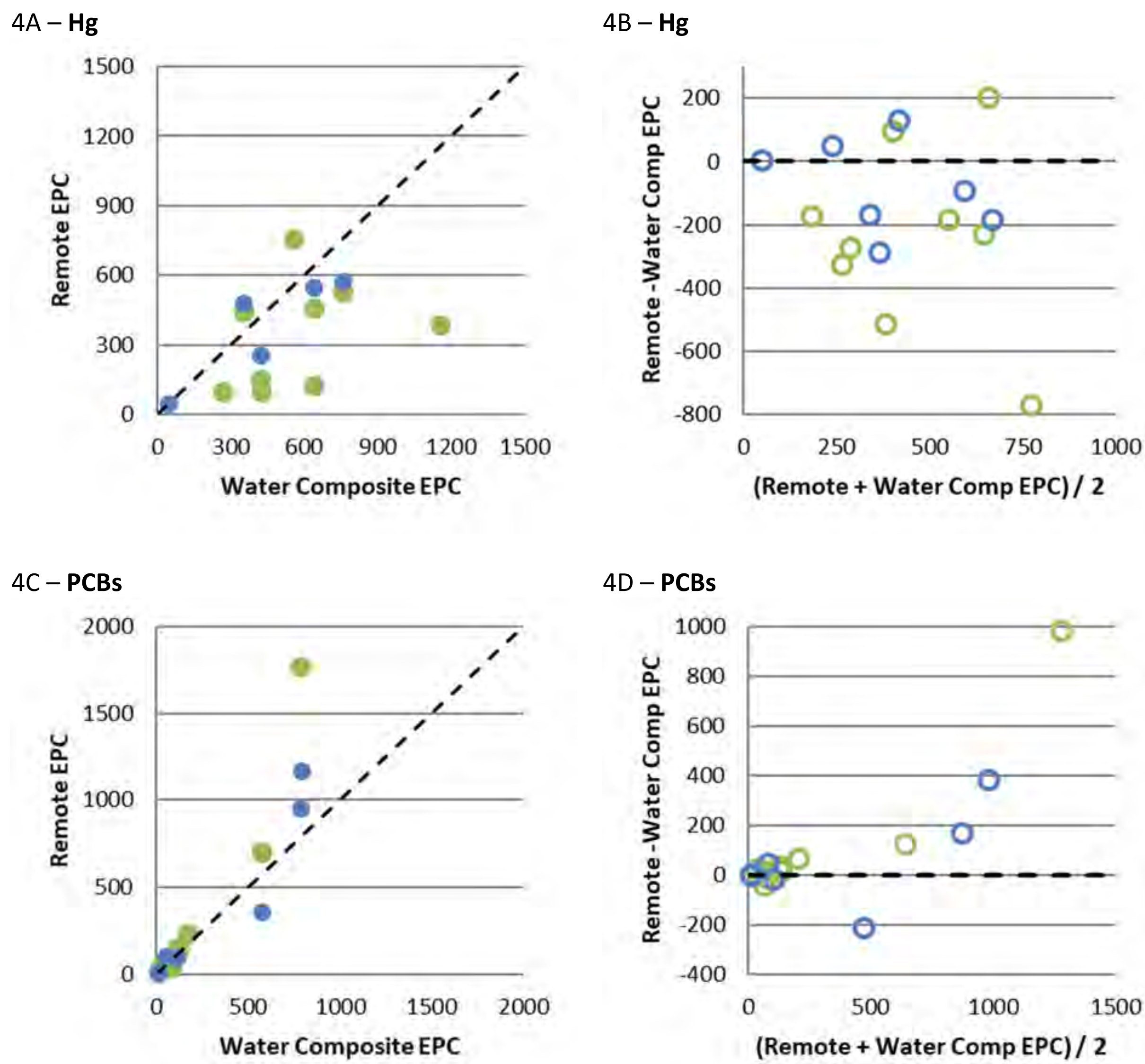

Figure 4. Estimated particle concentration comparisons between remote suspended-sediment samples versus manually collected composite samples, and comparisons of the differences between the methods against their means. Figures 4A and 4C show the 1:1 line (dashed black line), and Figures 4B and 4D show the zero line as dashed. Data for samples collected with the Hamlin sampler are green, and data for samples collected using the Walling tube are blue.

While remote sampling methods could be used as an alternative for cost saving and in places where manual sampling is not feasible, interpreting the data from remote samples and comparing them to the composite samples remains challenging. Whereas the remote methods collect primarily a concentrated, whole storm integrated suspended sediment sample, the manually composited water samples include some proportion of dissolved concentration, which conflates the metric of comparison (EPC) between the methods. In addition, the data collected thus far from the Hamlin sampler has a largely different grain size distribution than collected by the manual water composite method. Another challenge with these remote sampling data is that they cannot be used to estimate loads without corresponding sediment load estimates, which are not readily available at this point.

In summary, remote samplers show some promise as a relative ranking or prioritization tool based on the data collected to date. This pilot study will continue into WY 2018 and possibly beyond. The additional data being collected should help confirm whether these samplers have value as a reconnaissance tool. If that proves to be the case, they can be used as a low-cost screening and ranking tool to identify watersheds where greater investment in manual sampling and other methods of investigation may be needed.

Pros and cons of the remote sampling method

The pilot study to assess effectiveness of remote samplers is still in progress. The samplers have been successfully deployed at 12 locations, with the Hamlin sampler tested at nine and the Walling tube sampler tested at seven locations. A preliminary comparison between remote sampling and manual sampling methods is presented in Table 8a and 8b. Generally speaking, it is anticipated that remote sampling methods will be more cost-effective because they allow for multiple sites to be monitored during a single storm event. There would be initial costs to purchase the equipment, and labor would be required to deploy and process samples. In addition, there will always be logistical constraints (such as turbulence, tidal influences or securing the samplers in hardened channels) that complicate use of the remote devices and require manual monitoring at a particular site. The data collected from the remote sampling methodologies is generally less straightforward to interpret than water grab or composite samples, and overall would be mostly useful for ranking sites for different pollutants but not for load calculations. Therefore, the remote sampling method may best be used as a companion to manual monitoring methods to reduce costs and collect data for other purposes, providing some value as a cost-effective reconnaissance and prioritization tool.

With these concerns raised, the sampling program for WY 2018 will continue to build out the dataset for comparing samples derived from composite and remote sampling methods. The future testing of the remote samplers will need to include more side-by-side Hamlin and Walling tube sites to better compare them and confirm whether the Walling tubes indeed perform well even in circumstances when the Hamlin sampler may not. An articulated versions of the Walling tube also needs to be tested in a stormdrain setting. The additional data from this pilot effort should provide more confidence in the importance of bias and the range of differences among methods. They may also shed light on the causes of bias and differences, either broad ones across the region or specific to a site (e.g., land use) or event (e.g., storm intensity, duration, sample grain size, organic carbon).

Table 8a. Preliminary comparison of the advantages and disadvantages of the remote sampling method versus the manual sampling method for the screening of sites.

Category	Remote Sampling Relative to Manual Sampling	Notes
Cost	Less	Both manual and remote sampling include many of the same costs, though manual sampling generally requires more staff labor related to tracking the storm carefully in order to deploy field staff at just the right time. The actual sampling also requires more labor for manual sampling, especially during long storms. There are some greater costs for remote sampling related to having to drive to the site twice (to deploy and then to retrieve) and then slightly more for post-sample processing, but these additional costs are minimal relative to the amount of time required to track storms and sample on site during the storm. See additional details in Table 8b below.
Sampling Feasibility	Some advantages, some disadvantages	Remote sampling has a number of feasibility advantages over manual sampling. With remote sampling, manpower is less of a constraint; there is no need to wait on equipment (tubing, Teflon bottle, graduated cylinder) cleaning at the lab; the samplers can be deployed for longer than a single storm event, if desired; the samplers composite more evenly over the entire hydrograph; and conceivably, with the help of municipalities, remote samplers may be deployed in storm drains in the middle of streets. On the contrary, at this time there is no advantage to deploy remote samplers (and perhaps it is easier to just manually sample) in tidal locations since they must be deployed and retrieved within the same tidal cycle, although we are beginning to think of solutions to this challenge.
Data Quality	Assessment incomplete	Comparison between the remote sampler and manual sampling results are being assessed in this study. Through WY 2017 sampling, the 16 results for PCBs (using either sampler) have a range in relative percent differences (RPDs)[12] between water manual composite and remote sample of -62 – 84%, and a mean of 21%. For Hg, the range in RPD is -134 to 32%, with a mean of -42%. If remote samplers can be used consistently over multiple storm events, it is reasonable to think that the extended sample collection would improve the representativeness of the sample.
Data Uses	Equivalent or slightly lower	At this time, both the remote and manual sampling collect data for a single storm composite which is then used for screening purposes. The water concentration data from the manual water composites may also be used to estimate loads if the volume is known or can be estimated (e.g., using the RWSM). Water concentration data from remote samplers cannot be used for this purpose.
Human stresses and risks associated with sampling program	Much less	Manual sampling involves a great deal of stressful planning and logistical coordination to sample storms successfully; these stresses include irregular schedules and having to cancel other plans; often working late and unpredictable hours; working in wet and often dark conditions after irregular or insufficient sleep and added risks under these cumulative stresses. Some approaches to remote sampling (e.g., not requiring exact coincidence with storm timing) could greatly reduce many of these stresses (and attendant risks).

[12] RPD is the relative percent difference, calculated as: $\mathrm{RPD} = \dfrac{\text{Difference (between replicate samples)}}{\text{Average (replicate samples)}} \times 100\%$

Table 8b. Detailed preliminary labor and cost comparison between the remote sampling method versus the manual composite sampling method for the screening of sites.

Task	Remote Sampling Labor Hours Relative to Manual Sampling	Manual Composite Sampling Task Description	Remote Sampling Task Description
Sampling Preparation in Office	Equivalent	Cleaning tubing/bottles; preparing bottles, field sampling basic materials	Cleaning sampler; preparing bottles, field sampling basic materials
Watching Storms	Much less	Many hours spent storm watching and deciding if/when to deploy	Storm watching is minimized to only identifying appropriate events with less/little concern about exact timing
Sampling Preparation at Site	Equivalent	Set up field equipment	Deploy sampler
Driving	More (2x)	Drive to and from site	Drive to and from site 2x
Waiting on Site for Rainfall to Start	Less	Up to a few hours	No time since field crew can deploy equipment prior to rain arrival
On Site Sampling	Much less	10-20 person hours for sampling and field equipment clean up	2 person hours to collect sampler after storm
Sample Post-Processing	Slightly more (~2 person hours)	NA	Distribute composited sample into separate bottles; takes two people about 1 hour per sample
Data Management and Analysis	Equivalent	Same analytes and sample count (and usually same matrices)	Same analytes and sample count (and usually same matrices)

Preliminary site rankings based on all available data (including previous studies)

A relative ranking was generated for PCBs and Hg based on both water concentrations and EPCs for all the available data. This analysis differs from the rankings reported in Table 5 in that all available data were considered, not just the data collected for this study. The additional data included in this section primarily is comprised of data collected in intensive loadings studies from 2003-2010 and 2012-2014, a similar reconnaissance study implemented in WY 2011, and studies of green infrastructure conducted between 2010 and the present.

While there are always challenges associated with interpreting data in relation to highly variable factors, including antecedent conditions, storm specific rainfall intensity, and watershed specific source-release-transport processes, the objective here is to provide evidence to help identify watersheds that might have disproportionately elevated PCB or Hg concentrations or EPCs. Given the nature of the reconnaissance sampling design, the absolute rank is much less certain but it is unlikely that the highest ranked locations would drop in ranking much if more sampling was conducted.

PCBs

Based on water composite concentrations for all available data, the 10 highest ranking sites for PCBs are (in order from higher to lower): Pulgas Pump Station-South, Santa Fe Channel, Industrial Rd Ditch, Line

12H at Coliseum Way, Sunnyvale East Channel, Outfall at Gilman St., Pulgas Pump Station-North, Ettie Street Pump Station, Ridder Park Dr Storm Drain, and Outfall to Lower Silver Creek (Table 9, Figure 6). The old industrial land use for these sites ranges from 3-79%, highlighting the challenge of using land use alone as a guide to identify high leverage areas. Using PCB EPCs, the ten most polluted sites are: Pulgas Pump Station-South, Industrial Rd Ditch, Line 12H at Coliseum Way, Santa Fe Channel, Pulgas Pump Station-North, Gull Dr SD, Outfall at Gilman St., Outfall to Colma Ck on service road near Littlefield Ave., Outfall to Lower Silver Creek, and Ettie Street Pump Station. Eight sampling sites made both of the top 10 lists; one site (Gull Dr SD) was ranked high in EPCs but very low on water concentration because of very low suspended sediment mass, and Sunnyvale East Channel exhibited elevated water concentrations but low EPC.

To a large degree, sites that rank high for PCB water concentrations also rank high for EPCs (Figure 7). Watersheds that rank high in water concentration but low in EPC suggest that there are sources present but the EPC is diluted by relatively higher rates of clean sediment. Examples include Line 13A at end of slough and Line 12K at Coliseum Entrance. Conversely, those watersheds that rank high in EPC but not high in water concentration suggest that PCB mobilization is high relative to sediment mobilization, often with samples having a relatively low SSC. Examples of this include Gull Dr. SD and Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Circle. This latter scenario is more likely to occur in watersheds that are highly impervious with little input of clean sediment.

The data collected in WY 2017 added new information to the regional dataset. In addition to identifying two new top-10 ranked PCB EPC sites, the WY 2017 stormwater sampling efforts also identified several more sites with moderately high EPCs (Figure 6). This additional large cohort of sites with moderately elevated EPCs was likely a result of a site selection process that targeted watershed areas with greater older industrial influences.

Most of the sites measured have PCB EPCs that are higher than average conditions needed for attainment of the TMDL. The PCB load allocation of 2 kg from the TMDL (SFBRWQCB 2008) translates to a mean water concentration of 1.33 ng/L and a mean particle concentration of 1.4 ng/g. These calculations assume an annual average flow from small tributaries of 1.5 km^3 (Lent et al., 2012) and an average annual suspended sediment load of 1.4 million metric tons (McKee et al., 2013). Keeping in mind that the estimates of regional flow and regional sediment loads are subject to change as further interpretations are completed, only five sampling locations observed to date (Gellert Park bioretention influent stormwater, Duane Ct. and Triangle Ave., East Antioch nr Trembath, Refugio Ck at Tsushima St. and Haig St. SD) have a composite averaged PCB water concentration of < 1.33 ng/L (Table 9) and none of 78 sampling locations have composite averaged PCB EPCs <1.4 ng/g (Table 9; Figure 6 and 7). The lowest PCB EPC measured to date is for Marsh Creek (2.9 ng/g).

Table 9. PCB and total mercury (HgT) water concentrations and estimated particle concentrations (EPCs) measured in the Bay area based on all data collected in stormwater since water year 2003 and that focused on urban sources (79 sites in total for PCBs and HgT). This dataset is sorted high-to-low for PCB EPC to provide preliminary information on potential leverage. Note: Ranks with a half number are the result of two watersheds with the same rank.

Watershed/Catchment	County	Water Year Sampled	Area (km^2)	Impervious Cover (%)	Old Industrial Land Use (%)	Polychlorinated Biphenyls (PCBs)				Total Mercury (HgT)			
						Estimated Particle Concentration		Composite/Mean Water Concentration		Estimated Particle Concentration		Composite/Mean Water Concentration	
						(ng/g)	Rank	(pg/L)	Rank	(µg/g)	Rank	(ng/L)	Rank
Pulgas Pump Station-South	San Mateo	2011-2014	0.58	87%	54%	8222	1	447,984	1	0.35	42.5	19	56
Industrial Rd Ditch	San Mateo	2016	0.23	85%	79%	6139	2	159,606	3	0.53	26	14	63
Line 12H at Coliseum Way	Alameda	2017	0.97	71%	10%	2601	3	156,060	4	0.60	18	36	42
Santa Fe Channel	Contra Costa	2011	3.3	69%	3%	1295	4	197,923	2	0.57	21.5	86	12.5
Pulgas Pump Station-North	San Mateo	2011	0.55	84%	52%	893	5	60,320	7	0.40	36	24	52.5
Gull Dr SD	San Mateo	2016	0.30	78%	54%	859	6	8,592	43	0.56	23	6	76
Outfall at Gilman St.	Alameda	2016	0.84	76%	32%	794	7	65,670	6	5.31	1	439	4
Outfall to Colma Ck on service rd nr Littlefield Ave. (359)	San Mateo	2017	0.09	88%	87%	788	8	33,875	14	0.21	62	9	73
Outfall to Lower Silver Creek	Santa Clara	2015	0.17	79%	78%	783	9	44,643	10	0.42	34	24	52.5
Ettie Street Pump Station	Alameda	2011	4.0	75%	22%	759	10	58,951	8	0.69	14	55	25.5
S Linden Ave SD (291)	San Mateo	2017	0.78	88%	57%	736	11	11,781	32	0.78	11	12	68
Austin Ck at Hwy 37	Solano	2017	4.9	61%	2%	573	12	11,450	34	0.64	16	13	67
Ridder Park Dr Storm Drain	Santa Clara	2015	0.50	72%	57%	488	13	55,503	9	0.33	46	37	41
Line 12I at Coliseum Way	Alameda	2017	3.4	63%	9%	398	14	36,974	12	0.13	72	12	70
Sunnyvale East Channel	Santa Clara	2011	15	59%	4%	343	15	96,572	5	0.20	64	50	29
Line-3A-M at 3A-D	Alameda	2015	0.88	73%	12%	337	16	24,791	18	1.17	5	86	12.5
Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir	Contra Costa	2017	37	18%	5%	284	17	6,528	48	0.26	55	6	75
North Richmond Pump Station	Contra Costa	2011-2014	2.0	62%	18%	241	18	13,226	30	0.81	10	47	30.5
Seabord Ave Storm Drain SC-050GAC580	Santa Clara	2015	1.4	81%	68%	236	19	19,915	23	0.55	25	47	30.5

Watershed/Catchment	County	Water Year Sampled	Area (km^2)	Impervious Cover (%)	Old Industrial Land Use (%)	Polychlorinated Biphenyls (PCBs)				Total Mercury (HgT)			
						Estimated Particle Concentration		Composite/Mean Water Concentration		Estimated Particle Concentration		Composite/Mean Water Concentration	
						(ng/g)	Rank	(pg/L)	Rank	(µg/g)	Rank	(ng/L)	Rank
Line 12M at Coliseum Way	Alameda	2017	5.3	69%	22%	222	20	24,090	19	0.36	39	40	37
Line 4-E	Alameda	2015	2.0	81%	27%	219	21	37,350	11	0.35	42.5	59	22
Glen Echo Creek	Alameda	2011	5.5	39%	0%	191	22	31,078	16	0.21	63	73	18
Seabord Ave Storm Drain SC-050GAC600	Santa Clara	2015	2.8	62%	18%	186	23	13,472	29	0.53	27	38	39.5
Line 12F below PG&E station	Alameda	2017	10	56%	3%	184	24	21,000	22	0.37	37	43	34
South Linden Pump Station	San Mateo	2015	0.14	83%	22%	182	25	7,814	46	0.68	15	29	48
Gull Dr Outfall	San Mateo	2016	0.43	75%	42%	174	26	5,758	52	0.32	48	10	72
Taylor Way SD	San Mateo	2016	0.27	67%	11%	169	27	4,227	57	1.16	6	29	49
Line 9-D	Alameda	2015	3.6	78%	46%	153	28	10,451	36	0.24	56.5	17	57.5
Meeker Slough	Contra Costa	2015	7.3	64%	6%	142	29	8,560	44	1.27	4	76	16
Rock Springs Dr Storm Drain	Santa Clara	2015	0.83	80%	10%	128	30	5,252	53	0.93	8	38	39.5
Charcot Ave Storm Drain	Santa Clara	2015	1.8	79%	24%	123	31	14,927	26	0.56	24	67	20
Veterans Pump Station	San Mateo	2015	0.52	67%	7%	121	32	3,520	61	0.47	30	14	62
Gateway Ave Storm Drain	San Mateo	2015	0.36	69%	52%	117	33	5,244	54	0.44	31	20	55
Guadalupe River at Hwy 101	Santa Clara	2003-2006, 2010, 2012-2014	233	39%	3%	115	34	23,736	20	3.60	3	603	1
Line 9D1 PS at outfall to Line 9D	Alameda	2016	0.48	88%	62%	110	35	18,086	25	0.72	13	118	8.5
Tunnel Ave Ditch	San Mateo	2016	3.0	47%	8%	109	36	10,491	35	0.76	12	73	19
Valley Dr SD	San Mateo	2016	5.2	21%	7%	109	37	10,442	37	0.28	53	27	51
Runnymede Ditch	San Mateo	2015	2.1	53%	2%	108	38	28,549	17	0.19	66	52	28
E. Gish Rd Storm Drain	Santa Clara	2015	0.45	84%	70%	99	39	14,365	27	0.59	20	85	14
Line 3A-M-1 at Industrial Pump Station	Alameda	2015	3.4	78%	26%	96	40	8,923	39	0.34	44	31	45
Line 13A at end of slough	Alameda	2016	0.83	84%	68%	96	41	34,256	13	0.33	45	118	8.5
Rosemary St SD 066GAC550C	Santa Clara	2017	3.7	64%	11%	89	42	4,112	59	0.59	19	27	50
North Fourth St SD 066GAC550B	Santa Clara	2017	1.0	68%	27%	87	43	4,174	58	0.48	29	23	54

Watershed/Catchment	County	Water Year Sampled	Area (km^2)	Impervious Cover (%)	Old Industrial Land Use (%)	Polychlorinated Biphenyls (PCBs)				Total Mercury (HgT)			
						Estimated Particle Concentration		Composite/Mean Water Concentration		Estimated Particle Concentration		Composite/Mean Water Concentration	
						(ng/g)	Rank	(pg/L)	Rank	(µg/g)	Rank	(ng/L)	Rank
Zone 4 Line A	Alameda	2007- 2010	4.2	68%	12%	82	44	18,442	24	0.17	68	30	47
Forbes Blvd Outfall	San Mateo	2016	0.40	79%	0%	80	45	1,840	69	0.64	17	15	61
Storm Drain near Cooley Landing	San Mateo	2015	0.11	73%	39%	79	46	6,473	50	0.43	32	35	43
Lawrence & Central Expwys SD	Santa Clara	2016	1.2	66%	1%	78	47	4,506	56	0.23	58	13	64.5
Condensa St SD	Santa Clara	2016	0.24	70%	32%	74	48	2,602	67	0.33	47	12	71
San Leandro Creek	Alameda	2011-2014	8.9	38%	0%	66	49	8,614	42	0.86	9	117	10
Oddstad Pump Station	San Mateo	2015	0.28	74%	11%	62	50	9,204	38	0.37	38	55	25.5
Line 4-B-1	Alameda	2015	1.0	85%	28%	57	51	8,674	41	0.28	51.5	43	33
Zone 12 Line A under Temescal Ck Park	Alameda	2016	17	30%	4%	54	52	7,804	47	0.29	50	42	35
Victor Nelo PS Outfall	Santa Clara	2016	0.58	87%	4%	51	53	2,289	68	0.35	40	16	59
Line 12K at Coliseum Entrance	Alameda	2017	16	31%	1%	48	54	31,958	15	0.43	33	288	5
Haig St SD	Santa Clara	2016	2.1	72%	10%	43	55	1,454	71	0.19	65	7	74
Colma Ck at S. Linden Blvd	San Mateo	2017	35	41%	3%	37	56	2,645	66	0.22	61	15	60
Line 12J at mouth to 12K	Alameda	2017	8.8	30%	2%	35	57	6,483	49	0.40	35	73	17
S Spruce Ave SD at Mayfair Ave (296)	San Mateo	2017	5.1	39%	1%	30	58	3,359	62	0.35	41	39	38
Lower Coyote Creek	Santa Clara	2005	327	22%	1%	30	59	4,576	55	0.24	56.5	34	44
Calabazas Creek	Santa Clara	2011	50	44%	3%	29	60	11,493	33	0.15	71	59	22
E Outfall to San Tomas at Scott Blvd	Santa Clara	2016	0.67	66%	31%	27	61	2,799	65	0.13	73	13	64.5
San Lorenzo Creek	Alameda	2011	125	13%	0%	25	62	12,870	31	0.18	67	41	36
Stevens Creek	Santa Clara	2011	26	38%	1%	23	63	8,160	45	0.22	59.5	77	15
Guadalupe River at Foxworthy Road/ Almaden Expressway	Santa Clara	2010	107	22%	0%	19	64	3,120	63	4.09	2	529	2
Duane Ct and Ave Triangle SD	Santa Clara	2016	1.0	79%	23%	17	65	832	73	0.27	54	13	66
Lower Penitencia Creek	Santa Clara	2011, 2015	12	65%	2%	16	66	1,588	70	0.16	69.5	17	57.5

Watershed/Catchment	County	Water Year Sampled	Area (km^2)	Impervious Cover (%)	Old Industrial Land Use (%)	Polychlorinated Biphenyls (PCBs)				Total Mercury (HgT)			
						Estimated Particle Concentration		Composite/Mean Water Concentration		Estimated Particle Concentration		Composite/Mean Water Concentration	
						(ng/g)	Rank	(pg/L)	Rank	(µg/g)	Rank	(ng/L)	Rank
Borel Creek	San Mateo	2011	3.2	31%	0%	15	67	6,129	51	0.16	69.5	58	24
San Tomas Creek	Santa Clara	2011	108	33%	0%	14	68	2,825	64	0.28	51.5	59	22
Zone 5 Line M	Alameda	2011	8.1	34%	5%	13	69.5	21,120	21	0.57	21.5	505	3
Belmont Creek	San Mateo	2011	7.2	27%	0%	13	69.5	3,599	60	0.22	59.5	53	27
Refugio Ck at Tsushima St	Contra Costa	2017	11	23%	0%	9	71	533	74	0.51	28	30	46
Walnut Creek	Contra Costa	2011	232	15%	0%	7	72	8,830	40	0.07	75	94	11
Rodeo Creek at Seacliff Ct. Pedestrian Br.	Contra Costa	2017	23	2%	3%	5	73	13,863	28	0.05	76	119	7
Lower Marsh Creek	Contra Costa	2011-2014	84	10%	0%	3	74	1,445	72	0.11	74	44	32
East Antioch nr Trembath	Contra Costa	2017	5.3	26%	3%	NR[a]	NR[a]	<MDL	NR[a]	0.31	49	12	69
San Pedro Storm Drain	Santa Clara	2006	1.3	72%	16%	No data				1.12	7	160	6
El Cerrito Bioretention Influent	Contra Costa	2011	0.00	74%	0%	442	NR[a]	37690	NR[a]	0.19	NR[a]	16	NR[a]
Fremont Osgood Road Bioretention Influent	Alameda	2012, 2013	0.00	76%	0%	45	NR[a]	2906	NR[a]	0.12	NR[a]	10	NR[a]
Gellert Park Daly City Library Bioretention Influent	San Mateo	2009	0.02	40%	0%	36	NR[a]	725	NR[a]	1.01	NR[a]	22	NR[a]

[a]NR = site not included in ranking. All sites that are not included in the ranking are very small catchments with unique sampling designs for evaluation of green infrastructure.

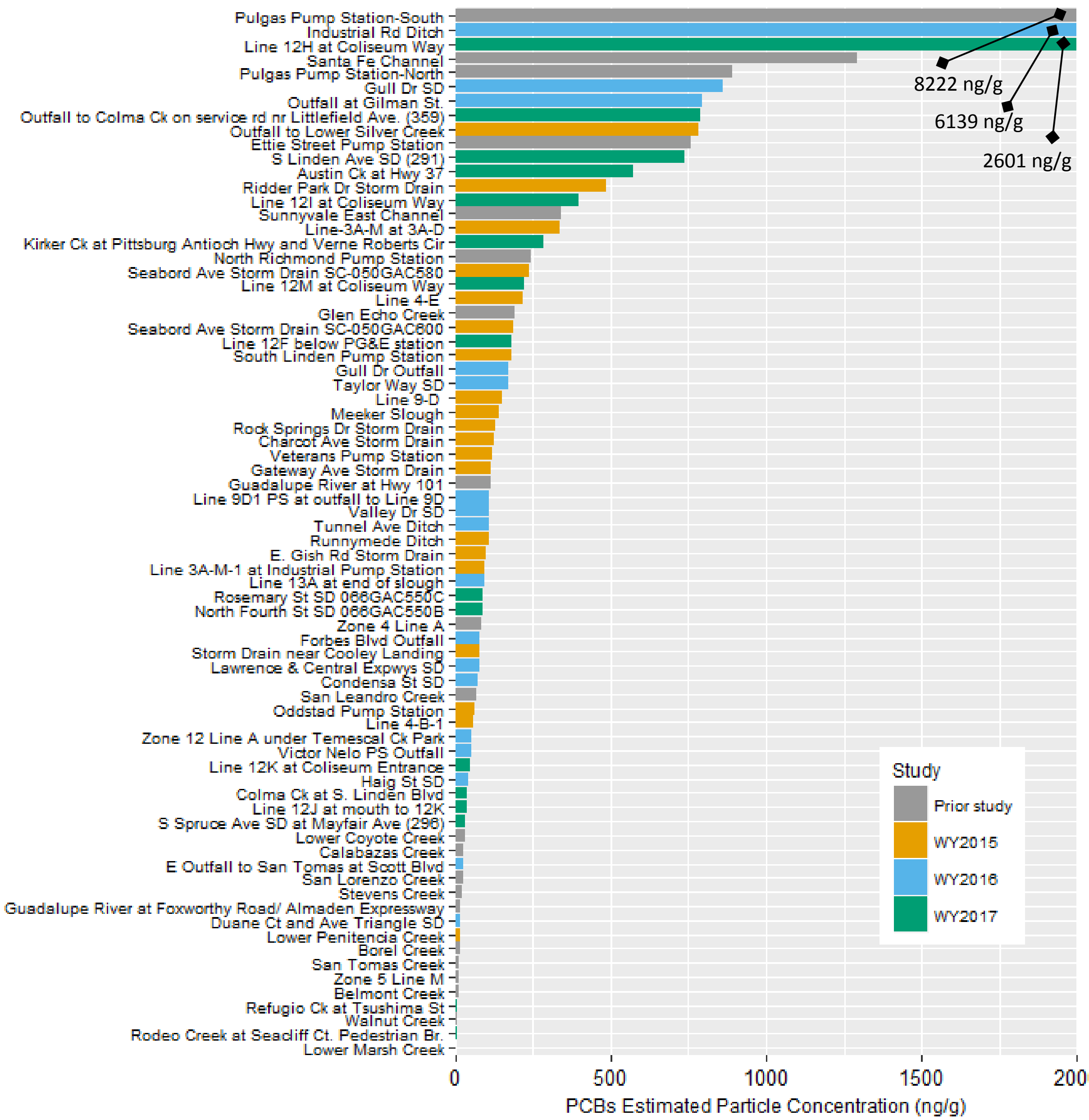

Figure 6. PCB estimated particle concentrations for watershed sampling sites measured to date (water years 2003-2017; where more than one storm is sampled at a site, the reported value is the average of the storm composite samples). Note that PCB EPCs for Pulgas Pump Station-South (8,222 ng/g), Industrial Road Ditch (6,139 ng/g) and for Line 12H at Coliseum Way (2,601 ng/g) are beyond the extent of this graph. The sample count represented by each bar in the graph is provided in Appendix B.

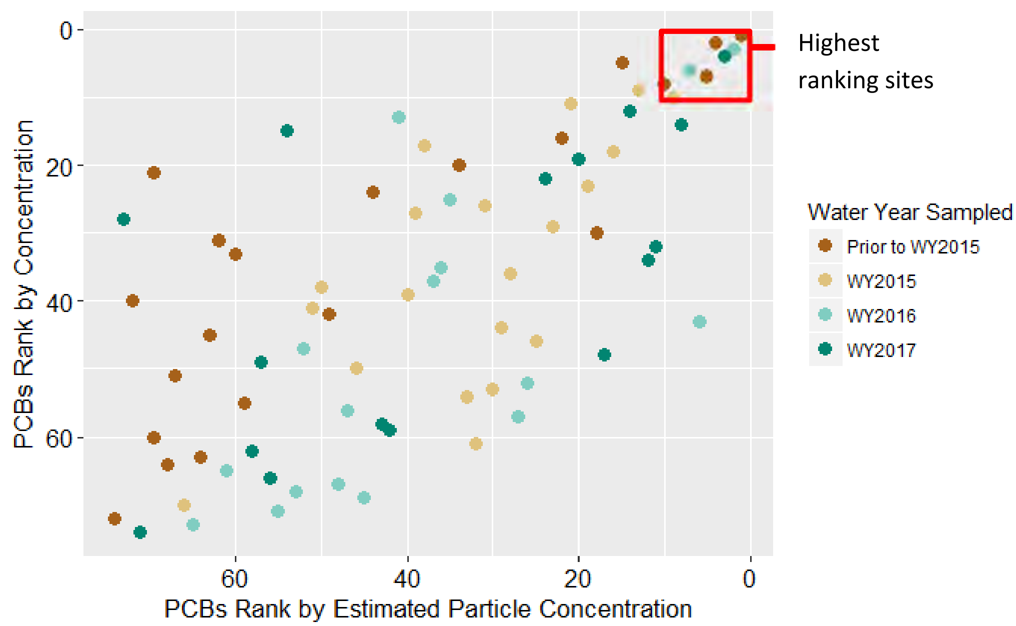

Figure 7. Comparison of site rankings for PCBs based on estimated particle concentrations versus water concentrations. 1 = highest rank; 75 = lowest rank.

Mercury

Based on composite water concentrations, the 10 highest ranking sites for HgT are the Guadalupe River at Hwy 101, Guadalupe River at Foxworthy Road/ Almaden Expressway, Zone 5 Line M, Outfall at Gilman St., Line 12K at the Coliseum Entrance, San Pedro Storm Drain, Rodeo Creek at Seacliff Ct. Pedestrian Br., Line 13-A at end of slough, Line 9-D-1 PS at outfall to Line 9-D and San Leandro Creek (Table 9). Just one of these (Outfall at Gilman St.) also ranked in the top 10 for PCBs.

In addition to the two Guadalupe River mainstem sites, the 10 most polluted sites based on EPCs are Outfall at Gilman St., Meeker Slough, Line 3A-M at 3A-D, Taylor Way SD, San Pedro Storm Drain, Rock Springs Dr. Storm Drain, San Leandro Creek and North Richmond Pump Station (Table 9; Figure 8). Management action in these watersheds might be most cost effective for reducing HgT loads. Only one of these top 10 sites was also identified as elevated for PCBs (Outfall at Gilman St.), but eight additional watersheds rank in the top 20 for both pollutants (Figure 9), providing the opportunity for treating both pollutants. Twenty-one sites measured to date have EPCs <0.25 µg/g, which, given a reasonable expectation of error bars of 25% around the measurements, could be considered equivalent to or less than 0.2 µg/g of Hg on suspended solids (the particulate Hg concentration that was specified in the Bay and Guadalupe River TMDLs (SFBRWQCB, 2006; 2008)).

Site ranking for HgT presented a different picture from PCBs. Sites ranking high based on water concentration are not necessarily ranked high for EPC with the exception of a few sites (Figure 10). Given the atmospheric deposition of Hg across the landscape (McKee et al., 2012), and the highly variable sediment erosion in Bay Area watersheds, it is possible that a watershed could have very elevated HgT stormwater concentrations but very low EPCs. The best example of this is Walnut Creek, which was ranked 11th highest for stormwater composite concentrations but 75th for EPCs. Therefore, HgT sites need to be ranked more carefully than PCBs.

Another important point is that there are a number of watersheds that have relatively low Hg concentrations. The HgT load allocation of 80 kg from the TMDL (add citation for TMDL) translates to a mean water concentration of 53 ng/L. These calculations assume an annual average flow from small tributaries of 1.5 km^3 (Lent et al., 2012). Forty-nine of 79 sampling locations tested have composite HgT water concentrations below this concentration (Table 9). The impervious cover from these low-ranking sites ranges from 10 to 88%, and there are likely very few Hg sources in these watersheds besides atmospheric deposition[13].

Relationships between PCBs and Hg and other trace substances and land-cover attributes

Beginning in WY 2003, many sites have been evaluated for a range of trace elements in addition to PCBs and HgT. These sites include the fixed station loads monitoring sites on Guadalupe River at Hwy 101 (McKee et al., 2006), Zone 4 Line A (Gilbreath et al., 2012a), North Richmond Pump Station (Hunt et al., 2012) and at four sites for which only Cu was measured (Lower Marsh Creek, San Leandro Creek, Pulgas Pump Station-South, and Sunnyvale East Channel) (Gilbreath et al., 2015a). Copper data were also collected at the inlets to several pilot performance studies for bioretention (El Cerrito: Gilbreath et al., 2012b; Fremont: Gilbreath et al., 2015b), and Cu, Cd, Pb, and Zn data were collected at the Daly City Library Gellert Park demonstration bioretention site (David et al., 2015). During WYs 2015, 2016, and 2017, trace element data were collected at an additional 29 locations (Table 6). When all these data are pooled, the resulting dataset has samples sizes of: n=39 sites for Cu; n=33 for Cd, Pb, and Zn; and n=32 for As. Data for Mg and Se were not included due to small sample size. Organic carbon has been more widely collected, including at 28 locations in this study and an additional 21 locations in previous studies.

A Spearman rank correlation analysis was conducted to investigate relationships between EPCs of PCBs and HgT, trace elements, and impervious land cover and old industrial land use (Table 10). In the case of Guadalupe River, the HgT data were removed from the analysis because of historic mining influence in the watershed[14]. Estimated particle concentrations were chosen for this analysis for the same reasons as

[13] Multiple studies in the Bay Area on atmospheric deposition rates for HgT reported very similar wet deposition rates of 4.2 µg/m^2/y (Tsai and Hoenicke, 2001) and 4.4 µg/m^2/y (Steding and Flegal, 2002), and Tsai and Hoenicke reported a total (wet + dry) deposition rate of 18-21 µg/m^2/y. Tsai and Hoenicke computed volume-weighted mean mercury concentrations in precipitation based on 59 samples collected across the Bay Area of 8.0 ng/L. They reported that wet deposition contributed 18% of total annual deposition; scaled to volume of runoff, an equivalent stormwater concentration is 44 ng/L (8 ng/L/0.18 = 44 ng/L).

[14] Historic mining in the Guadalupe River watershed caused a unique positive relationship between Hg, Cr, and Ni, and there are unique inverse correlations between Hg and other typically urban metals such as Cu and Pb (McKee et al., 2005).

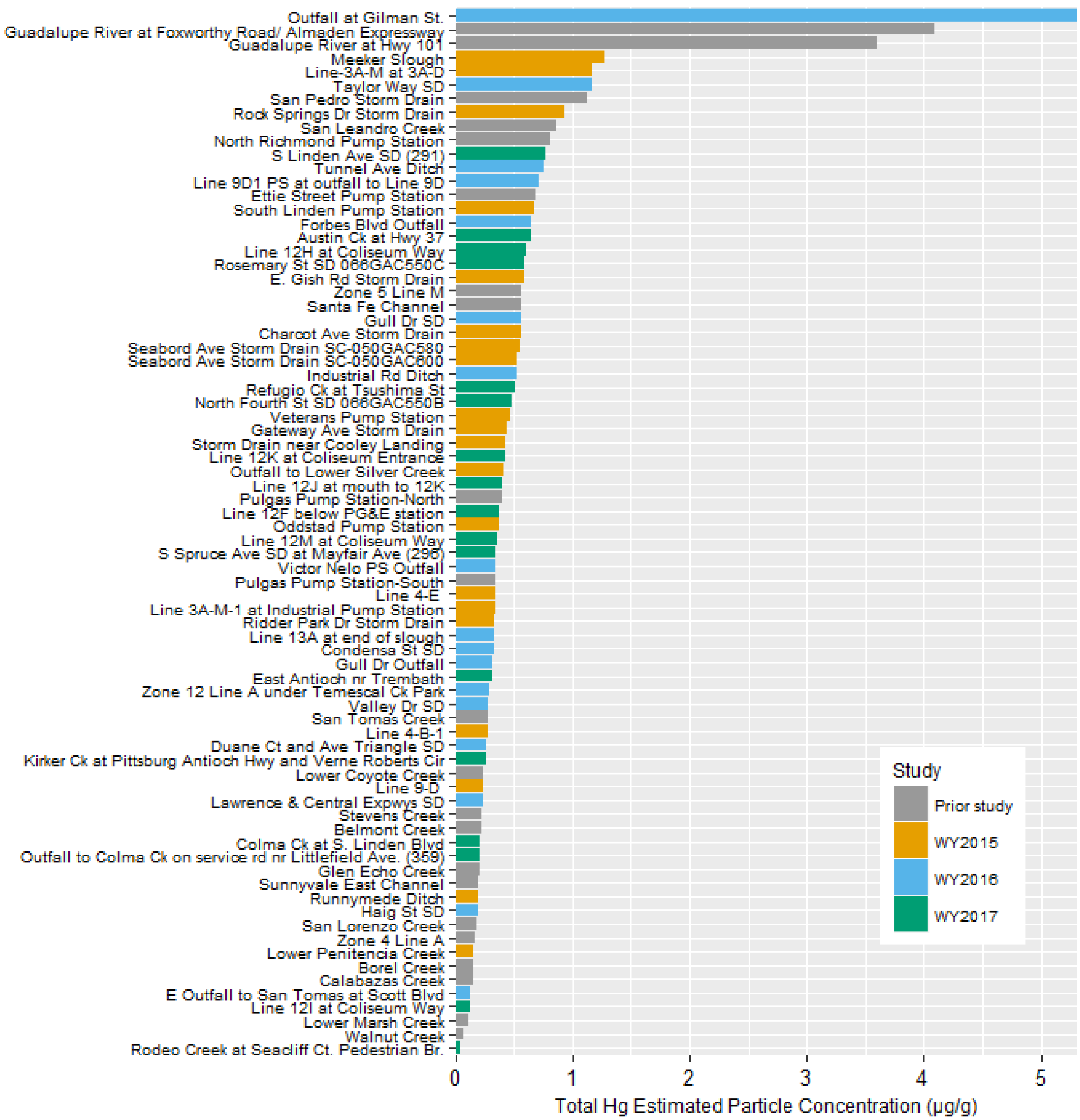

Figure 8. All watershed sampling locations measured to date (water years 2003-2017) ranked by total mercury (HgT) estimated particle concentrations. The sample count represented by each bar in the graph is provided in Appendix B.

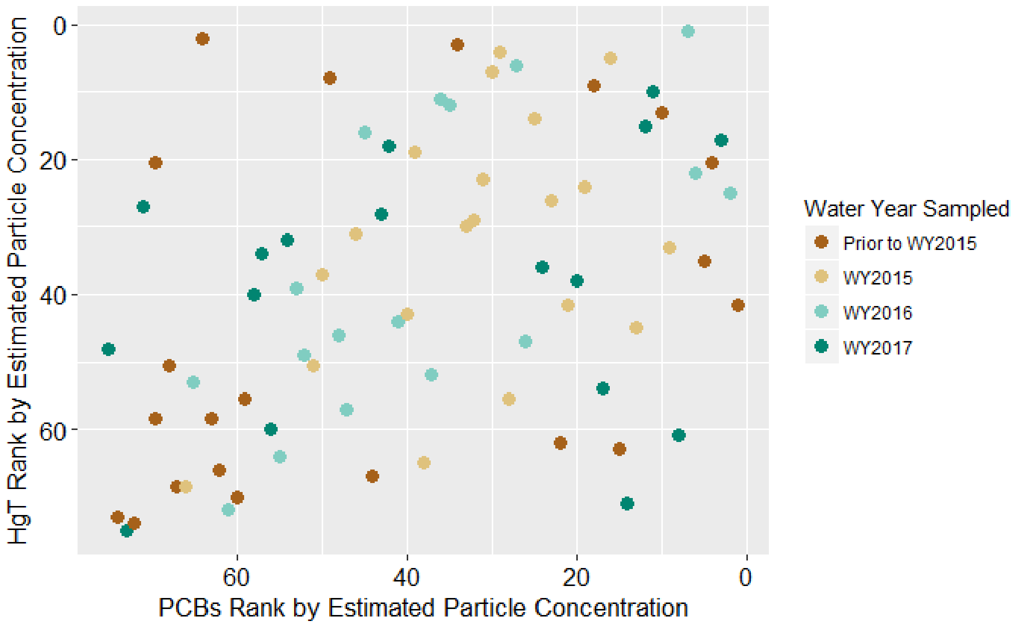

Figure 9. Comparison of site rankings for PCB and total mercury (HgT) estimated particle concentrations. 1 = highest rank; 75 = lowest rank. One watershed ranks in the top 10 for both PCBs and HgT, and nine watersheds rank in the top 20 for both pollutants.

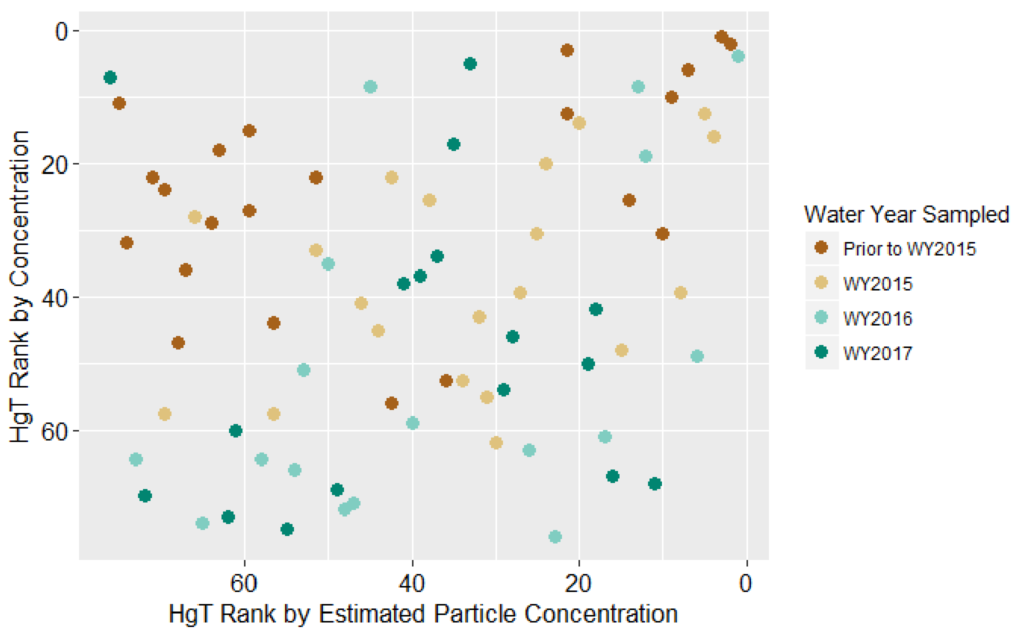

Figure 10. Comparison of site rankings for total mercury (HgT) estimated particle concentrations and water concentrations. 1 = highest rank; 76 = lowest rank.

described above and in McKee et al. (2012): the influence of variable sediment production across Bay Area watersheds is best normalized out so that variations in the influence of pollutant sources and mobilization can be more easily observed between sites.

PCBs correlate positively with impervious cover, old industrial land use and HgT, and inversely correlate with watershed area (Table 10). These observations are consistent with previous analysis (McKee et al., 2012), and make conceptual sense given that larger watersheds tend to have mixed land use and thus a lower proportional amount of PCB source areas.

There was also a positive but relatively weak correlation between PCBs and HgT which makes sense given the general relationships between impervious cover and old industrial land use and both PCBs and HgT. However, the weakness of the relationship is probably associated with the larger role of atmospheric recirculation in the mercury cycle and large differences between the use history of each pollutant. PCBs is a legacy contaminant that was used as dielectrics, plasticizers, and oils. Mercury was used in electronic devices, pressure and heat sensors, pigments, mildewcides, and dentistry and has a strong contemporary signal in addition to legacy usage.

Total Hg also has relationships to impervious cover, old industrial land use, and watershed area that are similar to but weaker than those for PCBs and these geospatial variables.

Neither PCBs nor Hg have strong correlations with other trace metals. Based on this analysis using the available pooled data, there is no support for the use of trace metals as a surrogate investigative tool for either PCB or HgT pollution sources.

To further explore these relationships, the PCB data were examined graphically (Figure 11). The graphs show that the three highest PCB concentrations are in small watersheds that have a high proportion of impervious cover and old industrial area. But the lack of a strong correlation between these metrics indicates that not all small, highly impervious watersheds have high PCB concentrations. The data also indicate the presence of outliers that may be worth exploring with additional data.

Table 10. Spearman Rank correlation matrix based on estimated particle concentrations of stormwater samples collected in the Bay Area since water year 2003 (see text for data sources and exclusions). Sample size in correlations ranged from 28 to 79. Values shaded in light blue have a p <0.05.

	PCBs (pg/mg)	*HgT (ng/mg)*	*Arsenic (ug/mg)*	*Cadmium (ug/mg)*	*Copper (ug/mg)*	*Lead (ug/mg)*	*Zinc (ug/mg)*	*Area (sq km)*	*% Imperviousness*	*% Old Industrial*	*% Clay (<0.0039 mm)*	*% Silt (0.0039 to <0.0625 mm)*	*% Sands (0.0625 to <2.0 mm)*
HgT (ng/mg)	0.43												
Arsenic (ug/mg)	-0.61	-0.06											
Cadmium (ug/mg)	-0.27	0.23	0.67										
Copper (ug/mg)	-0.07	0.16	0.56	0.74									
Lead (ug/mg)	-0.25	0.18	0.58	0.86	0.71								
Zinc (ug/mg)	-0.24	0.27	0.50	0.80	0.89	0.69							
Area (sq km)	-0.45	-0.34	0.01	-0.24	-0.43	-0.09	-0.41						
% Imperviousness	0.56	0.33	-0.35	0.02	0.20	-0.08	0.18	-0.77					
% Old Industrial	0.58	0.31	-0.47	-0.20	-0.22	-0.25	-0.14	-0.55	0.74				
% Clay (<0.0039 mm)	0.26	0.15	-0.12	0.04	-0.22	-0.04	-0.15	-0.23	0.04	0.10			
% Silt (0.0039 to <0.0625 mm)	-0.13	0.06	-0.14	-0.19	0.27	0.00	0.16	0.21	-0.05	-0.04	-0.35		
% Sands (0.0625 to <2.0 mm)	-0.21	-0.23	0.09	-0.01	0.02	0.07	0.00	0.24	-0.08	-0.04	-0.90	0.15	
TOC (mg/mg)	0.27	0.43	0.70	0.60	0.87	0.47	0.76	-0.49	0.45	0.17	-0.13	0.11	-0.04

p value <0.05

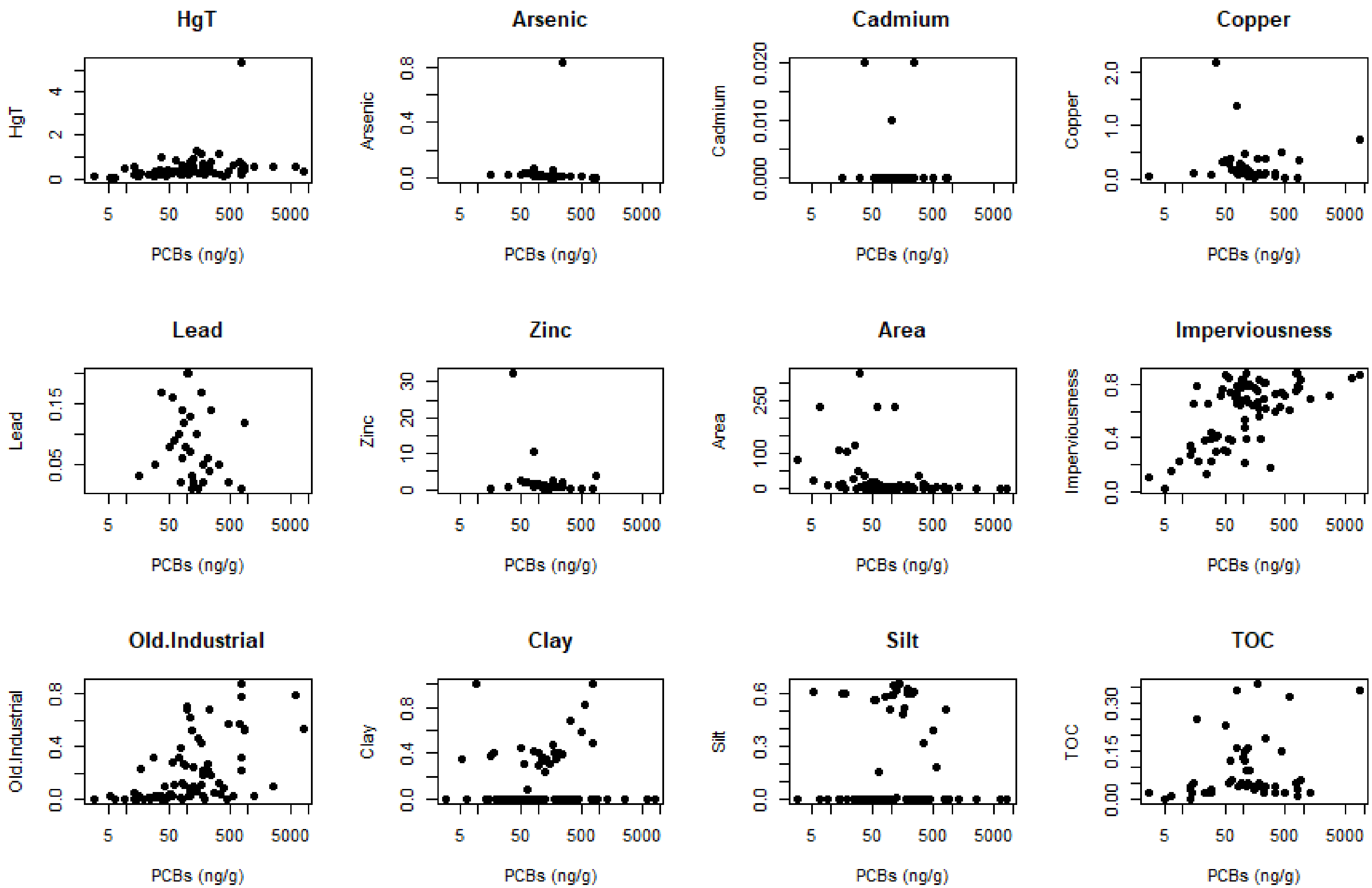

Figure 11. Relationships between observed estimated particle concentrations of PCBs and total mercury (HgT), trace elements, and impervious land cover and old industrial land use.

Sampling progress in relation to data uses

Sampling completed in older industrial areas can be used as an indicator of progress towards identifying areas for potential management. It has been argued previously that old industrial land use and the specific source areas found within or in association with older industrial areas are likely to have higher concentrations and loads of PCBs and HgT (McKee et al., 2012; McKee et al., 2015).

RMP sampling for PCBs and HgT since WY 2003 has included 34% of the old industrial land use in the region. The best effort so far has occurred in Santa Clara County (96% of this land use is in watersheds that have been sampled), followed by San Mateo County (51%) and Alameda County (41%). In Contra Costa County, only 11% of old industrial land use is in watersheds that have been sampled, and just 1% in Solano County. The disproportional coverage in Santa Clara County is due to sampling several large watersheds (Lower Penitencia Creek, Lower Coyote Creek, Guadalupe River at Hwy 101, Sunnyvale East Channel, Stevens Creek and San Tomas Creek) that have older industrial land use upstream from their sampling points. Of the remaining older industrial land use yet to be sampled, 46% of it lies within 1 km and 67% within 2 km of the Bay. These areas are more likely to be tidal, likely to include heavy industrial areas that were historically serviced by rail and ship based transport and military areas, but are often very difficult to sample due to a lack of public rights of way and tidal conditions. A different sampling strategy may be needed to effectively assess what pollution might be associated with these areas to better identify areas for potential management.

Summary and Recommendations

During WYs 2015-2017, composite water samples were collected at 55 sites during at least one storm event and analyzed for PCBs, HgT and SSC, as well as trace metals, organic carbon, and grain size for a select subset. Sampling efficiency was increased by sampling two nearby sites during a single storm. In parallel, a second sample was collected at nine of the sampling sites using a Hamlin remote suspended sediment sampler, and at seven sites using a Walling tube sampler. From this dataset, a number of sites with elevated PCB and HgT concentrations and EPCs were identified, in part because of an improved site selection process that focused on older industrial landscapes. The testing of the remote samplers showed mixed results and further testing is needed. Based on the WY 2015-2017 results, the following recommendations are made.

- Continue to select sites based on the four main selection objectives (Section 2.2). The majority of the sampling effort should be devoted to identify potential high leverage areas with high unit area loads or EPCs/concentrations. Selecting sites by focusing on older industrial and highly impervious landscapes appears successful in identifying high leverage areas and should continue.
- Continue to use the composite sampling design as developed and applied during WYs 2015-2017 with no further modifications. In the event of a higher-rainfall wet season, it may be possible to sample tidally influenced sites when there is a greater likelihood that more storm events will fall within the required tidal windows.

- If WY 2018 sampling includes resampling a site previously sampled, present an improved analysis of the potential for composite, single-storm sampling design to return false negative results (low or moderate concentrations when high concentrations are possible) (see Appendix A for discussion of the possibility for false negatives). Develop a procedure for selecting and resampling sites that return lower than expected concentrations or EPCs.
- Preliminary results from the remote sampler study indicate that the samplers show promise as a screening tool for PCBs, but less so for Hg. More Hamlin samples have been collected than Walling tube samples, and few side-by-side deployments have been made. It is therefore recommended that the testing should continue, with a focus on using the Walling tube sampler, and where the Hamlin is deployed a Walling tube should especially be deployed for comparison between the two remote samplers.
- Develop an improved (advanced) data analysis method for identifying and ranking watersheds of management interest for further characterization or investigation. This recommendation will be carried out in the 2018 calendar year.

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Appendices

Appendix A – Sampling Method Development

The monitoring program implemented in WYs 2015, 2016, and 2017 was based on a previous monitoring design that was trialed in WY 2011 when multiple sites were visited during one or two storm events. In that study, multiple discrete stormwater samples were collected at each site and analyzed for a number of POCs (McKee et al., 2012). At the 2014 SPLWG meeting, an analysis of previously collected stormwater sample data from both reconnaissance and fixed station monitoring was presented (SPLWG et al. 2014). A comparison of three sampling designs for Guadalupe River at Hwy 101 (sampling 1, 2, or 4 storms, respectively: functionally 4, 8, and 16 discrete samples) showed that PCB estimated particle concentrations (EPC) at this site can vary from 45-287 ng/g (1 storm design), 59-257 ng/g (2 storm design), and 74-183 ng/g (4 storm design) between designs, suggesting that the number of storms sampled for a given watershed has big impacts on the EPCs and therefore the potential relative ranking among sites. A similar analysis that explores the relative ranking based on a random 1-storm composite or 2-storm composite design was also presented for other monitoring sites (Pulgas Pump Station-South, Sunnyvale East Channel, North Richmond Pump Station, San Leandro Creek, Zone 4 Line A, and Lower Marsh Creek). This analysis showed that the potential for a false negative could occur due to a low number of sampled storms, especially in smaller and more urbanized watersheds where transport events can be more acute due to lack of channel storage. The analysis further highlighted the trade-off between gathering information at fewer sites with more certainty versus at more sites with less certainty. Based on these analyses, the SPLWG recommended a 1-storm composite per site design with allowances that a site could be revisited if the measured concentrations were lower than expected, either because a low-intensity storm was sampled or other information suggested that potential sources exist.

In addition to composite sampling, a pilot study was designed and implemented to test remote suspended sediment samplers based on enhanced water column settling. Four sampler types were considered: the single-stage siphon sampler, the CLAM sampler, the Hamlin sampler, and the Walling tube. The SPLWG recommended the single-stage siphon sampler be dropped because it allowed for collection of only a single stormwater sample at a single time point, and therefore offers no advantage over manual sampling but requires more effort and expense to deploy. The CLAM sampler was also dropped as it had limitations affecting the interpretation of the data; primarily its inability to estimate the volume of water passing through the filters and the lack of performance tests in high turbidity environments. As a result, the remaining two samplers (Hamlin sampler and Walling tube) were selected for the pilot study as previous studies showed the promise of using these devices in similar systems (Phillips et al., 2000; Lubliner, 2012). The SPLWG recommended piloting these samplers at 12 locations[15] where manual water composites would be collected in parallel to test the comparability between sampling methods.

[15] Note that so far due to climatic constraints, only 9 and 7 locations have been sampled with the Hamlin and Walling samplers, respectively. Additional samples using the Walling sampler are planned for WY 2018.

Appendix B – Quality assurance

The sections below report quality assurance reviews on WYs 2015, 2016, and 2017 data only. The data were reviewed using the quality assurance program plan (QAPP) developed for the San Francisco Bay Regional Monitoring Program for Water Quality (Yee et al., 2017). That QAPP describes how RMP data are reviewed for possible issues with hold times, sensitivity, blank contamination, precision, accuracy, comparison of dissolved and total phases, magnitude of concentrations versus concentrations from previous years, other similar local studies or studies described from elsewhere in peer-reviewed literature and PCB (or other organics) fingerprinting. Data handling procedures and acceptance criteria can differ among programs, however, for the RMP the underlying data were never discarded. Because the results for "censored" data were maintained, the effects of applying different QA protocols can be assessed by a future analyst if desired.

Suspended Sediment Concentration and Particle Size Distribution

In WY 2015, the SSC and particle size distribution (PSD)[16] data from USGS-PCMSC were acceptable, aside from failing hold-time targets. SSC samples were all analyzed outside of hold time (between 9 and 93 days after collection, exceeding the 7-day hold time specified in the RMP QAPP); hold times are not specified in the RMP QAPP for PSD. Minimum detection limits (MDLs) were generally sufficient, with <20% non-detects (NDs) reported for SSC and the more abundant Clay and Silt fractions. Extensive NDs (>50%) were generally reported for the sand fractions starting as fine as 0.125 mm and larger, with 100% NDs for the coarsest (Granule + Pebble/2.0 to <64 mm) fraction. Method blanks and spiked samples are not typically reported for SSC and PSD. Blind field replicates were used to evaluate precision in the absence of any other replicates. The relative standard deviation (RSD) for two field blind replicates of SSC were well below the 10% target. Particle size fractions had average RSDs ranging from 12% for Silt to 62% for Fine Sand. Although some individual fractions had average relative percent difference (RPD) or RSDs >40%, suspended sediments in runoff (and particle size distributions within that SSC) can be highly variable, even when collected by minutes, so results were flagged as estimated values rather than rejected. Fines (clay and silt) represented the largest proportion (~89% average) of the mass.

In 2016 samples, SSC and PSD was analyzed beyond the specified 7-day hold time (between 20 and 93 days after collection) and qualified for holding-time violation but not censored. No hold time is specified for grain-size analysis. Method detection limits were sufficient to have some reportable results for nearly all the finer fractions, with extensive NDs (> 50%) for many of the coarser fractions. No method blanks or spiked samples were analyzed/reported, common with SSC and PSD. Precision for PSD could not be evaluated as no replicates were analyzed for 2016. Precision of the SSC analysis was evaluated using the field blind replicates and the average RSD of 2.12% was well within the 10% target Method Quality Objective (MQO). PSD results were similar to other years, dominated by around 80% Fines.

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[16] Particle size data were captured for % Clay (<0.0039 mm), % Silt (0.0039 to <0.0625 mm), % V. Fine Sand (0.0625 to <0.125 mm), % Fine Sand (0.125 to <0.25 mm), % Medium Sand (0.25 to <0.5 mm), % Coarse Sand (0.5 to <1.0 mm), % V. Coarse Sand (1.0 to <2.0 mm), and % Granule + Pebble (>2.0 mm). The raw data can be found in appendix B.

Average SSC for whole-water samples (excluding those from passive samplers) was in a reasonable range of a few hundred mg/L.

In 2017, method detection limits were sufficient to have at least one reportable result for all analyte/fraction combinations. Extensive non-detects (NDs > 50%) were reported for only Granule + Pebble/2.0 to <64 mm (90%). The analyte/fraction combinations Silt/0.0039 to <0.0625 mm; Sand/Medium 0.25 to <0.5 mm; Sand/Coarse 0.5 to <1.0 mm; Sand/V. Coarse 1.0 to <2.0 mm all had 20% (2 out of 10) non-detects. No method blanks were analyzed for grain size analysis. SSC was found in one of the five method blanks at a concentration of 1 mg/L. The average SSC concentration for the 3 method blanks in that batch was 0.33 mg/L < than the average method blank method detection limit of 0.5 mg/L. No blank contamination qualifiers were added. No spiked samples were analyzed/reported. Precision for grain size could not be evaluated as there was insufficient amount of sample for analysis of the field blind replicate. Precision of the SSC analysis was examined using the field blind replicates with the average RSD of 29.24% being well above the 10% target MQO, therefore they were flagged with the non-censoring qualifier "VIL" as an indication of possible uncertainty in precision.

Organic Carbon in Water

Reported TOC and DOC data from EBMUD and ALS were acceptable. In 2015, TOC samples were field acidified on collection, DOC samples were field or lab filtered as soon as practical (usually within a day) and acidified after, so were generally within the recommended 24-hour holding time. MDLs were sufficient with no NDs reported for any field samples. TOC was detected in only one method blank (0.026 mg/L), just above the MDL (0.024 mg/L), but the average blank concentration (0.013 mg/L) was still below the MDL, so results were not flagged. Matrix spike samples were used to evaluate accuracy, although many samples were not spiked high enough for adequate evaluation (must be at least two times the parent sample concentration). Recovery errors in the remaining DOC matrix spikes were all below the 10% target MQO. TOC errors in WY 2015 averaged 14%, above the 10% MQO, and TOC was therefore qualified but not censored. Laboratory replicate samples evaluated for precision had an average RSD of <2% for DOC and TOC, and 5.5% for POC, within the 10% target MQO. RSDs for field replicates were also within the target MQO of 10% (3% for DOC and 9% for TOC), so no precision qualifiers were needed.

POC and DOC were also analyzed by ALS in 2016. One POC sample was flagged for a holding time of 104 days (past the specified 100 days). All OC analytes were detected in all field samples and were not detected in method blanks, but DOC was detected in filter blanks at 1.6% of the average field sample and 5% of the lowest field sample. The average recovery error was 4% for POC evaluated in LCS samples, and 2% for DOC and TOC in matrix spikes, within the target MQO of 10%. Precision on POC LCS replicates averaged 5.5% RSD, and 2% for DOC and TOC field sample lab replicates, well within the 10% target MQO. No recovery or precision qualifiers were needed. The average 2016 POC was about three times higher than 2014 results. DOC and TOC were 55% and 117% of 2016 results, respectively.

In 2017, method detection limits were sufficient with no non-detects (NDs) reported except for method blanks. DOC and TOC were found in one method blank in one lab batch for both analytes. Four DOC and 8 TOC results were flagged with the non-censoring qualifier "VIP". TOC was found in the field blank and it's three lab replicates at an average concentration of 0.5375 mg/L which is 8.6% of the average concentration found in the field and lab replicate samples (6.24 mg/L). Accuracy was evaluated using the matrix spikes except for POC which was evaluated using the laboratory control samples. The average %error was less than the target MQO of 10% for all three analytes; DOC (5.2%), POC (1.96%), and TOC (6.5%). The laboratory control samples were also examined for DOC and TOC and the average %error was once again less than the 10% target MQO. No qualifying flags were needed. Precision was evaluated using the lab replicates with the average RSD being well below the 10% target MQO for all three analytes; DOC (1.85%), POC (0.97%), and TOC (1.89%). The average RSD for TOC including the blind field replicate and its lab replicates was 2.32% less than the target MQO of 10%. The laboratory control sample replicates were examined and the average RSD was once again well below the 10% target MQO. No qualifying flags were added.

PCBs in Water and Sediment

PCBs samples were analyzed for 40 PCB congeners (PCB-8, PCB-18, PCB-28, PCB-31, PCB-33, PCB-44, PCB-49, PCB-52, PCB-56, PCB-60, PCB-66, PCB-70, PCB-74, PCB-87, PCB-95, PCB-97, PCB-99, PCB-101, PCB-105, PCB-110, PCB-118, PCB-128, PCB-132, PCB-138, PCB-141, PCB-149, PCB-151, PCB-153, PCB-156, PCB-158, PCB-170, PCB-174, PCB-177, PCB-180, PCB-183, PCB-187, PCB-194, PCB-195, PCB-201, PCB-203). Water (whole water and dissolved) and sediment (separately analyzed particulate) PCB data from AXYS were acceptable. EPA 1668 methods for PCBs recommend analysis within a year, and all samples were analyzed well within that time (maximum 64 days). MDLs were sufficient with no NDs reported for any of the PCB congeners measured. Some blank contamination was detected in method blanks for about 20 of the more abundant congeners, with only two PCB 008 field sample results censored for blank contamination exceeding one-third the concentration of PCB 008 in those field samples. Many of the same congeners detected in the method blank also were detected in the field blank, but at concentrations <1% the average measured in the field samples and (per RMP data quality guidelines) always less than one-third the lowest measured field concentration in the batch. Three target analytes (part of the "RMP 40 congeners"), PCBs 105, 118, and 156, and numerous other congeners were reported in laboratory control samples (LCS) to evaluate accuracy, with good recovery (average error on target compounds always <16%, well within the target MQO of 35%). A laboratory control material (modified NIST 1493) was also reported, with average error 22% or better for all congeners. Average RSDs for congeners in the field replicate were all <18%, within the MQO target of 35%, and LCS RSDs were ~2% or better. PCB concentrations have not been analyzed in remote sediment sampler sediments for previous POC studies, so no inter-annual comparisons could be made. PCBs in water samples were similar to those measured in previous years (2012-2014), ranging from 0.25 to 3 times previous averages, depending on the congener. Ratios of congeners generally followed expected abundances in the environment.

AXYS analyzed PCBs in dissolved, particulate, and total fraction water samples for 2016. Numerous congeners had several NDs, but extensive NDs (>50%) were reported for only PCBs 099 and 201 (both 60% NDs). Some blank contamination was detected in method blanks, with results for some congeners in field samples censored due to concentrations that were less than 3 times higher than the highest concentration measured in a blank. This was especially true for dissolved-fraction field samples with low concentrations. Accuracy was evaluated using the laboratory control samples. Again, only three of the PCBs (PCB 105, PCB 118, and PCB 156) reported in the field samples were included in LCS samples (most being non-target congeners), with average recovery errors for those of <10%, well below the target MQO of 35%. Precision on LCS and blind field replicates was also good, with average RSDs <5% and <15%, respectively, well below the 35% target MQO. Average PCB concentrations in total fraction water samples were similar to those measured to previous years, but total fraction samples were around 1% of those measured in 2015, possibly due to differences in the stations sampled.

AXYS also analyzed PCBs in dissolved, particulate, and total fraction water samples for 2017. Numerous congeners had several NDs but none extensively. Some blank contamination was detected in method blanks, with results for some congeners in field samples censored due to concentrations that were less than 3 times higher than the highest concentration measured in a blank. This was especially true for dissolved-fraction field samples with low concentrations. Accuracy was evaluated using the laboratory control samples. Again, only three of the PCBs (PCB 105, PCB 118, and PCB 156) reported in the field samples were included in LCS samples (most being non-target congeners), with average recovery errors for those of <10%, well below the target MQO of 35%. Precision on LCS replicates was also good, with average RSDs <5%, well below the 35% target MQO.

Trace Elements in Water

Overall the 2015 water trace elements (As, Cd, Pb, Cu, Zn, Hg) data from Brooks Rand Labs (BRL) were acceptable. MDLs were sufficient with no NDs reported for any field samples. Arsenic was detected in one method blank, and mercury in four method blanks; the results were blank corrected, and blank variation was <MDL. No analytes were detected in the field blank. Recoveries in certified reference materials (CRMs) were good, averaging 2% error for mercury to 5% for zinc, all well below the target MQOs (35% for arsenic and mercury; 25% for all others). Matrix spike and LCS recovery errors all averaged below 10%, well within the accuracy MQOs. Precision was evaluated in laboratory replicates, except for mercury, which was evaluated in certified reference material replicates (no mercury lab replicates were analyzed). RSDs on lab replicates ranged from <1% for zinc to 4% for arsenic, well within target MQOs (35% for arsenic and mercury; 25% for all the other analytes). Mercury CRM replicate RSD was 1%, also well within the target MQO. Matrix spike and laboratory control sample replicates similarly had average RSDs well within their respective target MQOs. Even including the field heterogeneity from blind field replicates, precision MQOs were easily met. Average concentrations were up to 12 times higher than the average concentrations of 2012-2014 POC water samples, but whole water composite samples were in a similar range those measured in as previous years.

For 2016 the quality assurance for trace elements in water reported by Brooks Applied Lab (BRL's name post-merger) was good. Blank corrected results were reported for all elements (As, Cd, Ca, Cu, Hardness (as $CaCO_3$), Pb, Mg, Hg, Se, and Zn). MDLs were sufficient for the water samples with no NDs reported for Cd, Cu, Pb, Hg, and Zn. Around 20% NDs were reported for As, Ca, Hardness, and Mg, and 56% for Se. Mercury was detected in a filter blank, and in one of the three field blanks, but at concentrations <4% of the average in field samples and (per RMP data quality guidelines) always less than one-third the lowest measured field concentration in the batch. Accuracy on certified reference materials was good, with average %error for the CRMs ranging from 2 to 18%, well within target MQOs (25% for Cd, Ca, Cu, Pb, Mg, Zn; 35% for As, Hg, and Se). Recovery errors on matrix spike and LCS results on these compounds was also good, with the average errors all below 9%, well within target MQOs. The average error of 4.8% on a Hardness LCS was within the target MQO of 5%. Precision was evaluated for field sample replicates, except for Hg, where matrix spike replicates were used. Average RSDs were all < 8%, and all below their relevant target MQOs (5% for Hardness; 25% for Cd, Ca, Cu, Pb, Mg, Zn; 35% for As, Hg, and Se). Blind field replicates were also consistent, with average RSDs ranging from 1% to 17%, all within target MQOs. Precision on matrix spike and LCS replicates was also good. No qualifiers were added. Average concentrations in the 2016 water samples were in a similar range of POC samples from previous years (2003-2015), with averages ranging 0.1x to 2x previous years' averages.

In 2017, the data was overall good and all field samples were usable. Blank corrected results were reported for all elements (As, Cd, Ca, Cu, Hardness (as $CaCO_3$), Pb, Mg, Hg, Se, and Zn). MDLs were sufficient for the water samples with no NDs reported. The Hg was also not detected. Accuracy on certified reference materials was good, with average %error for the CRMs within 12%, well within target MQOs (25% for Cd, Ca, Cu, Pb, Mg, Zn; 35% for As, Hg, and Se). Recovery errors on matrix spike and LCS results on these compounds were also all within target MQOs. Precision was evaluated for field sample replicates. Average RSDs were all < 8%, and all below their relevant target MQOs (5% for Hardness; 25% for Cd, Ca, Cu, Pb, Mg, Zn; 35% for As, Hg, and Se).

Trace Elements in Sediment

A single sediment sample was obtained in 2015 from fractionating one Hamlin sampler and analyzing for As, Cd, Pb, Cu, Zn, and Hg concentration on sediment. Overall the data were acceptable. MDLs were sufficient with no NDs for any analytes in field samples. Arsenic was detected in one method blank (0.08 mg/kg dw) just above the MDL (0.06 mg/kg dw), but results were blank corrected and the blank standard deviation was less than the MDL so results were not blank flagged. All other analytes were not detected in method blanks. CRM recoveries showed average errors ranging from 1% for copper to 24% for mercury, all within their target MQOs (35% for arsenic and mercury; 25% for others). Matrix spike and LCS average recoveries were also within target MQOs when spiked at least 2 times the native concentrations. Laboratory replicate RSDs were good, averaging from <1% for zinc to 5% for arsenic, all well within the target MQOs (35% for arsenic and mercury; 25% for others). Matrix spike RSDs were all 5% or less, also well within target MQOs. Average results ranged from 1 to 14 times higher than the average concentrations for the RMP Status and Trend sediment samples (2009-2014). Results were reported for Mercury and Total Solids in one sediment sample analyzed in two laboratory batches. Other client samples (including lab replicates and Matrix Spike/Matrix Spike replicates), a certified reference material (CRM), and method blanks were also analyzed. Mercury results were reported blank corrected.

In 2016, a single sediment sample was obtained from a Hamlin sampler, which was analyzed for total Hg by BAL. MDLs were sufficient with no NDs reported, and no target analytes were detected in the method blanks. Accuracy for mercury was evaluated in a CRM sample (NRC MESS-4). The average recovery error for mercury was 13%, well within the target MQO of 35%. Precision was evaluated using the laboratory replicates of the other client samples concurrently analyzed by BAL. Average RSDs for Hg and Total

Solids were 3% and 0.14%, respectively, well below the 35% target MQO. Other client sample matrix spike replicates also had RSDs well below the target MQO, so no qualifiers were needed for recovery or precision issues. The Hg concentration was 30% lower than the 2015 POC sediment sample.

Appendix C – Figures 7 and 10 Supplementary Info

Table 11: Sample counts for data displayed in Figures 7 and 10 bar graphs. For samples with a count of 2 or more, the central tendency was used which was calculated as the sum of the pollutant water concentrations divided by the sum of the SSC data.

Catchment	Year Sampled	PCB Sample Count	HgT Sample Count
Belmont Creek	Prior to WY2015	3	4
Borel Creek	Prior to WY2015	3	5
Calabazas Creek	Prior to WY2015	5	5
Charcot Ave Storm Drain	WY2015	1	1
Condensa St SD	WY2016	1	1
Duane Ct and Ave Triangle SD	WY2016	1	1
E Outfall to San Tomas at Scott Blvd	WY2016	1	1
E. Gish Rd Storm Drain	WY2015	1	1
Ettie Street Pump Station	Prior to WY2015	4	4
Forbes Blvd Outfall	WY2016	1	1
Gateway Ave Storm Drain	WY2015	1	1
Glen Echo Creek	Prior to WY2015	4	4
Guadalupe River at Foxworthy Road/ Almaden Expressway	Prior to WY2015	14	46
Guadalupe River at Hwy 101	Prior to WY2015	119	261
Gull Dr Outfall	WY2016	1	1
Gull Dr SD	WY2016	1	1
Haig St SD	WY2016	1	1
Industrial Rd Ditch	WY2016	1	1
Lawrence & Central Expwys SD	WY2016	1	1
Line 13A at end of slough	WY2016	1	1
Line 3A-M-1 at Industrial Pump Station	WY2015	1	1
Line 4-B-1	WY2015	1	1
Line 9-D	WY2015	1	1
Line 9D1 PS at outfall to Line 9D	WY2016	1	1
Line-3A-M at 3A-D	WY2015	1	1
Line4-E	WY2015	1	1
Lower Coyote Creek	Prior to WY2015	5	6
Lower Marsh Creek	Prior to WY2015	28	31
Lower Penitencia Creek	WY2015	4	4
Meeker Slough	WY2015	1	1
North Richmond Pump Station	Prior to WY2015	38	38
Oddstad Pump Station	WY2015	1	1

Outfall at Gilman St.	WY2016	1	1
Outfall to Lower Silver Creek	WY2015	1	1
Pulgas Pump Station-North	Prior to WY2015	4	4
Pulgas Pump Station-South	Prior to WY2015	29	26
Ridder Park Dr Storm Drain	WY2015	1	1
Rock Springs Dr Storm Drain	WY2015	1	1
Runnymede Ditch	WY2015	1	1
San Leandro Creek	Prior to WY2015	39	38
San Lorenzo Creek	Prior to WY2015	5	6
San Pedro Storm Drain	Prior to WY2015		3
San Tomas Creek	Prior to WY2015	5	5
Santa Fe Channel	Prior to WY2015	5	5
Seabord Ave Storm Drain SC-050GAC580	WY2015	1	1
Seabord Ave Storm Drain SC-050GAC600	WY2015	1	1
South Linden Pump Station	WY2015	1	1
Stevens Creek	Prior to WY2015	6	6
Storm Drain near Cooley Landing	WY2015	1	1
Sunnyvale East Channel	Prior to WY2015	42	41
Taylor Way SD	WY2016	1	1
Tunnel Ave Ditch	WY2016	1	1
Valley Dr SD	WY2016	1	1
Veterans Pump Station	WY2015	1	1
Victor Nelo PS Outfall	WY2016	1	1
Walnut Creek	Prior to WY2015	6	5
Zone 12 Line A under Temescal Ck Park	WY2016	1	1
Zone 4 Line A	Prior to WY2015	69	94
Zone 5 Line M	Prior to WY2015	4	4
Line 12H at Coliseum Way	WY2017	1	1
Outfall to Colma Ck on service rd nr Littlefield Ave. (359)	WY2017	1	1
S Linden Ave SD (291)	WY2017	1	1
Austin Ck at Hwy 37	WY2017	1	1
Line 12I at Coliseum Way	WY2017	1	1
Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir	WY2017	1	1
Line 12M at Coliseum Way	WY2017	1	1
Line 12F below PG&E station	WY2017	1	1
Rosemary St SD 066GAC550C	WY2017	1	1
North Fourth St SD 066GAC550B	WY2017	1	1
Line 12K at Coliseum Entrance	WY2017	1	1

Colma Ck at S. Linden Blvd	WY2017	1	1
Line 12J at mouth to 12K	WY2017	1	1
S Spruce Ave SD at Mayfair Ave (296)	WY2017	1	1
Refugio Ck at Tsushima St	WY2017	1	1
Rodeo Creek at Seacliff Ct. Pedestrian Br.	WY2017	1	1
East Antioch nr Trembath	WY2017	1	1