FAIRFIELD-SUISUN SEWER DISTRICT
1010 CHADBOURNE ROAD • FAIRFIELD, CALIFORNIA 94534 • (707) 429-8930 • WWW.FSSD.COM
GREGORY G. BAATRUP, GENERAL MANAGER

March 30, 2018 UR

Mr. Bruce Wolfe, Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Attn: Jan O'Hara, Water Resources Control Engineer

RE: Fairfield-Suisun Urban Runoff Management Program
Urban Creeks Monitoring Report – WY2017

Dear Mr. Wolfe:

The attached Urban Creeks Monitoring Report represents the Fairfield-Suisun Urban Runoff Management Program's submittal in compliance with the Municipal Regional Permit (MRP) Reporting Provision C.8.h.iii of NPDES Permit No. CA S612008 as adopted via Order No. R2-2015-0049.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,

Kevin A. Cullen

Kevin A. Cullen, P.E.
Senior Environmental Engineer

cc: James Paluck, City of Fairfield
Nick Lozano, City of Suisun City

Attachment

Vallejo Flood & Wastewater District

(707) 644-8949 (Admin)
(707) 644-8976 (Billing)
VallejoWastewater.org
450 Ryder Street
Vallejo, CA 94590

March 30, 2018

Mr. Bruce Wolfe, Executive Officer
San Francisco Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Attention: Jan O'Hara, Water Resources Control Engineer

VALLEJO FLOOD AND WASTEWATER DISTRICT URBAN CREEKS MONITORING REPORT WY2017

The attached Urban Creeks Monitoring Report represents the Vallejo Flood and Wastewater District's submittal in compliance with the Municipal Regional Permit (MRP) Reporting Provision C.8.h.iii of NPDES Permit No. CA S612008 as adopted via Order No. R2-2015-0049.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

VALLEJO FLOOD AND WASTEWATER DISTRICT

JENNIFER HARRINGTON
Environmental Services Director

cc: Derek Crutchfield, City of Vallejo

URBAN CREEKS MONITORING REPORT

Water Year 2017 (October 1, 2016 – September 30, 2017)

Submitted to the San Francisco Bay Regional Water Quality Control Board in Compliance with Provision C.8.h.iii
NPDES Permit No. CAS612008

March 31, 2018

Submitted by the Fairfield-Suisun Urban Runoff Management Program and the City of Vallejo and Vallejo Flood and Wastewater District

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Prepared for:

Fairfield-Suisun Urban Runoff Management Program

City of Vallejo/Vallejo Flood and Wastewater District

Prepared by:

Armand Ruby Consulting
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Dixon, CA 95620

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ACCWP	Alameda County Clean Water Program
BASMAA	Bay Area Stormwater Management Agencies Association
B-IBI	benthic index of biological integrity
BMI	benthic macroinvertebrate
CCCWP	Contra Costa Clean Water Program
CSCI	California Stream Condition Index
DO	dissolved oxygen
DPR	Department of Pesticide Regulations
EPA	U.S. Environmental Protection Agency
FSURMP	Fairfield-Suisun Urban Runoff Management Program
GIS	Geographic Information System
IBI	index of biological integrity
IMS	information management system
mg/L	milligram per liter
MMI	multi-metric index
MPC	BASMAA Monitoring and Pollutants of Concern Committee
MRP	Municipal Regional Permit
MRP 2.0	Order R2-2015-0049
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
SPoT	Streams Pollution Trends
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
VFWD	Vallejo Flood and Wastewater District
WLA	wasteload allocation
WQO	water quality objective
WY	water year

Table 1. Water Year 2017 summary table. All sites are designated Urban areas in Region 2 (SF Bay).

Site ID	Creek Name	Permittee	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]
207R03132	Jameson Canyon	FSURMP	38.2042	-122.146	X	X	X						
207R03388	Jameson Canyon	FSURMP	38.206	-122.152	X	X	X						
207R03116	Laurel	FSURMP	38.2535	-122.02	X	X	X	X	X		X	X	
207R03344	McCoy	FSURMP	38.28796	-122.02075	X	X	X						
207LED020	Ledgewood	FSURMP	38.24336	-122.03786						X			
207UAV030	Union Avenue	FSURMP	38.26353	-122.0375						X			
207SSL010	Suisun Slough	FSURMP	38.23322	-122.03786						X			
207R03504	Rindler	Vallejo	38.1372	-122.2183						X			
207BRS010	Blue Rock Springs	Vallejo	38.1113	-122.2050						X			
207BRS004	Blue Rock Springs	Vallejo	38.1220	-122.2229						X			
207BRS006	Blue Rock Springs	Vallejo	38.119822	-122.216338							X		
207BRS030	Blue Rock Springs	Vallejo	38.120740	-122.198909							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 Fairfield-Suisun Urban Runoff Program (FSURMP), Vallejo Flood and Wastewater District (VFWD) and the City of Vallejo 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). This report, including all appendices and attachments, fulfills the requirements of MRP 2.0 provision C.8.h.iii 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 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)

There was no third party monitoring of Solano County sites in WY 2017.

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 Pollutants of Concern (POC) loads monitoring, the Bay Area Stormwater Management Agencies Association (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.

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

The FSURMP, City of Vallejo and VFWD contribute to the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). 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).

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. In particular, 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, four sites were monitored under the regional/probabilistic design for bioassessment, physical habitat, and related water chemistry parameters. One of the four bioassessment sites from WY 2017 was targeted for monitoring of water and sediment toxicity and sediment chemistry. Targeted monitoring was conducted at three continuous water temperature monitoring locations, one general water quality monitoring location, and six 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.

Solano permittees are required to initiate one SSID project during the MRP 2 permit term and intend to do so in WY 2018.

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.

Solano permittees are not required to monitor for POC under MRP 2.0.

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

Dry weather samples are required at one site in Solano County in the permit term. Samples were collected at one site on Laurel Creek in July 2017 and analyzed for water and sediment toxicity and sediment chemistry. All toxicity test results were determined not to be toxic.

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 Fairfield-Suisun Urban Runoff Program (FSURMP), Vallejo Flood and Wastewater District (VFWD) and the City of Vallejo 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). This report, including all appendices and attachments, fulfills the requirements of MRP 2.0 provision C.8.h.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 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. 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 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 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 an 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 Flood and Wastewater 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 requires water quality data collected by permittees to comply with and 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.

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.

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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. All Solano permittees comply with this provision by making financial contributions to the San Francisco Bay Regional Monitoring Program for purposes of increased efficiencies.

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.

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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. 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 Solano permittees to the SFBRWQCB 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
Pathogen indicators		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.

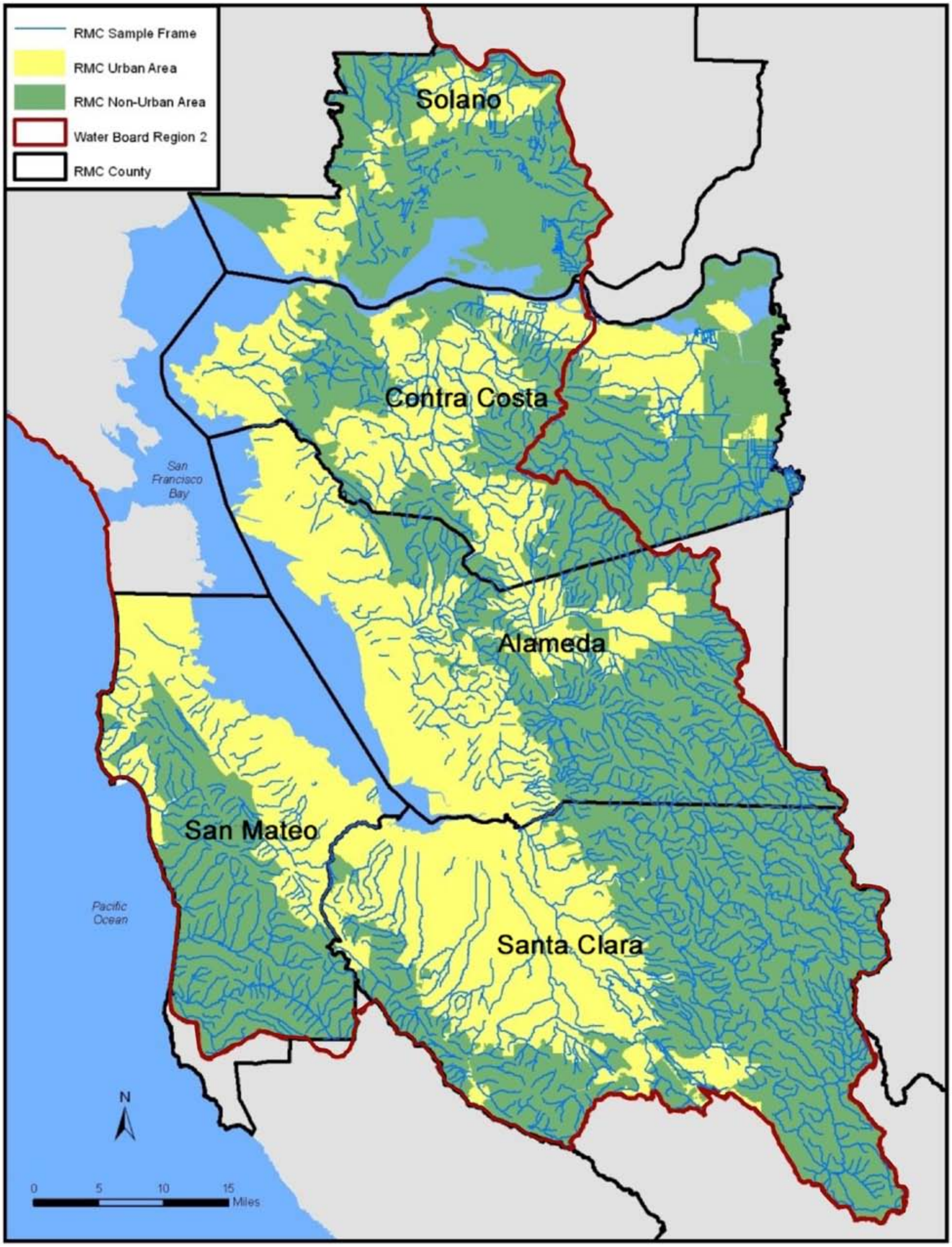
4.1.1. Regional/Probabilistic Monitoring

The regional/probabilistic creek status monitoring report (Appendix 1) documents the results of monitoring performed by the Solano County permittees during WY 2017 under the regional/probabilistic monitoring design developed by the RMC. During WY 2017, four sites were monitored for bioassessment, physical habitat, and related water chemistry parameters.

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 (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. 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 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.

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



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 four 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 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 four 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 four 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 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. The only observed exceedance of the applicable criteria in WY 2017 occurred at the McCoy Creek site (2017R03344), where the chloride value of 400 mg/L exceeded the water quality criterion. As noted below, this site also experienced unusually high chlorine measurements.

Chlorine

Water samples were collected and analyzed for free and total chlorine in the field (using a Hach colorimeter) during bioassessment monitoring. Two sites (Laurel Creek and McCoy Creek) had chlorine levels that exceeded the trigger threshold values.

4.1.1.2. Dry Weather Water and Sediment Toxicity, Sediment Chemistry

Samples were collected at one site on Laurel Creek (207R03116) in July 2017 and analyzed for water and sediment toxicity and sediment chemistry. All toxicity test results were determined not to be toxic. Sediment chemistry results revealed exceedances of the threshold effect concentration (TEC) for copper, nickel and zinc in the Laurel Creek sediment sample.

4.1.2. Local/Targeted Monitoring

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

- Three continuous water temperature monitoring locations

- One general water quality monitoring locations
- Six 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. 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.

All three sites monitored for continuous temperature with a HOBO device exceeded the WAT threshold of 17 ^{o}C. Similarly, both sonde deployment periods recorded WATs that exceeded the threshold.

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.

Over 50% of both sonde deployment periods recorded DO levels that met the trigger threshold.

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.

The summer sonde deployment recorded pH levels that exceeded the threshold criteria.

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.

Specific conductance measurements at Laurel Creek did not exceed stated WQOs during either monitoring period.

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 *E. coli,* three of the six stations (Union Avenue Creek, Rindler Creek and Blue Rock Springs Creek) exceeded the single sample maximum concentration for water contact recreation criteria.

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. Threshold Exceedances for Water Year 2017 in Solano County

Creek	Index Period	Parameter	Criterion Exceedance
Blue Rock Springs 030	April 16 – Sep 12 2017	Continuous water temp (HOBO)	>1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Blue Rock Springs 006	April 16 – Sep 12 2017	Continuous water temp (HOBO)	>1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Laurel	April 27 – Sep 22 2017	Continuous water temp (HOBO)	>1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Laurel	May 25 – June 5 2017; Sep 8 – Sep 20 2017	Continuous water temp (Sonde)	1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Laurel	May 25 – June 5 2017; Sep 8 – Sep 20 2017	Continuous water quality – DO	≥ 20% results < 7.0 mg/L
Laurel	Sep 8 – Sep 20 2017	Continuous water quality - pH	≥ 20% results < 6.5 or > 8.5
Blue Rock Springs 030	Sep 13 2017	*E. coli*	Single grab sample > EPA criterion of 130 CFU/100 ml
Blue Rock Springs 006	Sep 13 2017	*E. coli*	Single grab sample > EPA criterion of 130 CFU/100 ml
Union Ave.	Aug 29 2017	*E. coli*	Single grab sample > EPA criterion of 130 CFU/100 ml
Blue Rock Springs 030	April 16 – Sep 12 2017	Continuous water temp (HOBO)	>1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Blue Rock Springs 006	April 16 – Sep 12 2017	Continuous water temp (HOBO)	>1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Laurel	April 27 – Sep 22 2017	Continuous water temp (HOBO)	>1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Laurel	May 25 – June 5 2017; Sep 8 – Sep 20 2017	Continuous water temp (Sonde)	1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Laurel	May 25 – June 5 2017; Sep 8 – Sep 20 2017	Continuous water quality – DO	≥ 20% results < 7.0 mg/L
Jameson Canyon 3132	May-June 2017	CSCI	CSCI score < 0.795
Jameson Canyon 3388	May-June 2017	CSCI	CSCI score < 0.795
Laurel 3116	May-June 2017	CSCI	CSCI score < 0.795
McCoy 3344	May-June 2017	CSCI	CSCI score < 0.795
McCoy 3344	May-June 2017	Chloride	> 400 mg/L WQO
Laurel 3116	May-June 2017	Chlorine	> 0.1 mg/L, field-measured
McCoy 3344	May-June 2017	Chlorine	> 0.1 mg/L, field-measured
Laurel 3116	Summer, 2017	Sediment chemistry (Cu, Ni, Zn)	3 TECq values>1.0

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 Solano permittees beginning by the end of the permit term

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. Solano 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 2017 monitoring include temperature, DO, pH, and bacteria (*E. coli*).

For the regional/probabilistic parameters, data trigger thresholds exceeded by WY 2016 and 2017 data involve bioassessment benthic taxonomy results (SoCal B-IBI and CSCI scores at all sites monitored), sediment chemistry, specifically pyrethroid pesticide toxic unit equivalents (WY 2016 only) and metals (copper, nickel, zinc), and chloride/chlorine levels, especially in McCoy Creek. 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.

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

Pollutants of Concern (POC) monitoring is not required of the Solano permittees in MRP 2.0. In concurrence with the other RMC Programs, the POC is report is attached (Appendix 4), in recognition of regional requirements for POC monitoring.

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 Solano County, Laurel Creek (207R03116), as summarized below. Per RMC decision, wet weather pesticide monitoring requirements will be met as a group, and Solano permittees will not be sampling during the current permit term.

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 (Laurel Creek, site 207R03116), and tested for toxicity to several different aquatic species, as required by MRP 2.0. All test results were determined not to be toxic and 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 (Laurel Creek, site 207R03116), 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.

Three constituents exhibited results with a TEC value greater than 1.0 in the Laurel 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.

Several pyrethroid pesticides were detected at the Laurel Creek site, with bifenthrin measured at the highest concentration, as is typical in urban creeks in California. 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 0.48, indicating that the sample did not exceed the MRP threshold of a sum of TU Equivalents greater than or equal to 1.0, and pyrethroid pesticide levels were not likely to be sufficient to cause toxicity in the creek sediments.

Two other pesticides (carbaryl and the fipronil degradate fipronil sulfone) also were detected at relatively low levels.

7.3. Sediment Triad Analysis

Stressor evaluation results for sites with data collected for sediment chemistry, sediment toxicity, and bioassessment parameters are summarized in Appendix 1.

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.

8. References

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URBAN CREEKS MONITORING REPORT

Appendix A: REGIONAL/PROBABILISTIC PARAMETERS

Water Year 2017 (October 1, 2016 – September 30, 2017)

Submitted in Compliance with Provision C.8.h.iii
NPDES Permit No. CAS612008

March 31, 2018

Submitted by the Fairfield-Suisun Urban Runoff Management Program and the City of Vallejo and Vallejo Flood and Wastewater District

Program Participants

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- City of Vallejo
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List of Acronyms

ACCWP	Alameda Countywide Clean Water Program
AFDM	ash-free dry mass
A-IBI	Algal Index of Biological Integrity
BASMAA	Bay Area Stormwater Management Agencies Association
B-IBI	Benthic Index of Biological Integrity
BMI	Benthic Macroinvertebrate
CCC	Criterion continuous concentration
CCCWP	Contra Costa Clean Water Program
CDFW	California Department of Fish and Wildlife
CMC	Criteria maximum concentration
CSCI	California Stream Condition Index
CTR	California Toxics Rule
DQO	Data Quality Objective
EPT	Ephemeroptera, Plecoptera, Tricoptera
FSURMP	Fairfield Suisun Urban Runoff Management Program
GIS	Geographic Information System
GRTS	Generalized Random Tessellated Stratified
IBI	Index of Biological Integrity
LC50	Lethal Concentration to 50% of test organisms
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MRP	Municipal Regional Permit
ND	Non-Detect Data
NorCal B-IBI	Northern California Benthic Index of Biological Integrity
NT	Non-Target
PCB	Polychlorinated biphenyl
PEC	Probable Effect Concentration
PHab	Physical Habitat Assessment
PSA	Perennial Streams Assessment
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RL	Reporting limit
RMC	Regional Monitoring Coalition
RPD	Relative Percent Difference
RWB	Reach-Wide Benthos
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
SoCal B-IBI	Southern California Benthic Index of Biological Integrity
SOP	Standard Operating Procedure
SSID	Stressor/Source Identification
SWAMP	Surface Water Ambient Monitoring Program

TEC	Threshold Effect Concentration
TKN	Total Kjeldahl Nitrogen
TMDL	Total maximum daily load
TNS	Target Not Sampled
TOC	Total Organic Carbon
TP	Total phosphorus
TS	Target Sampled
TU	Toxicity Unit
U	Unknown
UCMR	Urban Creeks Monitoring Report
USEPA	U.S. Environmental Protection Agency
VFWD	Vallejo Flood and Wastewater District
WQO	Water quality objective
WY	Water Year

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Executive Summary

This monitoring report documents the results of creek status monitoring activities and data collected using a probabilistic monitoring design performed by the Fairfield Suisun Urban Runoff Management Program (FSURMP) and the City of Vallejo and Vallejo Sanitation and Flood Control District (VSFCD) during the 2017 Water Year (WY). Together with the UCMR Appendix B, this report submittal completes the required reporting for Provision C.8.d of the Municipal Regional Permit (MRP) for Urban Stormwater issued by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB; Order No. R2-2015-0049). Reporting requirements for monitoring components are established in provision C.8.h.iii of the MRP.

The results of the WY 2017 monitoring revealed the following:

- Analysis of benthic macroinvertebrate (BMI) taxonomy for the four bioassessment sites monitored in WY 2017 produced benthic index of biological integrity (B-IBI) scores ranging in condition category from poor to very poor.
- CSCI scores from all four bioassessment sites are below the MRP 2.0 threshold, indicating that these streams are biologically degraded.
- The 2017 dry weather water and sediment sample (site 207R03116, Laurel Creek) exhibited no toxicity to test species.
- Water chemistry data produced from samples collected at the four bioassessment sites exceeded water quality standards at one site (207R03344, McCoy Creek) for one constituent (chloride).
- Of the four sites where chlorine was measured, 2 sites (50%) exceeded the threshold for free chlorine and/or total chlorine; both sites (Laurel Creek and McCoy Creek) contain substantial flow from urban runoff sources in the dry summer months, when both exceedances occurred.
- The sediment triad site (site 207R03116, Laurel Creek) had levels of copper, nickel and zinc that exceeded the threshold values for MRP 2.0.
- Based on four years of triad analyses, Laurel Creek warrants further investigation for low IBI and CSCI scores, chlorine exeedances, and toxicity issues.

1.0 Introduction

This report documents the results of creek status monitoring performed by municipal stormwater permittees in Solano County during water year (WY) 2017 (October 1, 2016 - September 30, 2017), under a regional/probabilistic monitoring design. 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" (Appendix 2 to the WY 2017 UCMR), 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).

The regional/probabilistic creek status monitoring design was developed and implemented by the Regional Monitoring Coalition (RMC). Members of the Bay Area Stormwater Management Agencies Association (BASMAA) formed the RMC in early 2010 to collaboratively implement the monitoring requirements found in Provision C.8 of the original Municipal Regional Permit for urban stormwater in Region 2 (Order No. R2-2009-0074). This collaborative arrangement continues following the adoption of MRP 2 (Order No. R2-2015-0049) in 2015. 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 Flood and Wastewater District (Vallejo)

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 Workgroup is a subgroup of the BASMAA Monitoring and Pollutants of Concern Committee (MPC). The RMC Workgroup meets and communicates regularly to coordinate planning and implementation of MRP monitoring-related activities. The RMC Workgroup meetings are coordinated by a RMC coordinator funded by the participating stormwater programs, and include participation by staff from the SFBRWQCB and San Francisco Estuary Institute (SFEI). SFBRWQCB staff participation includes regional representation of the State of California's Surface Water Ambient Monitoring Program (SWAMP), and SFEI staff participation includes representation of the California Environmental Data Exchange Network (CEDEN).

Through the RMC Workgroup, the RMC developed a Quality Assurance Project Plan (QAPP; BASMAA, 2016a), Standard Operating Procedures (SOPs; BASMAA, 2016b), data management tools, and reporting templates and guidelines for creek status and trends monitoring conducted in compliance with MRP Provisions C.8.d and C.8.g.

The RMC Workgroup divided the creek status and trends monitoring requirements into those parameters that reasonably could be included within a regional/probabilistic design, and those that, 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 1.1.

Table 1-1. Creek status and trends monitoring parameters by monitoring design type per MRP Provisions C.8.d and C.8.g.

Biological Response and Stressor Indicators	Monitoring Design	
	Regional (Probabilistic)	Local (Targeted)
Bioassessment, physical habitat assessment, CSCI	X	
Nutrients (and other water chemistry associated with bioassessment)	X	
Chlorine	X	
Water toxicity (dry weather)	X	
Sediment chemistry and toxicity (dry weather)	X	
Water chemistry and toxicity (wet weather) [a]	X	
Continuous general water quality (sonde data: temperature, dissolved oxygen, pH, specific conductivity)		X
Temperature (HOBO data loggers)		X
Bacteria (pathogen indicators)		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.

The Fairfield-Suisun permittees are required to perform creek status and trends monitoring during the current permit cycle for both local/targeted parameters and regional/probabilistic parameters, as shown in Table 1-2.

The remainder of this report addresses Study Area and Monitoring Design (Section 2.0), Monitoring Methods (Section 3.0), Results and Data Interpretation (Section 4.0), and Conclusions and Next Steps (Section 5.0).

Table 1-2. Creek status and trends monitoring requirements for Solano County permittees per MRP Provisions C.8.d and C.8.g (number of samples per permit term)

Biological Response and Stressor Indicators	Program		Status
	Fairfield-Suisun	Vallejo	
Per MRP Prov. C.8.d.:			
Bioassessment, physical habitat assessment, CSCI	8	4	4 sites completed, Fairfield-Suisun, WY 2017
Nutrients (and other water chemistry associated with bioassessment)	8	4	4 sites completed, Fairfield-Suisun, WY 2017
Chlorine	8[b]	4[b]	4 sites completed, Fairfield-Suisun, WY 2017
Temperature (HOBO data loggers)	2[b]	2[b]	
Continuous general water quality (sonde data: temperature, dissolved oxygen, pH, specific conductivity)	2 spring, 2 summer	2 spring, 2 summer	
Bacteria (Pathogen Indicators)	3	3	
Per MRP Prov. C.8.g.:			
Water toxicity (dry weather)	1[c]		
Sediment chemistry and toxicity (dry weather)	1[c]		
Water chemistry and toxicity (wet weather) [a]	1[c]		

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

b To be completed by end of second year of permit

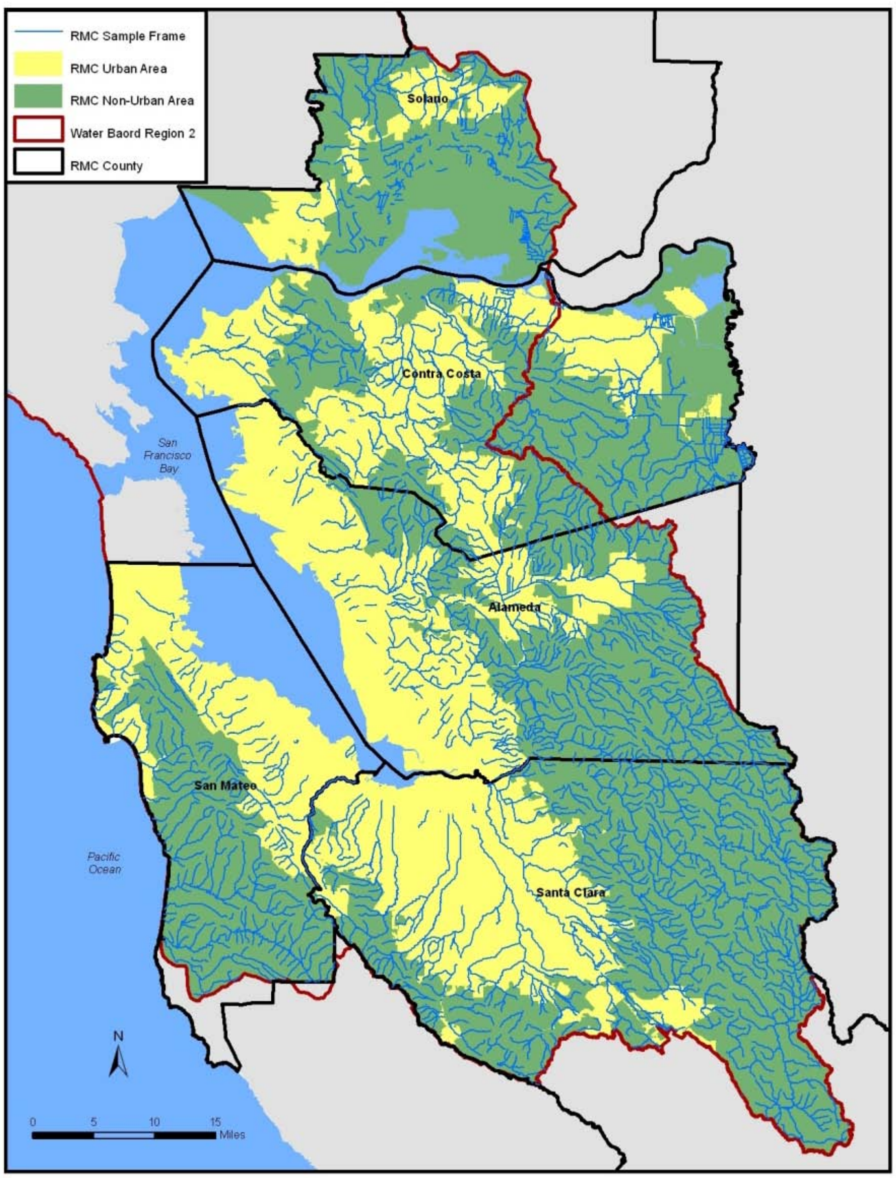
c One sample for Fairfield-Suisun and Vallejo combined

2.0 Study Area and Monitoring Design

2.1 RMC 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.

Figure 2-1. Map of BASMAA RMC Area, County Boundaries and Major Creeks



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 (USEPA) and Oregon State University (Stevens and Olson, 2004). GRTS offers multiple benefits for coordinating amongst monitoring entities including the ability to develop a spatially balanced design that produces statistically representative data with known confidence intervals. The GRTS approach has been implemented recently in California by several agencies including the statewide Perennial Streams Assessment (PSA) conducted by SWAMP (Ode et al., 2011) and the regional monitoring performed by the Southern California Stormwater Monitoring Coalition (SMC, 2007). For the purpose of developing the RMC's probabilistic design, the RMC area is considered to define the sample frame and represent the "sample universe."

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 management questions about regional water quality and beneficial use conditions in the creeks of the San Francisco Bay Area.

2.2.1 Management Questions

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

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

These questions can be more fully answered on both a regional and county-specific basis in future years, once sample sizes increase, and upon implementation of a region-wide approach to data analysis.

2.2.2 Site Selection

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 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. RMC participants coordinated with the SFBRWQCB by identifying additional non-urban sites from their respective counties for SWAMP sampling.

2.3 Monitoring Design Implementation

Status and trends monitoring was conducted in non-tidally influenced, flowing water bodies (i.e., creeks, streams and rivers), at sites selected from the master list produced by the GRTS random draw. Methods used to evaluate sites and conduct the required monitoring are described in section 3.

3.0 Monitoring Methods

Monitoring data were collected following the BASMAA RMC quality assurance plan and standard operating procedures (BASMAA 2016a; BASMAA 2016b). Monitoring data were collected using comparable methods to those outlined in the California Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance Project Plan and were submitted electronically in SWAMP-compatible format by FSURMP and VFWD to SFBRWQCB pursuant to Provision C.8.h.

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 that described by SCCWRP[1] (2012). Each site was evaluated to determine if it met the following RMC sampling location criteria:

1. The location (latitude/longitude) provided for a site is located on or is within 300 meters (m) of a non-impounded receiving water body.
2. Site is not tidally influenced.
3. Site is wadeable during the sampling index period.
4. Site has sufficient flow during the sampling index period to support standard operation procedures for biological and nutrient sampling.
5. Site is physically accessible and can be entered safely at the time of sampling.
6. Site may be physically accessed and sampled within a single day.
7. Landowner(s) grant permission to access the site.[2]

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

Site evaluations were completed during the second step via field reconnaissance visits. Based on the outcome of site evaluations, sites were classified into one of four categories:

- **Target** – Sites that met all seven criteria above were classified as **target sampleable** status **(TS),** and sites that met criteria 1 through 4, but did not meet at least one of criteria 5 through 7 were classified as **target non-sampleable (TNS)**.
- **Non-Target (NT)** – Sites that did not meet 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 that the site was a valid receiving water body and information for any of the seven criteria was unconfirmed.

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

- Wet Flowing (continuously wet or nearly so, flowing water)

[1] Communication with managers for the SMC and the PSA are ongoing to ensure the consistency of site evaluation protocols.
[2] 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.

- Wet Trickle (continuously wet or nearly so, very low flow (trickle, less than 0.1 L/second)
- Majority Wet (discontinuously wet, greater than 25% by length of stream bed covered with water (isolated pools)
- Minority Wet (discontinuously wet, less than 25% of stream bed by length covered with water (isolated pools)
- No Water (no surface water present)

Observations of flow status occurring during fall site reconnaissance events prior to occurrence of significant precipitation, and spring sampling occurring post-wet-weather season 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.

3.1.1 WY 2017 Monitoring Sites

During Water Year 2017 (October 1, 2016 –September 30, 2017) regional/probabilistic monitoring was conducted at four sites in Fairfield-Suisun. Regional/probabilistic parameters were monitored at the regional/probabilistic locations listed in Table 3-1, and as shown in Figure 3-1.

Table 3-1. Regional/probabilistic sites and monitoring parameters monitored in Water Year 2017 in Solano County.

Site ID	Creek Name	Latitude	Longitude	Sample Date	Bioassessment, Water, Chemistry, PHab	Water Toxicity	Sediment Chemistry & Toxicity	Chlorine
207R03132	Jameson Canyon Creek	38.20402	-122.14593	05/08/2017	X			X
207R03388	Jameson Canyon Creek	38.20491	-122.15027	05/25/2017	X			X
207R03116	Laurel Creek	38.254	-122.02067	06/01/2017	X	X	X	X
207R03344	McCoy Creek	38.2506	-122.0063	06/08/2017	X			X

Note: latitudes/longitudes are as measured in the field

Figure 3-1. Regional/probabilistic sites monitored in Solano County in Water Year 2017.

Note: All bioassessment sites were monitored for water chemistry and chlorine in the spring. The Triad site was monitored for bioassessment, water chemistry and chlorine in the spring and for water/sediment toxicity, sediment chemistry and chlorine in the fall.

3.2 Field Sampling and Data Collection Methods

Field data and samples were collected in accordance with SWAMP-comparable methods and procedures, as described in the RMC QAPP (BASMAA, 2016a) and associated SOPs (BASMAA, 2016b). The SOPs were developed using a standard format including health and safety cautions and considerations. Sampling methods and procedures include pre-fieldwork mobilization activities to prepare equipment 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.

Table 3-2. RMC Standard Operating Procedures (SOPs) Pertaining to Regional Creek Status Monitoring

SOP #	Procedure
FS-1	BMI and algae bioassessments and physical habitat assessments
FS-2	Manual Collection of Water Samples for Chemical Analysis, Bacteriological Analysis, and Toxicity Testing
FS-3	Manual Field measurements
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 ID naming conventions
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 m stream reach that was divided into 11 equidistant transects placed perpendicular to the direction of flow. The sampling position within each transect alternated between 25%, 50%, and 75% distance of the wetted width of the stream (see SOP FS-1, BASMAA, 2016b).

Benthic Macroinvertebrates

BMIs were collected via kick-net sampling using the Reach-wide Benthos (RWB) method described in RMC SOP FS-1 (BASMAA, 2016b). Samples were collected from a 1-square-foot area approximately 1 m downstream of each transect. The benthos were disturbed by manually rubbing areas of coarse substrate, followed by disturbing the upper layers of finer substrate to a depth of 4–6 inches to dislodge any remaining invertebrates into the net. Slack water habitat procedures were used at transects with deep and/or slow-moving water (Ode, 2007). 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% ethanol.

Algae

Filamentous algae and diatoms also were collected using the Reach-wide Benthos (RWB) method described in SOP FS-1 (BASMAA, 2016b), based on the SWAMP Bioassessment Wadeable Streams Protocol (Ode et al. 2007). Algae samples were collected synoptically with BMI samples. The sampling position within each transect was the same as used for BMI sampling, except that algae samples were collected six 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 particular substrate occurring at the site (i.e., erosional, depositional, large and/or immobile, etc.) per RMC SOP FS-1. Erosional substrates included any material (substrate or organics) that was small enough to be removed from the stream bed, but large enough in size to isolate an area equal in size 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 40 mL subsample was extracted from the algae composite sample and combined with 10 mL of 10% formalin into a 50 mL sample tube for taxonomic identification of diatoms. Similarly, a 45 mL subsample was taken from the algae composite sample and put in a 50 mL tube for taxonomic identification of soft algae. These samples were shipped overnight on ice to the laboratory for analysis. Upon receipt, 5 mL glutaraldehyde was added to the soft algae tube to preserve the sample.

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 using pre-combusted filters. Both filter samples were placed in Whirl-Paks, covered in aluminum foil, and immediately placed on ice for transport to the analytical laboratory.

Physical Habitat

Physical habitat assessments (PHab) were conducted at each BMI bioassessment sampling event using the PHab protocols described in Ode (2007) (see SOP FS-1, BASMAA, 2016b). Physical habitat data were collected at each of the 11 transects and at 10 additional inter-transects (located between each main transect) by implementing the “Basic” level of effort, with the following additional measurements and assessments as defined in the “Full” level of effort (as prescribed in the MRP): water depth and pebble counts, cobble embeddedness, flow habitat delineation, and instream habitat complexity. At algae sampling locations, additional assessment of presence of micro- and macroalgae was conducted during the pebble counts. In addition, water velocities were measured at a single location in the sample reach (when possible) using protocols described in Ode (2007).

3.2.2 Physicochemical Measurements

Dissolved oxygen, temperature, conductivity, and pH were measured during bioassessment sampling 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 0.1 m below the water surface at locations of the stream that appears to be completely mixed, ideally at the centroid of the stream. Measurements occurred upstream of sampling personnel and equipment and upstream of areas where bed sediments had been disturbed, or prior to such bed disturbance.

3.2.3 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), associated with bioassessment monitoring. Sample containers were rinsed, as appropriate, using ambient water and completely filled and recapped below water surface whenever possible. An intermediate container was used to collect water for all sample containers with preservative already added in advance by 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, with the exception of analysis of AFDM and chlorophyll-a samples, which were field-frozen on dry ice by some sampling teams where appropriate.

3.2.4 Chlorine

Water samples were collected and analyzed for free and total chlorine using a Hach Pocket Colorimeter. Chlorine measurements in water were conducted during spring bioassessments and during dry season monitoring for sediment chemistry, sediment toxicity, and water toxicity.

3.2.5 Water Toxicity

Samples were collected using the Standard Grab Sample Collection Method described above, filling the required number of 2.25-L labeled amber glass bottles with ambient water, putting them on ice to cool to 4°C ± 2°C, and delivering to the laboratory within the required hold time. Bottle labels include station ID, sample code, matrix type, analysis type, project ID, and date and time of collection. The laboratory was notified of the impending sample delivery to meet the 24-hour sample delivery time requirement. Procedures used for sampling and transporting samples 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 / measurements were collected at the same event, sediment samples were collected after any 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 started 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 aliquotted into separate jars for chemical and toxicological analysis using standard clean sampling techniques (see SOP FS-6, BASMAA, 2016b). Sample jars were submitted to respective laboratories per SOP FS-9 (BASMAA, 2016b).

3.3 Laboratory Analysis Methods

RMC participants agreed to use the same laboratory for individual parameters, developed standards for contracting with the labs, and coordinated quality assurance issues. All samples collected by RMC participants that were sent to laboratories for analysis were analyzed and reported per SWAMP-comparable methods as described in the RMC QAPP (BASMAA, 2016a). Analytical laboratory methods, reporting limits and holding times for chemical water quality parameters are also reported in the WY 2012 UCMR BASMAA (2012a). 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 according to 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. Diatom and soft algae identifications were harmonized with the California Algae and Diatom Taxonomic Working Group’s Master Taxa List. Laboratory processing included identification and enumeration of 300 natural units of soft algae and 600 diatom valves to the lowest practical taxonomic level.
- CalTest, Inc. – water chemistry (nutrients etc.), sediment chemistry, chlorophyll-a, AFDM. Upon receipt at the laboratory, samples were immediately logged and preserved as necessary. USEPA-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 according to species-specific protocols published by USEPA.

3.4 Data Analysis

In this report only the data collected by Solano County permittees during WY 2017 for regional/probabilistic parameters are presented and analyzed. This includes data collected during bioassessment monitoring, which includes BMI and algae taxonomy, water chemistry and physical habitat evaluations at four sites, as well as water and sediment toxicity and sediment chemistry data from one of those four sites. The bioassessment data are then used to evaluate stream conditions, and the associated physical, chemical and toxicity testing data are then analyzed to identify potential stressors that may be impacting 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, and report on those per MRP Provision C.8.h.iii.

The creek status monitoring results are subject to potential follow-up actions, per MRP 2 provisions C.8.d and C.8.g, if they meet certain 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. Planned SSID projects are summarized for the RMC region in tabular form in Appendix C of the Solano WY 2017 UCMR.

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 the 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.

Analysis of MRP Provision C.8.d monitoring data for local/targeted parameters (not included in the probabilistic design) is reported in the Local/Targeted Creek Status Monitoring Report (Appendix B of the Solano WY 2017 UCMR).

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 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

In this report the biological condition of each probabilistic site monitored in Solano County in WY 2017 was evaluated principally through analysis of BMI and algal taxonomic metrics, and calculation of associated benthic index of biological integrity (B-IBI) and algal index of biological integrity (A-IBI) scores. An IBI is an analytical tool involving calculation of a site condition score based on a compendium of biological metrics.

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. A GIS system is used to derive expected biological conditions based on modeled geophysical characteristics of the watershed upstream of the sampling site.

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.

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 using PHab scores. For this report, 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) that each can be scored for a total of 0–20 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 LC50 values (LC50 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 LC50 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 & 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 field data 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, and laboratories provide internal QA/QC data for review by RMC Program staff.

Results from field work and laboratory assessments were reviewed by the local Program Quality Assurance Officers for each Program. 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.

4.0 Results

4.1 Statement of Data Quality

Field data sheets and lab reports were reviewed by the local Program Quality Assurance Officer and the results were evaluated against the appropriate DQOs. Results were compiled for both qualitative (representativeness and comparability) and quantitative metrics (completeness, precision, and accuracy). Identified QA/QC issues are briefly summarized below by analytical category.

4.1.1 Bioassessment

The New Zealand mudsnail (*Potamopyrgus antipodarum*), a non-native invasive species, was confirmed at one of the four Solano County sites: 207R03116 (Laurel Creek). This finding is not a QA/QC issue *per se*, but requires that field crews take special precautions to effectively decontaminate equipment so as to prevent cross-contamination and transfer of the invasive mud snail between sites.

4.1.2 Sediment Chemistry

No significant issues reported.

4.1.3 Water Chemistry

No significant issues reported.

4.1.4 Sediment Toxicity

No significant issues reported.

4.1.5 Water Toxicity

No significant issues reported.

4.2 Biological Condition Assessment

Condition assessment addresses the RMC core management question “What is the condition of aquatic life in creeks in the RMC area; 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 in Solano County during WY 2017 are shown in Table 4-1. Properties of the aquatic life use indicators used for this condition assessment that were observed at the Solano County sites monitored in WY 2017 are reported in Sections 4.2.1 (benthic macroinvertebrates) and 4.2.2 (algae), and discussed in relation to the designated aquatic life beneficial uses in section 4.2.3. Due to the relatively small sample size available after the third year of implementing the RMC regional probabilistic monitoring design, results are presented only in terms of the available data from urbanized portions of Solano County. Future reports may provide additional analysis at the countywide program and regional levels, as well as comparisons between urban and non-urban land use sites.

4.2.1 Benthic Macroinvertebrate Metrics

BMI taxonomic metrics are shown in Table 4-2 for the Solano County creek status sites monitored in the spring index period of WY 2017.

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 geophysical 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 geophysical characteristics). Environmental predictor data were generated in GIS (as described below) using the upstream drainage area of each bioassessment sampling location.

The watershed boundaries for the four monitored sites were derived from the USGS web mapping tool StreamStats (v. 4), using the site GPS locations as measured in the field and provided by Solano RCD. The delineated watershed/catchment areas were reviewed for accuracy using ArcGIS 10.6 and Google Earth. The resulting watershed delineations are illustrated in Figure 4-1.

The watershed boundaries were merged in ArcGIS and analyzed to calculate a range of environmental predictors necessary for the CSCI score calculations, including site elevation, temperature, annual precipitation, elevation range, mean monthly precipitation, bulk soil density, soil erodibility, and phosphorous geology.

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 site with a CSCI score of less than 0.795 is considered to be biologically “degraded”, and should be evaluated for consideration as a possible SSID study location.

The results of the CSCI calculations are presented in Table 4-3. As shown in Table 4-3, every Solano County 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.

The two Jameson Canyon Creek watersheds are substantially smaller in size and somewhat higher in elevation and produced substantially higher CSCI scores than the Laurel Creek and McCoy Creek sites.

Table 4-1. Creeks monitored in WY 2017 and, where they exist, associated designated beneficial uses listed in the San Francisco Bay Region Basin Plan (SFBRWQCB 2015).

Site ID	Waterbody monitored	AGR	MUN	FRSH	GWR	IND	PROC	COMM	SHELL	COLD	EST	MAR	MIGR	RARE	SPWN	WARM	WILD	REC-1	REC-2	NAV
SOLANO COUNTY																				
207R03132	Jameson Canyon Creek																			
207R03388	Jameson Canyon Creek																			
207R03116	Laurel Creek			E						E			E		E	E	E	E	E	
207R03344	McCoy Creek																			

Notes:

COLD = Cold Fresh Water Habitat
FRSH = Freshwater Replenishment
GWR - Groundwater Recharge
MIGR = Fish Migration
MUN = Municipal and Domestic Water

NAV = Navigation
RARE= Preservation of Rare and Endangered Species
REC-1 = Water Contact Recreation
REC-2 = Non-contact Recreation

WARM = Warm Freshwater Habitat
WILD = Wildlife Habitat
P = Potential Use
E = Existing Use
L = Limited Use.
* = “Water quality objectives apply; water contact recreation is prohibited or limited to protect public health” (SFBRWQCB 2013).

Table 4-2. BMI Metrics for Solano County Bioassessment Sites Monitored in Water Year 2017

	FSURMP Bioassessment Sites, Spring 2017			
Metrics	**Jameson Canyon Creek 207R03132**	**Jameson Canyon Creek 207R03388**	**Laurel Creek 207R03116**	**McCoy Creek 207R03344**
Richness:				
Taxonomic	21	20	17	18
EPT	5	4	1	1
Ephemeroptera	4	3	1	0
Plecoptera	1	0	0	0
Trichoptera	0	1	0	1
Coleoptera	3	2	0	1
Predator	8	7	3	6
Diptera	9	8	4	7
Composition:				
EPT Index (%)	10	6.2	0.8	0.7
Sensitive EPT Index (%)	0.8	0.2	0.0	0.7
Shannon Diversity	1.67	1.66	1.93	1.89
Dominant Taxon (%)	31	45	39	29
Non-insect Taxa (%)	19	25	59	39
Tolerance:				
Tolerance Value	5.6	5.8	6.8	6.1
Intolerant Organisms (%)	1.0	0.5	0.0	0.0
Intolerant Taxa (%)	14	15	0.0	0.0
Tolerant Organisms (%)	2.2	2.8	53	18
Tolerant Taxa (%)	19	25	41	33
Functional Feeding Groups:				
Collector-Gatherers (%)	66	77	52	86
Collector-Filterers (%)	31	16	4.7	3.1
Scrapers (%)	97	93	56	89
Predators (%)	0.2	0.3	39	0.8
Shredders (%)	3.0	6.9	3.7	9.4
Other (%)	0.2	0.2	0.0	0.0
Estimated Abundance:	0.0	0.0	0.8	0.7
Composite Sample (11 ft^2)				
#/ft^2	2143	1627	751	819
#/m^2	195	148	68	74
SoCal B-IBI	**39**	**31**	**16**	**13**
B-IBI Condition Category	Poor	Poor	Very Poor	Very Poor

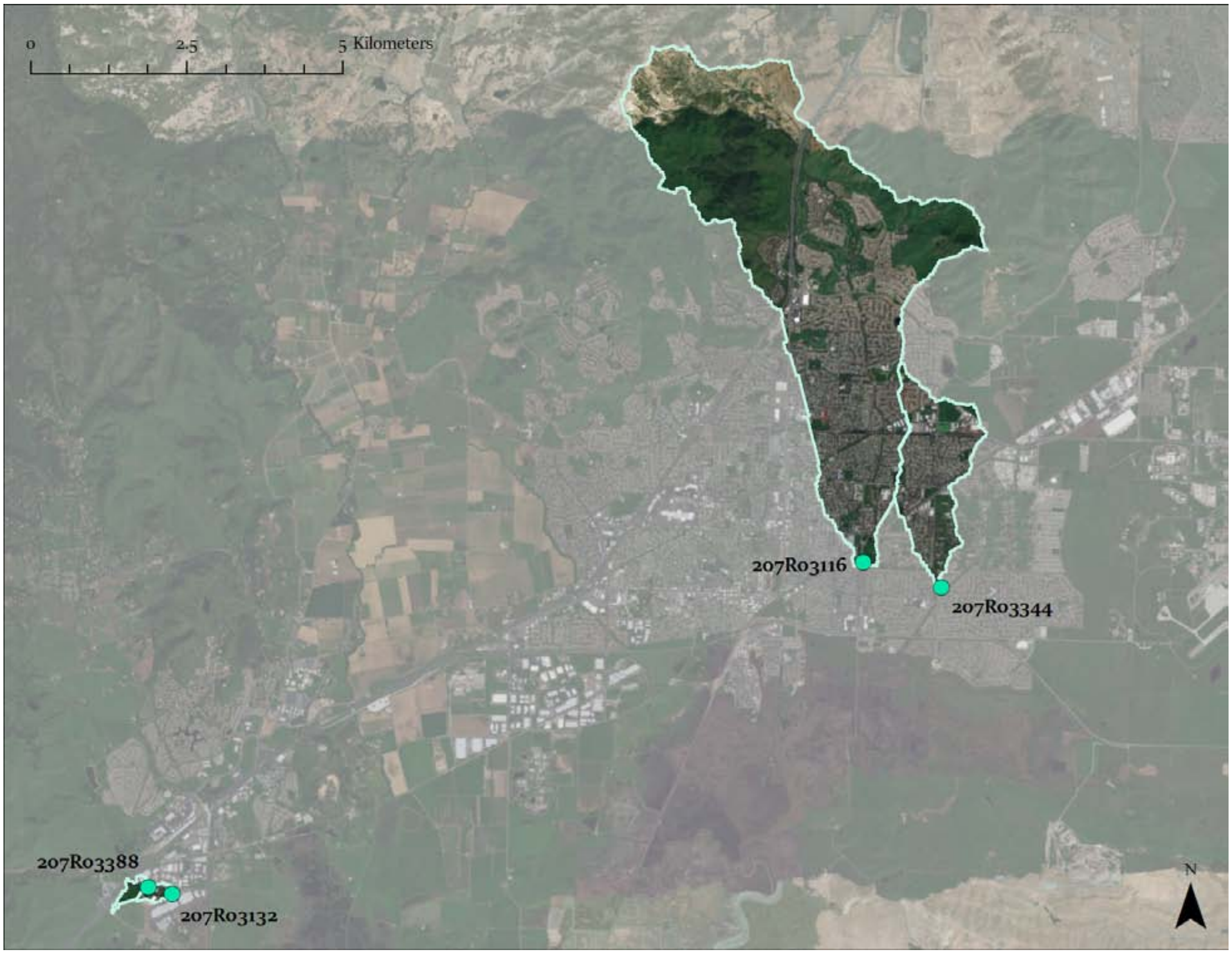


Figure 4-1. Delineated watersheds for bioassessment sites monitored in Solano County in WY 2017.

Table 4-3: Results of CSCI Calculations for Solano County Bioassessment Sites Sampled in WY 2017.

Station Code	Waterbody	Sample Date	Area (km^2)	Elevation (m)	Land Use	Percent Impervious Area (%)	Total Number Unique Taxa	CSCI Score
207R03132	Jameson Canyon Creek	5/18/2017	0.3	13	Urban	23	25	0.67
207R03388	Jameson Canyon Creek	5/23/2017	0.1	19	Urban	48	23	0.66
207R03116	Laurel Creek	6/1/2017	18.1	8	Urban	23	18	0.39
207R03344	McCoy Creek	6/8/2017	2.8	5	Urban	27	21	0.43

4.2.2 Algae Metrics

During WY 2017 algae samples were collected as part of the bioassessment monitoring at four sites in Fairfield-Suisun. 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, eleven soft algae metrics, and five IBIs (D18, H20, H21, H23, S2) were calculated from the taxonomic data, following work performed on Southern California streams (Fetscher et al. 2014).

The five calculated A-IBI scores are shown in summary in Table 4-4 for each bioassessment site monitored in WY 2017. A discussion of the results for each of the five IBIs follows.

The average D18 diatom IBI score across the four sites was 28.5 (Table 4-5). The highest score (40) occurred at sites 207R03116 and 207R03388 while site 207R003344 had the lowest score (2). The two high sites had similar proportions of diatoms requiring >50% dissolved oxygen (DO) saturation and sediment tolerant/highly motile diatoms, but different proportions of halobiontic (0.52 vs 0.341) and nitrogen heterotrophs (0.104 vs 0.254) suggesting site 207R03388 may have less dissolved salts but more nitrogen in the system (Table 4-6). Site 207R03344 had the highest proportions of halobiontic, nitrogen autotrophs, and sediment tolerant/highly motile diatom species. All four sites had less than 2% of diatom species indicative of low total phosphorous levels suggesting phosphorous is not a limiting factor in these streams. Planothidium spp was dominant at sites 207R03132 and 207R03388 while also occurring at site 207R03116. Nitzschia spp also occurred in the top five dominant list at all sites except 207R03116. 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 25.75 but the scores among the sites differed with site 207R03116 (68) scoring much higher than the other three sites (≤17; Table 4-7). Site 207R03116 had low proportions of high copper (CU), non-reference, and green algae belonging to CRUS (Cladophora glomerata, Rhizoclonium hieroglyphicum, Ulva flexuosa, and Stigeoclonium spp) indicators and about half of the biovolume from ZHR (Zygnemataceae, heterocystous cyanobacteria, Rhodophyta) taxa (Table 4-8). All soft algae with attribute traits at site 207R03132 represent conditions of high copper, DOC, and non-reference conditions along with zero ZHR taxa. The other two lower scoring sites also had higher proportions and biovolumes of taxa associated with non-reference, high DOC status and belonging to CRUS. The biovolume at site 207R03116 was dominated by Vaucheria sp (50%) and Spirogyra sp (50%) while Chlorophyta (99.7%), Ulva flexuosa (97.9%), and Cladophora glomerata (44.5%) dominated the other three sites (207R03132, 207R03344, 207R03388, respectively). Site 207R03344 also had a high percentage of Oedogonium spp. All sites had zero species indicative of low total phosphorous concentrations. 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 (207R03116) and lowest (207R03344) scoring sites (Tables 4-9, 4-10, 4-11). H20 had a closer grouping of scores between the highest and lowest score while H21 and H23 were similar across sites. The main differences in the H20 IBI scores were due to the proportion of soft algae indicative of high copper and high DOC concentrations and diatom nitrogen heterotrophs. H21 IBI scores were driven by the biomass proportion of Chlorophyta and ZHR soft algae as well as the proportion of diatom nitrogen heterotrophs. The proportion of soft algae ZHR and CRUS taxa affected the differences in H23 IBI scores as well as the proportion of diatom nitrogen heterotrophs. 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 207R03116 (Laurel Creek) had the highest score across all five IBIs (D18, S2, H20, H21, H23). Site 207R03344 (McCoy Creek) had the lowest score for all five IBIs (D18, S2, H20, H21, H23). The diatom community appears to be healthier than the soft algae community at sites 207R03132 and 207R03388 when comparing the D18 and S2 scores. The proportion of diatom and algae species indicative of low total phosphorous (TP) and low total nitrogen (TN) concentrations was low or nonexistent at all four sites suggesting sufficient levels of phosphorous and nitrogen in the streams. The proportion of diatom nitrogen heterotrophs also indicated lower levels of nitrogen fixers at the higher scoring site 207R03116 and higher numbers of nitrogen fixers at the lowest scoring site 207R03344. The presence of halobiontic and sediment tolerant, highly motile diatom species affected scores across IBIs, especially for site 207R03344, suggesting the importance of low ionic strength/salinities and sediment qualities on a stronger diatom community. Soft algae scores were affected by the proportion of taxonomic groups and lack of species found within sites suggesting an impacted community at sites 207R03344 and 207R03388 as well as high proportions of taxa suggesting high copper and DOC at site 207R03132. Finally, the results should be interpreted with some caution since some of the signal may be due to a lack of assigned traits for SWAMP FinalIDs rather than environmental effects.

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 defined 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 Solano County Stations Sampled in 2017.

Station Code	Waterbody	Sample Date	D18 IBI Score	S2 IBI Score	H20 IBI Score	H21 IBI Score	H23 IBI Score
207R03132	Jameson Canyon Creek	5/18/2017	32	17	20	33	32
207R03388	Jameson Canyon Creek	5/23/2017	40	15	34	36	32
207R03116	Laurel Creek	6/1/2017	40	68	42	50	51
207R03344	McCoy Creek	6/8/2017	2	3	2	1	2

Table 4-5: Diatom IBI (D18) and individual metric scores for Solano County stations sampled in 2017.

Station Code	Waterbody	Sample Date	D18 IBI Score	Proportion halobiontic (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
207R03132	Jameson Canyon Creek	5/18/2017	32	2	1	2	6	5
207R03388	Jameson Canyon Creek	5/23/2017	40	4	1	5	5	5
207R03116	Laurel Creek	6/1/2017	40	1	1	8	4	6
207R03344	McCoy Creek	6/8/2017	2	0	1	0	0	0

Table 4-6: Diatom metric results for Solano County stations sampled in 2017.

Station Code	Sample Date	Proportion A minutissimum (d)	Proportion halobiontic (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)
207R03132	5/18/2017	0.005	0.423	0.257	0.014	0.014	0.398	0.154	0.971	0.838	0.012	0.257
207R03388	5/23/2017	0.002	0.341	0.25	0.013	0.013	0.254	0.358	0.9	0.833	0.012	0.25
207R03116	6/1/2017	0.007	0.52	0.202	0.012	0.021	0.104	0.66	0.889	0.758	0.072	0.227
207R03344	6/8/2017	0.003	0.811	0.525	0.019	0.019	0.532	0.217	0.95	0.5	0.026	0.717

Table 4-7: Soft Algae IBI (S2) and individual metric scores for Solano County stations sampled in 2017.

Station Code	Waterbody	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 of green algae belonging to CRUS (s, b) Score	Proportion ZHR (s, m) Score
207R03132	Jameson Canyon Creek	5/18/2017	17	0	0	0	0	10	0
207R03388	Jameson Canyon Creek	5/23/2017	15	3	4	0	0	2	0
207R03116	Laurel Creek	6/1/2017	68	10	4	0	10	10	7
207R03344	McCoy Creek	6/8/2017	3	1	0	0	0	1	0

Table 4-8: Soft algae metric results for Solano County stations sampled 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 of green algae belonging to CRUS (s, b)	Proportion ZHR (s, b)	Proportion ZHR (s, m)
207R03132	5/18/2017	1	1	0	1	0	0.283	0	0	0	0	0
207R03388	5/23/2017	0.25	0.5	0	0.5	0	0.505	0.505	0.505	0.882	0	0
207R03116	6/1/2017	0	0.5	0	0	0.333	0	0.5	0	0	0.5	0.417
207R03344	6/8/2017	0.333	0.714	0	0.571	0	1	1	1	0.989	0	0

Table 4-9: Hybrid (diatom and soft algae) IBI (H20) and individual metric scores for Solano County stations sampled in 2017.

Station Code	Waterbody	Sample Date	H20 IBI Score	Proportion halobiontic (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
207R03132	Jameson Canyon Creek	5/18/2017	20	2	0	0	1	0	2	6	5
207R03388	Jameson Canyon Creek	5/23/2017	34	4	3	4	1	0	5	5	5
207R03116	Laurel Creek	6/1/2017	42	1	10	4	1	0	8	4	6
207R03344	McCoy Creek	6/8/2017	2	0	1	0	1	0	0	0	0

Table 4-10: Hybrid (diatom and soft algae) IBI (H21) and individual metric scores for Solano County stations sampled in 2017.

Station Code	Waterbody	Sample Date	H21 IBI Score	Proportion Chlorophyta (s, b) Score	Proportion halobiontic (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
207R03132	Jameson Canyon Creek	5/18/2017	33	7	2	1	2	6	5	0
207R03388	Jameson Canyon Creek	5/23/2017	36	5	4	1	5	5	5	0
207R03116	Laurel Creek	6/1/2017	50	10	1	1	8	4	6	5
207R03344	McCoy Creek	6/8/2017	1	0	0	1	0	0	0	0

Table 4-11: Hybrid (diatom and soft algae) IBI (H23) and individual metric scores for Solano County stations sampled in 2017.

Station Code	Waterbody	Sample Date	H23 IBI Score	Proportion halobiontic (d) Score	Proportion high DOC indicators (s, sp) Score	Proportion low TP indicators (d) Score	Proportion N heterotrophs (d) Score	Proportion of 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
207R03132	Jameson Canyon Creek	5/18/2017	32	2	0	1	2	10	6	5	0
207R03388	Jameson Canyon Creek	5/23/2017	32	4	4	1	5	2	5	5	0
207R03116	Laurel Creek	6/1/2017	51	1	4	1	8	10	4	6	7
207R03344	McCoy Creek	6/8/2017	2	0	0	1	0	1	0	0	0

4.2.3 Analysis of Biological Condition Indicators

The condition assessment relies upon the observed B-IBI scores, as the algae IBI scores and metrics are still considered preliminary. As indicated below, the B-IBI scoring scheme options need to be further investigated, developed, and tested specifically for SF Bay Area creeks.

As indicated in Table 4-1, most of the bioassessment sites (3 of 4) monitored by Solano County for the RMC during Water Year 2017 do not have designated beneficial uses. However, most urban streams in the County that do have designated beneficial uses have both the WARM (warm water fishery) beneficial use and the COLD (cold water fishery) beneficial use. To the extent that benthic conditions may reflect or influence the viability of the fisheries in these water bodies, it may be assumed that benthic conditions in the lower categories (poor or very poor for SoCal B-IBI, CSCI scores below the acceptable MRP threshold) may indicate some difficulty in supporting the designated aquatic life beneficial uses.

Using the SoCal B-IBI scores and the CSCI scores, all four of the urban sites monitored in Solano County in WY 2017 would be considered potentially deficient regarding biological conditions necessary to support a viable fishery. In the absence of an available B-IBI developed for the San Francisco Bay Region, the SoCal B-IBI was used principally to assess the condition of BMI data sampled in the RMC area, and therefore these results should be considered provisional.

In comparing the biological condition results for the four sites monitored in WY 2-17:

- The highest SoCal B-IBI scores were produced at the two Jameson Canyon Creek sites
- The highest CSCI scores were produced at the two Jameson Canyon Creek sites
- The highest A-IBI scores on all five algae indices were produced at the Laurel Creek site
- The lowest A-IBI scores on all five algae indices were produced at the McCoy Creek site

4.3 Stressor Assessment

This section addresses the question, what are major stressors to aquatic life in the RMC area? The biological, chemical, physical and toxicity testing data produced by Solano permittees in WY 2017 were compiled and evaluated, and analyzed against the MRP 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). In the compilation of statistics for analytical chemistry that follow, when feasible, non-detect data (ND) were substituted with a concentration equal to one-half of the respective MDL as reported by the laboratory.

4.3.1 Physical Habitat Parameters

A wide range of physical habitat characteristics can influence the biological conditions of urban streams. Physical habitat condition was assessed on a preliminary basis using PHab scores (Table 4-12), computed for Solano County sites from three physical habitat attributes (epifaunal substrate/cover, sediment deposition, and channel alteration) measured in the field during bioassessment monitoring in Water Year 2017. The composite PHab score has a possible range from 0 to 60, with each of the contributing factors scored on a range of 0–20 points. Higher PHab scores reflect higher-quality habitat.

The two Jameson Canyon Creek sites, which produced the highest B-IBI and CSCI scores, also produced the highest Mini-PHab scores, while the McCoy Creek site, which produced the lowest algae IBI scores and also had lower B-IBI and CSCI scores, also produced the lowest pHab score, indicating that physical habitat characteristics may play a role in the quality of benthic invertebrate and algal biotic community composition at those sites.

Table 4-12. Physical Habitat Scores for Solano County Bioassessment Sites Monitored in WY 2017

Site Code	Creek name	Sample Date	Epifaunal Substrate	Sediment Deposition	Channel Alteration	Mini-PHab Score
207R03132	Jameson Canyon Creek	5/18/2017	10	4	15	29
207R03388	Jameson Canyon Creek	5/25/2017	10	7	13	30
207R03116	Laurel Creek	6/1/2017	8	2	13	23
207R03344	McCoy Creek	6/8/2017	4	5	6	15

4.3.2 Water Chemistry Parameters

The results of the water quality testing for samples collected as part of the WY 2017 bioassessment monitoring are shown in Table 4-13. Table 4-14 provides a summary of descriptive statistics for the nutrients and related conventional constituents collected in association with bioassessment monitoring. For the purposes of data analysis, Total Nitrogen was calculated as the sum of nitrate + nitrite + Total Kjeldahl Nitrogen (TKN).

At all four 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 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-plus-nitrite – 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. The only observed exceedance of the applicable criteria in WY 2017 occurred at the McCoy Creek site (207R03344), where the chloride value of 400 mg/L exceeded the water quality criterion. As noted below, this site also experienced unusually high chlorine measurements.

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, all four water samples produced measurable levels of free and total chlorine. In the case of Laurel Creek and McCoy Creek, the measured levels exceeded the MRP threshold of 0.1 mg/L; the McCoy Creek site measurements were particularly notable. Both Laurel Creek and McCoy Creek contain substantial flow from urban runoff sources. It is possible that the draining of a residential swimming pool caused one or both of these measurements. These conditions will be further investigated.

Table 4-13. Water Chemistry Results for Samples Collected in Water Year 2017

		FSURMP Bioassessment Sites, Spring 2017			
		Jameson Canyon Creek	Jameson Canyon Creek	Laurel Creek	McCoy Creek
Analyte	**Units**	207R03132	207R03388	207R03116	207R03344
Ammonia as N	mg/L	0.032	ND	0.07	0.25
Ash Free Dry Mass	mg/L	2160	5020	51700	20900
Chloride	mg/L	100	110	70	400
Chlorophyll a	mg/m^3	110	890	530	1600
Nitrate as N	mg/L	ND	ND	0.39	0.52
Nitrite as N	mg/L	0.001	0.002	0.007	0.013
Nitrogen, Total Kjeldahl	mg/L	0.48	0.66	0.7	1.0
Nitrogen, Total *	mg/L	0.48	0.66	1.10	1.53
OrthoPhosphate as P	mg/L	0.031	0.018	0.025	0.036
Phosphorus as P	mg/L	0.042	0.045	0.042	0.072
Silica as SiO2	mg/L	24	27	19	9.2

ND = non-detect
*Total nitrogen calculated as sum of Nitrite+Nitrate+TKN

Table 4-14. Descriptive Statistics for Water Chemistry Results Collected in Water Year 2017

Analyte	Units	Mean	Min.	Max.	N	N ≥ MDL
Ammonia as N	mg/L	0.117	0.032	0.25	4	3
Ash Free Dry Mass	mg/L	19945	2160	51700	4	4
Chloride	mg/L	170	70	400	4	4
Chlorophyll a	mg/m^3	782.5	110	1600	4	4
Nitrate as N	mg/L	0.455	0.39	0.52	4	2
Nitrite as N	mg/L	0.006	0.001	0.013	4	4
Nitrogen, Total Kjeldahl	mg/L	0.71	0.48	1.00	4	4
Nitrogen, Total *	mg/L	0.94	0.48	1.53	4	4
OrthoPhosphate as P	mg/L	0.028	0.018	0.036	4	4
Phosphorus as P	mg/L	0.05	0.042	0.072	4	4
Silica as SiO2	mg/L	19.8	9.2	27	4	4

ND = non-detect
Non-detects estimated as ½ MDL for calculation of mean
*Total nitrogen calculated as sum of Nitrite+Nitrate+TKN

Table 4-15. Water Quality Thresholds Available for Comparison to Water Year 2017 Water Chemistry Constituents

Sample Parameter	Threshold	Units	Frequency/ Period	Application	Source
Ammonia	0.025	mg/L	Annual median	Unionized 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	USEPA Nat'l. Rec. WQ Criteria, Aquatic Life Criteria
Chloride	860	mg/L	Criteria Maximum Concentration	Freshwater aquatic life	USEPA Nat'l. Rec. WQ 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; CA Code Title 22; USEPA Drinking Water Stds. Secondary MCL
Nitrate + Nitrite (as N)	10	mg/L	Maximum Contaminant Level	Areas designated as Municipal Supply	SF Bay Basin Plan Ch. 3

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]	# of Parameters >Threshold/ Water Body	% of Parameters >Threshold/ Water Body
207R03132	Jameson Canyon Creek	No	0.82	100	0.001	0	0%
207R03388	Jameson Canyon Creek	No	ND	110	0.002	0	0%
207R03116	Laurel Creek	No	2.09	70	0.397	0	0%
207R03344	McCoy Creek	No	1.40	**400**	0.533	1	33%
# Values >Threshold:			0	1	NA		
% Values >Threshold:			0%	25%	NA		

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

NA = threshold does not apply

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?
207R03132	Jameson Canyon Creek	5/18/2017	0.05	0.05	No
207R03388	Jameson Canyon Creek	5/25/2017	0.08	0.05	No
207R03116	Laurel Creek	6/1/2017	0.14	0.13	Yes
207R03344	McCoy Creek	6/8/2017	0.43	0.52	Yes
Number of samples exceeding 0.10 mg/L:			**2**	**2**	
Percentage of samples exceeding 0.10 mg/L:			**50%**	**50%**	

4.3.2 Water and Sediment Toxicity Testing

For water and sediment sample toxicity tests, the MRP 2 threshold for follow-up is exceeded when results indicate a toxicity test of growth, reproduction, or survival of any test organism is reported as "fail" in both the initial sampling, and a second, follow up sampling, and both have ≥ 50 percent effect. This applies to dry and wet weather, water column and sediment tests.

Dry-Season Aquatic Toxicity

Water samples were collected during the summer 2017 period (July 13, 2017) from site 207R03116 (Laurel Creek) and tested for toxic effects using four test species: an aquatic plant (*Selenastrum capricornutum*), three aquatic invertebrates (*Ceriodaphnia dubia*, *Chironomus dilutus, Hyalella azteca*), and one fish species (*Pimephales promelas* or fathead minnow).

There was no chronic or acute toxicity in the dry season water samples to any of the test species.

Dry Season Sediment Toxicity

During the dry season, sediment samples were collected from the same site (site 207R03116, Laurel Creek) where water toxicity samples were collected, and tested for both sediment toxicity and an extensive list of sediment chemistry constituents. For sediment toxicity, testing was performed with *H. azteca* and *C. dilutus*.

There was no toxicity in the dry season sediment samples to either of the test species.

4.3.3 Sediment Chemistry Parameters

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 sediment chemistry results are shown in Table 4-18. Analytes are presented in alphabetical order by chemical analyte group. Only detected constituents are shown; all other constituents were reported as non-detect, including all of the organochlorine pesticides.

Table 4-18. Results of Dry Weather Sediment Chemistry Samples Collected in Water Year 2017 (Detected Constituents Only)

			Site 207R03116 Laurel Creek
Type	**Analyte**	**Units***	**Result**
Metals	Arsenic	mg/Kg	6.5
	Cadmium	mg/Kg	0.22
	Chromium	mg/Kg	27
	Copper	mg/Kg	44
	Lead	mg/Kg	19
	Nickel	mg/Kg	30
	Zinc	mg/Kg	150
Polycyclic Aromatic Hydrocarbons	Dimethylnaphthalene, 2,6-	ng/g	21
	Fluoranthene	ng/g	43
	Pyrene	ng/g	43
Fipronil & Degradates	Fipronil Sulfone	ng/g	1.8
Pyrethroid Pesticides	Bifenthrin	ng/g	18
	Cyfluthrin, total	ng/g	0.87
	Cyhalothrin, total lambda-	ng/g	1.1
	Cypermethrin, total	ng/g	0.66
	Deltamethrin/Tralomethrin	ng/g	3.7
	Permethrin, total	ng/g	5.1
Total Organic Carbon	Total Organic Carbon	%	9.4

* All measurements reported as dry weight

Sediment chemistry results are evaluated as potential stressors in the following ways:

- Calculation of threshold effect concentration (TEC) quotients and probable effect concentration (PEC) quotients for each applicable analyte, using sediment TEC and PEC values provided by MacDonald et al. (2000); determine whether any TEC or PEC quotients are greater than or equal to 1.0 (per MRP threshold criteria; see Table 3-3).
- Calculation of pyrethroid toxic unit (TU) equivalents as sum of TU equivalents for all measured pyrethroids; determine whether site has sum of TU equivalents greater than or equal to 1.0 (per RMC decision, to account for potential pesticide-caused toxicity and conform with MRP 1 data analytical practice).

Constituents that were reported as non-detect were not included in the Total PAHs, TEC ratio, PEC ratio, or pyrethroid TU Equivalents calculations.

Table 4-19 provides calculated TEC quotients and PEC quotients for all non-pyrethroid sediment chemistry constituents, computed as the ratio of the measured concentration divided by the TEC or PEC value, per MacDonald et al. (2000). This table also provides a count of the number of constituents that exceed TEC or PEC values for each site, as evidenced by a TEC or PEC quotient greater than or equal to 1.0.

The monitored site (207R03116, Laurel Creek) exhibited three TEC ratios higher than 1, for the metals copper, nickel, and zinc. These sample results exceed the relevant MRP trigger criterion, and will be included in the ongoing list of threshold exceedances for consideration of potential follow-up as SSID projects.

Table 4-20 provides a summary of the calculated toxic unit equivalents for the pyrethroids for which there are published sediment toxicity (LC50) values in the literature, as well as a sum of calculated toxic unit (TU) equivalents for the monitored site. Because organic carbon mitigates the toxicity of pyrethroid pesticides in sediments, and because the published literature LC50 values are organic carbon-normalized, the LC50 values were derived on the basis of TOC-normalized pyrethroid concentrations. The pyrethroid concentrations as reported by the lab were divided by the measured TOC concentration at each site, and the TOC-normalized concentrations were then used to compute TU equivalents for each pyrethroid. The individual TU equivalents were then summed to produce a total pyrethroid TU equivalent value for the site.

Several pyrethroid pesticides were detected at the Laurel Creek site, with bifenthrin measured at the highest concentration, but when summed, the individual TU Equivalents add up to a TU Equivalent less than 1, as shown in Table 4-20. Therefore this site did not exceed the MRP threshold of a sum of TU Equivalents greater than or equal to 1.0, indicating that the pyrethroid pesticide levels were not likely to be sufficient to cause toxicity in the creek sediments.

Two other pesticides (carbaryl and the fipronil degradate fipronil sulfone) also were detected at relatively low levels.

Table 4-19 Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC) Quotients for WY 2017 Sediment Chemistry Constituents

		Site 207R03116		
		Laurel Creek		
Metals	**Sample Units***	**Sample**	**TEC Ratio**	**PEC Ratio**
Arsenic	mg/Kg	6.5	0.66	0.20
Cadmium	mg/Kg	0.22	0.22	0.04
Chromium	mg/Kg	27	0.62	0.24
Copper	mg/Kg	44	**1.39**	0.30
Lead	mg/Kg	19	0.53	0.15
Mercury	mg/Kg	NA		
Nickel	mg/Kg	30	**1.32**	0.62
Zinc	mg/Kg	150	**1.24**	0.33
Pesticides				
Chlordane	ng/g	NA		
Dieldrin	ng/g	NA		
Endrin	ng/g	NA		
Heptachlor Epoxide	ng/g	NA		
Lindane (gamma-BHC)	ng/g	NA		
Sum DDD	ng/g	NA		
Sum DDE	ng/g	NA		
Sum DDT	ng/g	NA		
Total DDTs	ng/g	NA		
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	43	0.10	0.02
Pyrene	ng/g	43	0.22	0.03
Total PAHs**	ng/g	152.8	0.09	0.007
Number with TECq or PECq ≥ 1.0:			**3**	0
COMBINED TEC RATIOS			6.41	
AVERAGE TEC RATIO			0.64	
COMBINED PEC RATIOS				1.93
AVERAGE PEC RATIO				0.19

* All measurements reported as dry weight

** Total PAHs include 24 individual PAH compounds; NDs were substituted at 1/2 MDL

ND = not detected; NA = not analyzed

Table 4-20. Calculated Pyrethroid Toxic Unit Equivalents, WY 2017 Sediment Chemistry Data

		Site 207R03116		
		Laurel Creek		
Pyrethroid pesticides	**LC50 (µg/g organic carbon)**	**Sample (ng/g)**	**Sample (µg/g organic carbon)**	**TU Equiv.**
Bifenthrin	0.52	18	0.1915	0.368
Cyfluthrin	1.08	0.87	0.0093	0.009
Cyhalothrin, lambda	0.45	1.1	0.0117	0.026
Cypermethrin	0.38	0.66	0.0070	0.018
Deltamethrin	0.79	3.7	0.0394	0.050
Esfenvalerate/Fenvalerate	1.54	ND		
Permethrin	10.8	4.7	0.0500	0.005
Sum (Pyrethroid TUs):				**0.48**

Note: Toxic Unit Equivalents (TUs) are calculated as ratios of measured pyrethroid concentrations to literature *Hyalella azteca* LC50 values. See: http://www.tdcenvironmental.com/resources/Pyrethroids-Aquatic-Tox-Summary.pdf for associated references.

Sediment Triad Analysis

Table 4-21 summarizes stressor evaluation results for those sites with data collected for sediment chemistry, sediment toxicity, and bioassessment parameters by Solano permittees in all water years of relevant monitoring (2013, 2014, 2017). Biological condition assessments are shown using a provisional regional consensus approach based on the SoCal B-IBI for WY 2013 and 2014 (MRP 1), and using the CSCI for WY 2017 (MRP 2). The results exhibited for Laurel Creek sediments indicate that follow-up investigation may be warranted.

Table 4-21. Summary of Sediment Quality Triad Evaluation Results, WY 2013-2017 Data

Water Year	Water Body	Site ID	B-IBI Condition Category	Sediment Toxicity	# TEC Quotients ≥ 1.0:	Mean PEC Quotient	Sum of TU Equiv.
2013	Laurel Creek	207R00236	NA	Yes	4	0.12	5.26
2013	Blue Rock Springs	207R05524	NA	No	5	0.13	0.19
2014	Laurel Creek	207R02732	Very Poor	Yes	1	0.14	0.38
2017	Laurel Creek	207R03116	Degraded	No	3	0.19	0.48

* Notes for Table 4-21:
B-IBI Condition Category is assessed based on the SoCal B-IBI for WY 2013 and 2014 (MRP 1), and based on the CSCI for WY 2017 (MRP 2).
Because of logistical issues regarding stream flow conditions, the Fairfield-Suisun (Laurel Creek) and Vallejo (Blue Rock Springs Creek) sediment sites monitored in WY 2013 are missing the bioassessment component, as shown in Table 4-21, and therefore do not have the full complement of monitoring results needed to evaluate the sediment triad.

5.0 Next Steps

Based on the results of the sediment triad analysis, the Solano County permittees will consider further evaluation of the conditions of Laurel Creek for potential follow-up as follows:

(1) Identify cause(s) of impacts and spatial extent.

(2) Where impacts are under Permittee's control, take management actions to minimize impacts; initiate no later than the second fiscal year following the sampling event.

Other issues warranting additional consideration for potential follow-up include:

- Low algal IBI, benthic IBI, and pHab scores in McCoy Creek
- Elevated chloride and chlorine levels in McCoy Creek, and to a lesser degree, Laurel Creek

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URBAN CREEKS MONITORING REPORT

Appendix B: LOCAL/TARGETED PARAMETERS

Water Year 2017 (October 1, 2016 – September 30, 2017)

Submitted in Compliance with Provision C.8.h.iii
NPDES Permit No. CAS612008

March 30, 2018

Submitted by the Fairfield-Suisun Urban Runoff Management Program and the City of Vallejo and Vallejo Flood and Wastewater District

Program Participants

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List of Acronyms

BASMAA	Bay Area Stormwater Management Agencies Association
DO	Dissolved Oxygen
DQO	Data Quality Objective
FSURMP	Fairfield Suisun Urban Runoff Management Program
GM	Geometric Mean
MPN	Most Probable Number
MRP	Municipal Regional Permit
QAPP	Quality Assurance Project Plan
RMC	Regional Monitoring Coalition
RWQC	Regional Water Quality Criterion
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SOP	Standard Operating Procedure
SSID	Stressor-source identification
STV	Standard Threshold Values
USEPA	United States Environmental Protection Agency
VFWD	Vallejo Flood and Wastewater District
WAT	Weekly average temperature
WQO	Water Quality Objectives
WY	Water Year

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Executive Summary

This monitoring report documents the results of local/targeted creek status monitoring activities performed by the Fairfield Suisun Urban Runoff Management Program (FSURMP) and the City of Vallejo and Vallejo Flood and Wastewater District (VFWD) during the 2017 Water Year (WY). Together with the UCMR Appendix 1, this report submittal completes the required reporting for monitoring requirements specified in provision C.8.d of the Municipal Regional Permit (MRP) for Urban Stormwater issued by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB; Order No. R2-2015-0049). Reporting requirements for provision C.8.d components are established in provision C.8.g.iii of the permit.

The permit-required local/targeted monitoring parameters for FSURMP and VFWD are stream temperature, general water quality and pathogen indicators. The Fairfield-Suisun permittees are required to monitor stream temperature and general water quality for two years in the current permit cycle, and pathogens once in the permit cycle. Vallejo permittees are required to monitor stream temperature twice in the current permit cycle, and continuous water quality and pathogens only once.

Hourly water temperature measurements were taken using a HOBO data logger at one location in Laurel Creek in Fairfield April 27 through September 22 2017 and at two locations in Blue Rock Springs Creek in Vallejo April 16 through September 12 2017.

General water quality monitoring (temperature, dissolved oxygen (DO), pH, and specific conductivity) was executed using YSI sondes at the same Laurel Creek location in Fairfield during the spring (May 25 – June 5 2017) and in the summer (Sep 8 – Sep 20 2017).

Pathogen indicator samples were collected in the summer at three locations in Fairfield (Ledgewood Creek, Union Avenue Creek and Suisun Slough) and three locations in Vallejo (all on Blue Rock Springs Creek). Grab samples were taken and sent for analysis of concentrations of fecal coliform, *E. coli*, and total coliform.

All targeted monitoring data were compared and evaluated against the available Water Quality Objectives (WQO's), and against additional criteria as required in provision C.8.d in the MRP. Table ES-1 summarizes monitoring results which exceeded trigger threshold criteria.

Table ES-1. Solano permittee exceedances in WY 2017

Creek	Index Period	Parameter	Criterion Exceedance
Blue Rock Springs 030	April 16 – Sep 12 2017	Continuous water temp (HOBO)	>1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Blue Rock Springs 006	April 16 – Sep 12 2017	Continuous water temp (HOBO)	>1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Laurel	April 27 – Sep 22 2017	Continuous water temp (HOBO)	>1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Laurel	May 25 – June 5 2017; Sep 8 – Sep 20 2017	Continuous water temp (Sonde)	1 WAT exceeds 17°C or 20% instantaneous results > 24°C
Laurel	May 25 – June 5 2017; Sep 8 – Sep 20 2017	Continuous water quality – DO	≥ 20% results < 7.0 mg/L
Laurel	Sep 8 – Sep 20 2017	Continuous water quality - pH	≥ 20% results < 6.5 or > 8.5
Blue Rock Springs 030	Sep 13 2017	*E. coli*	Single grab sample > EPA criterion of 130 CFU/100 ml
Blue Rock Springs 006	Sep 13 2017	*E. coli*	Single grab sample > EPA criterion of 130 CFU/100 ml
Union Ave.	Aug 29 2017	*E. coli*	Single grab sample > EPA criterion of 130 CFU/100 ml

1.0 Introduction

Members of the Bay Area Stormwater Management Agencies Association (BASMAA) formed the Regional Monitoring Coalition (RMC) in early 2010 to collaboratively implement the monitoring requirements found in Provision C.8 of the Municipal Regional Permit (MRP) for urban stormwater in Region 2 (Order No. R2-2015-0049). 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. The RMC divided the creek status monitoring requirements specified in provision C.8.d into those parameters that reasonably could be included within a regional/probabilistic design, and those that, 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 1-1.

This report focuses on the creek status monitoring activities that were conducted in Solano County in Water Year 2017 to comply with Provision C.8.d using a targeted (non-probabilistic) monitoring design.

This report provides a description of the monitoring sites (Section 2.0), monitoring methods (Section 3.0), results (Section 4.0), and next steps (Section 5.0).

Table 1-1. Creek status monitoring parameters sampled in compliance with MRP Provision C.8.c. in Water Year 2017.

Biological Response and Stressor Indicators	Monitoring Design	
	Regional Ambient (Probabilistic)	Local (Targeted)
Bioassessment & Physical Habitat Assessment	X	
Chlorine	X	
Nutrients	X	
Water Toxicity	X	
Sediment Toxicity	X	
Sediment Chemistry	X	
General Water Quality		X
Temperature		X
Bacteria		X

2.0 Monitoring Locations

Status and trends monitoring was conducted in non-tidally influenced, flowing water bodies (i.e., creeks, streams and rivers). During Water Year 2017 (October 1, 2016 – September 30, 2017) targeted monitoring was conducted as follows:

- Three continuous water temperature monitoring locations (one in Fairfield-Suisun and two in Vallejo)
- One general water quality monitoring location (Fairfield-Suisun)
- Six pathogen indicator monitoring locations (3 each, Fairfield-Suisun and Vallejo)

Water temperature, general water quality and pathogen indicators were monitored at the targeted locations listed in Table 2-1.

Table 2-1. Targeted sites and local reporting parameters monitored in Water Year 2017 in Solano County.

Site ID	Creek Name	Latitude	Longitude	Continuous Temperature	Water Quality	Pathogen Indicators
207LAU050	Laurel	38.29367	-122.02275	X	X	
207LED020	Ledgewood	38.24336	-122.03786			X
207UAV030	Union Avenue	38.26353	-122.0375			X
207SSL010	Suisun Slough	38.23322	-122.03786			X
207R03504*	Rindler	38.1372	-122.2183			X
207BRS010	Blue Rock Springs	38.1113	-122.2050			X
207BRS004	Blue Rock Springs	38.1220	-122.2229			X
207BRS006	Blue Rock Springs	38.119822	-122.216338	X		
207BRS030	Blue Rock Springs	38.120740	-122.198909	X		

* Site is part of the RMC probabilistic draw

Figure 2-1. Targeted sites monitored in Solano County in Water Year 2017.

3.0 Monitoring Methods

Targeted monitoring data were collected following the BASMAA RMC quality assurance plan and standard operating procedures (BASMAA 2016a; BASMAA 2016b). General water quality, continuous temperature and pathogen monitoring data were collected using comparable methods to those outlined in the California Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance Project Plan and were submitted electronically in SWAMP-compatible format by FSURMP and VFWD to SFBRWQCB pursuant to Provision C.8.h.

3.1 Field Data Collection Methods

Field data were collected in accordance with existing SWAMP-comparable methods and procedures, as described in the RMC Quality Assurance Project Plan (QAPP; BASMAA 2016a) and the associated Standard Operating Procedures (SOPs; BASMAA 2016b).

3.1.1 General Water Quality Measurements

A water quality monitoring device (YSI 6920 sonde probe) was deployed once in the spring (May 25 – June 5, concurrent with bioassessment) and once in the fall (Sep 8 – Sep 20) at Laurel Creek in Fairfield. The device was set to record measurements for dissolved oxygen, pH, electrical conductivity and temperature at 15 minute intervals throughout each deployment period.

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

3.1.2 Continuous Temperature Monitoring

Continuous water temperature data were collected in Fairfield at Laurel Creek (April 27 – Sep 22) and in Vallejo at two Blue Rock Springs Creek locations (April 16 – Sep 12). Digital temperature data loggers (HOBO Water Temp Pro V2) were deployed at each site and recorded stream temperature hourly in each waterway.

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

3.1.3 Pathogen Indicator Sampling

Water quality samples for pathogen indicator analysis were taken via grab samples at three targeted sites in Fairfield (Ledgewood Creek, Union Avenue Creek and Suisun Slough) on August 29 and three targeted sites in Vallejo (Blue Rock Springs Creek and Rindler Creek) on September 13. Sampling techniques included direct filling of containers and immediate transfer of samples to analytical laboratories within specified holding time requirements. Sampling and transporting procedures are described in RMC SOP FS-2 (BASMAA 2016b).

3.2 Quality Assurance & Control

Quality control procedures are described in detail in the BASMAA RMC QAPP (BASMAA 2016a). Data quality objectives (DQO's) were established to ensure quality of both quantitative and qualitative assessments. Field training was conducted among the RMC survey teams along with California Department of Fish and Wildlife (CDFW) staff to ensure that consistent and comparable field techniques were being utilized. All data collection followed the procedures outlined in the RMC SOPs (BASMAA 2016b), including documentation of data sheets and samples as well as sample handling and chain of custody. The laboratories that provided technical analytical services to the RMC were selected based on their ability to adhere to the required analytical protocols and sample handling requirements.

3.3 Data Quality Assessment Procedures

Results from field work and laboratory assessments were reviewed by the local Program Quality Assurance Officers for each Program and compared against the methods and procedures outlined in the SOPs and QAPP. Table 3-1 displays the data quality steps taken for targeted monitoring parameters.

Table 3-1. Data quality procedures implemented for targeted monitoring.

Procedure	Temperature (HOBO)	General Water Quality (YSI)	Pathogen Indicators Sampling
Pre-event calibration	X	(factory)	
Readiness review conducted	X	X	X
Check field data sheets for completeness	X	X	X
Post-deployment accuracy check conducted	X	(factory)	
Post sampling event report completed	X	X	X
Post event calibration conducted		(factory)	
Data review-compare drift against SWAMP MQO's		X	
Data review-check for outliers/out of water measurements	X	X	

3.4 Data Analysis and Interpretation

Targeted monitoring data were evaluated against water quality objectives (WQO's) or other relevant thresholds described in provision C.8.d in the MRP. The targeted monitoring thresholds used for analysis are displayed in Table 3-2. The sub-sections below provide details on the water quality thresholds derived from the San Francisco Basin Plan and USEPA sources, including an explanation of the threshold selected for analysis of temperature data.

Table 3-2. Description of water quality thresholds for Municipal Regional Permit C.8.d parameters monitored using a targeted design.

Constituent	Trigger Level	MRP 2 Provision
Temperature	≥2 weekly averages > 17°C (steelhead streams); or 20% of results > 24°C instantaneous maximum (per station)	C.8.d.iii.(4)
Temperature (continuous, sonde)	≥1 weekly average > 17°C (steelhead streams); or 20% of results > 24°C instantaneous maximum (per station)	C.8.d.iv.(4)a.
pH (continuous, sonde)	≥ 20% results < 6.5 or > 8.5	C.8.d.iv.(4)b.
Electrical conductivity (continuous, sonde)	≥ 20% results > 2000 uS	C.8.d.iv.(4)c.
Dissolved oxygen (continuous, sonde)	≥ 20% results < 7 mg/L (cold water fishery streams)	C.8.d.iv.(4)d.
Enterococci	> 130 CFU/100mL	C.8.d.v.(4)
E. coli	> 410CFU/100mL	C.8.d.v.(4)

3.4.1 Dissolved Oxygen (DO)

The Basin Plan (SFBRWQCB 2015) lists WQOs for DO in non-tidal waters as follows: 5.0 mg/L minimum for waters designated as warm water habitat (WARM) and 7.0 mg/L minimum for waters designated as COLD. Although these WQOs are suitable criteria for an initial evaluation of water quality impacts, further evaluation may be needed to determine the overall extent and degree that COLD and/or WARM beneficial uses are supported at a site. For example, further analyses may be necessary at sites in lower reaches of a water body that may not support salmonid spawning or rearing habitat, but may be important for upstream or downstream fish migration.

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

3.4.2 pH

WQOs for pH in surface waters are stated in the Basin Plan (SFBRWQCB 2015) 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 water quality objectives.

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. 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 via the standard threshold values (STV). 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 values of 130 cfu/100mL for Enterococci and 410 cfu/100mL for *E. coli*, representing the 36/1000 primary contact recreation levels for determining if a pathogen indicator collection sample site is a candidate for a stressor/source identification (SSID) project.

Table 3-3. U.S. EPA (2012) recommended Recreational Water Quality Criteria.

Criteria Elements	Recommendation 1 Estimated Illness Rate 36/1000		Recommendation 2 Estimated Illness Rate 32/1000	
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 DO, temperature and pH, the temperature trigger threshold specification is defined as follows:

> "…(the) maximum weekly average temperature 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 September 2017. The second cited section applies to temperature data recorded by the YSI sonde devices during the two periods in May and September, 2017.

In either case, the WAT was calculated as the average of seven daily average temperatures in nonoverlapping 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 which did not contain 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 a 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.

Neither of the streams monitored in 2017 (Laurel Creek and Blue Rock Springs Creek) are known to currently harbor populations of migratory fish species or resident salmonids.

4.0 Results

4.1 Statement of Data Quality

Field data sheets and lab reports were reviewed by the local Program Quality Assurance Officer and the results were evaluated against the appropriate DQOs. Results were compiled for both qualitative (representativeness and comparability) and quantitative metrics (completeness, precision, and accuracy).

The following information highlights the data quality assessment for each data collection activity:

- Temperature data from HOBO data loggers was collected at three sites, resulting in collection of 100% of the expected data.
- Continuous water quality data (temperature, pH, DO, conductivity) were collected during the spring and summer seasons in Fairfield (Laurel Creek) resulting in collection of 100% of the expected data.
- Continuous water quality is measured using rented equipment that is calibrated and checked for accuracy at the rental company; all calibration paperwork and accuracy checks were well within acceptable ranges for all constituents.
- Pathogen samples collected in WY 2017 were analyzed for *E. coli* and fecal coliform. They were not analyzed for Enterococci as required per MRP provision C.8.d.v. This oversight will be corrected via re-sampling in WY 2018. WY 2017 results were substantially higher than threshold values for *E. coli*, and thus WY 2018 sampling will target locations that will provide more information on these areas.

4.2 Monitoring Results

4.2.1 Water Temperature

Summary statistics for continuous water temperature data are shown in Table 4-1. In Fairfield, data were collected from April 27 through September 22 and represent hourly measurements taken at Laurel Creek for 150 days. In Vallejo, data were collected from April 16 through September 12 and represent hourly measurements taken at two locations on Blue Rock Springs Creek for 145 days. All data measured at both sites are shown in Figure 4-1. Non-overlapping weekly average temperatures (WAT) were calculated and are shown in Figure 4-2. The threshold values of 17 ^{o}C (for WAT calculations) and 24 ^{o}C (for instantaneous measurements) are presented on both Figures.

Table 4-1. Descriptive statistics for continuous water temperature measured with the HOBO data logger at Laurel and Blue Rock Springs Creeks, April - Sep 2017.

Site	207LAU050	207BRS006	207BRS030
Temperature	**Laurel Creek (°C)**	**Blue Rock Springs Ck (°C)**	**Blue Rock Springs Ck (°C)**
Minimum	14.12	13.55	14.24
Median	18.91	18.20	18.89
Mean	18.68	18.15	18.99
Maximum	21.75	19.29	24.61
MWAT	20.27	20.04	21.03
# of Measurements	3552	3356	3357

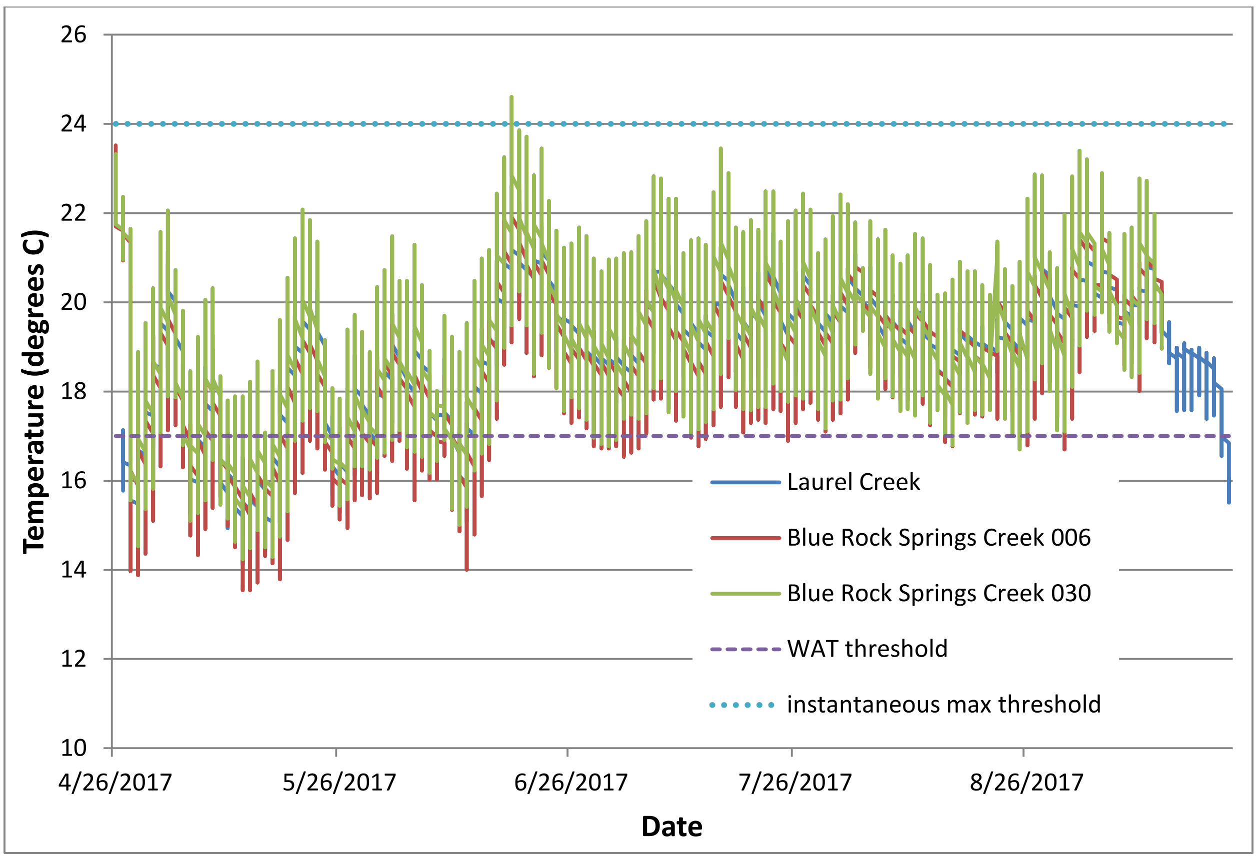

Figure 4-1. Continuous water temperature data collected with the HOBO data loggers at Laurel and Blue Rock Springs Creeks, April - Sep 2017.

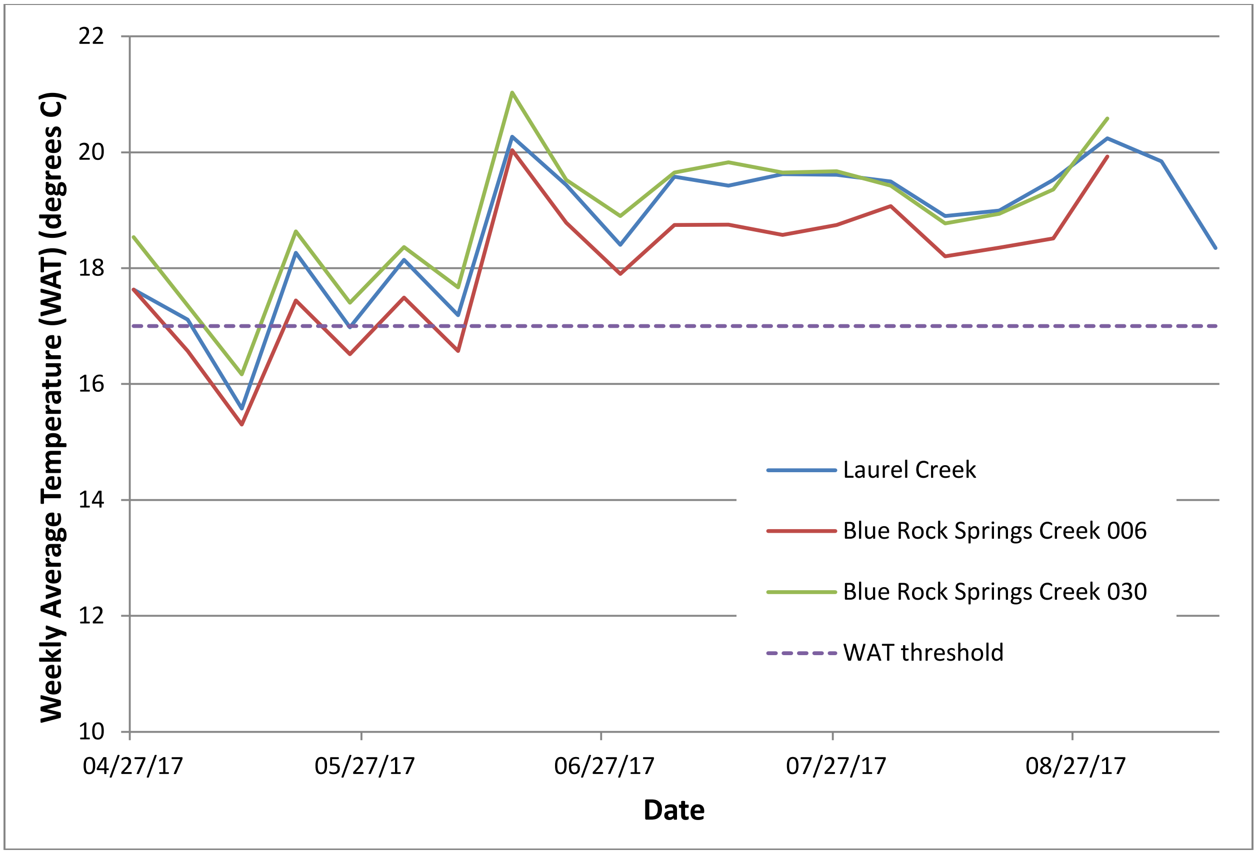

Figure 4-2. Weekly average water temperature data collected with the HOBO data loggers at Laurel and Blue Rock Springs Creeks, April - Sep 2017.

Stream temperatures (as WAT) were often above the threshold of 17°C in all three sites throughout the deployment period (Table 4-2), exceeding the water quality threshold for stream temperature. Only one site recorded instantaneous temperatures that exceeded 24 °C (207BRS030) on a very hot day in June 2017, but fell far short of meeting the trigger criteria of 20% of results above this value.

It should be noted that Blue Rock Springs Creek originates from an underground spring roughly 600 meters upstream of site 207BRS030. This area is known for mild geothermal activity, and the water is very warm where it emerges directly from the spring. While none of the stream sites monitored appear to have temperature conditions that would support salmonid populations, it is likely that Blue Rock Springs Creek remains warm primarily due to natural conditions.

Table 4-2. Continuous water temperature data measured at Solano County sites that exceed water quality criteria.

Site ID	Creek Name	Total # WATs	# WATs > 17°C	% instantaneous results > 24°C
207LAU050	Laurel	21	19	0
207BRS006	Blue Rock Springs	19	15	0
207BRS030	Blue Rock Springs	19	18	0.15

4.2.2 General Water Quality

Summary statistics for general water quality data collected using a YSI 6920 sonde in Laurel Creek during the spring (May 25-June 5) and summer (Sep 8-Sep 20) seasons are shown in Table 4.3. The data are also shown in Figure 4-3 below.

Table 4-3. Summary statistics for continuous water quality data during the 2017 spring and summer sampling periods at Laurel Creek in Fairfield.

Parameter	Statistic	Spring	Summer
Temp (°C)	Min	15.23	16.99
	Median	17.37	18.65
	Mean	17.36	18.70
	Max	19.42	20.34
Dissolved Oxygen (mg/L)	Min	3.90	1.16
	Median	6.90	4.43
	Mean	7.22	4.38
	Max	12.19	8.86
pH	Min	7.38	7.76
	Median	7.53	8.68
	Mean	7.58	8.88
	Max	8.04	9.98
Specific Conductivity (µS/cm)	Min	952	936
	Median	998	1044
	Mean	998	1042
	Max	1027	1139

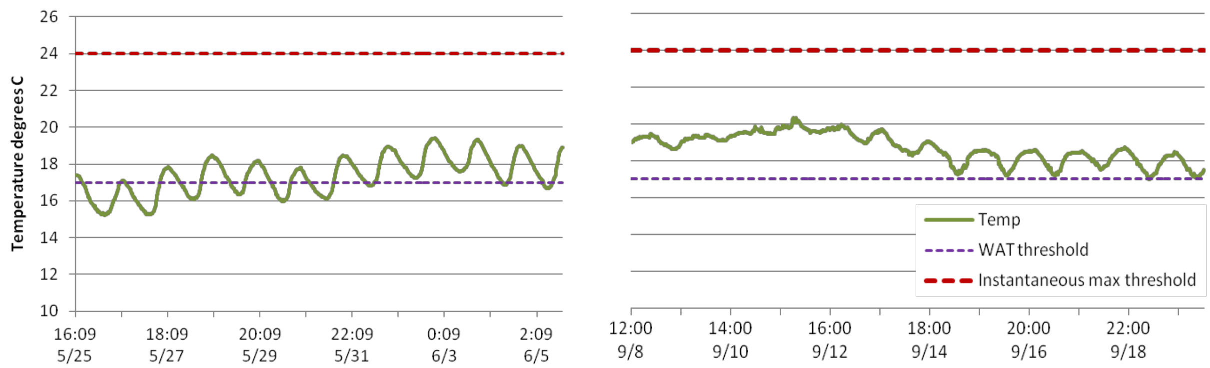

Figure 4-3a. Continuous water quality data (temperature) collected May and September 2017 at Laurel Creek.

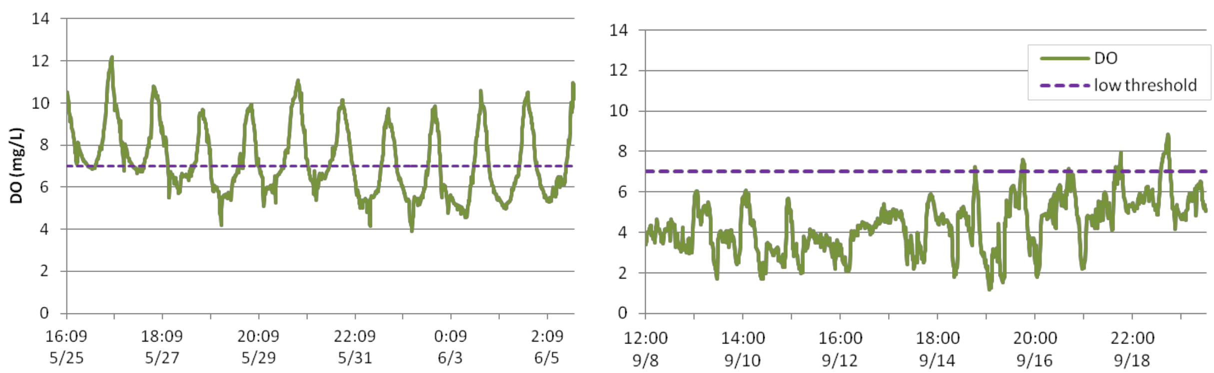

Figure 4-3b. Continuous water quality data (DO) collected May and September 2017 at Laurel Creek.

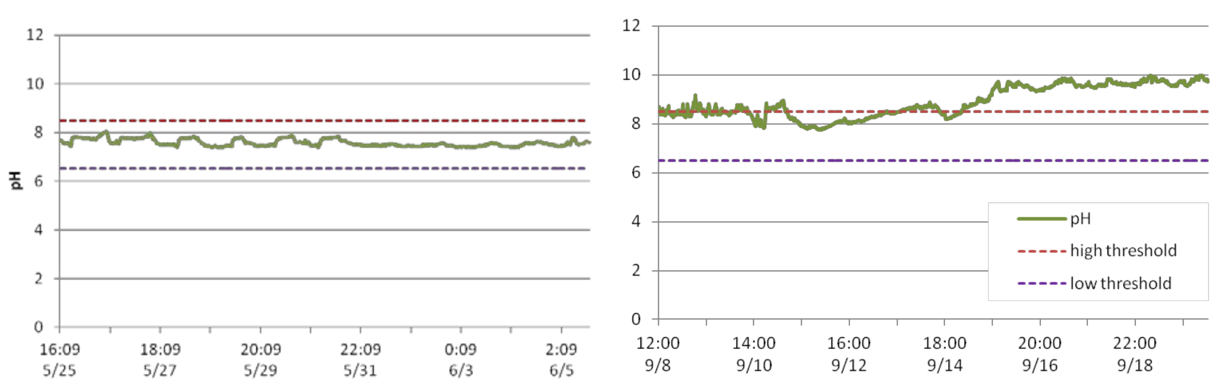

Figure 4-3c. Continuous water quality data (pH) collected May and September 2017 at Laurel Creek.

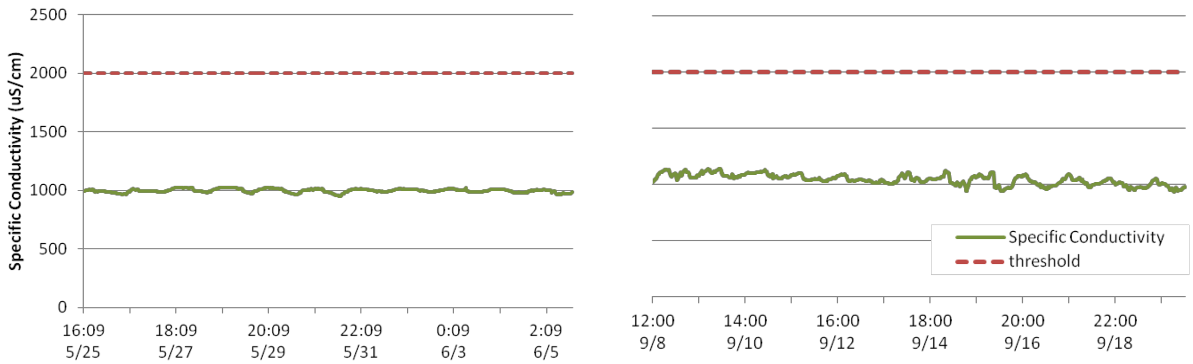

Figure 4-3d. Continuous water quality data (specific conductivity) May and September 2017 at Laurel Creek.

Consistent with the continuous temperature monitoring results from the HOBO datalogger at this same location on Laurel Creek, the sonde deployments measured very warm temperatures in both the spring and summer periods. Stream temperatures remained above 17°C throughout the summer deployment period, and thus the weekly average temperature (WAT) for this deployment met the trigger threshold for water quality criteria. Instantaneous temperatures never approached the upper threshold of 24°C in either spring or summer.

Dissolved oxygen measurements followed a predictably similar pattern to stream temperature, with the summer deployment consisting almost entirely of DO levels below the threshold criterion of 7 mg/L.

Continuous pH measurements were unusually high in the last five days of the summer deployment. Groundwater pH is often 8.5-9 in Solano County, and stream flows at this time of year are entirely due to urban runoff, much of which is sourced from groundwater. It is possible that in the very warm days of the summer deployment period there was a surge of groundwater from urban sources, but the recorded pH levels that approach 10 are unusually high even for groundwater.

Specific conductivity remained low and steady throughout both deployment periods.

Table 4-4 presents the comparisons of the continuous water quality data for temperature, dissolved oxygen, and pH measured at Laurel Creek for both deployment periods (May and September) to the water quality evaluation criteria specified in Table 3-2.

Table 4-4. Water temperature, dissolved oxygen, and pH data measured during spring and summer monitoring events that exceed water quality criteria identified in Table 3-2.

Site ID	Creek Name	Monitoring Period	# WATs > 17°C	% DO results <7.0 mg/l	% pH results <6.5 or >8.5
207LAU050	Laurel	May 25 – Jun 5	1	54.1%	0%
		Sep 8 – Sep 20	1	96.5%	62.6%

4.2.3 Pathogen indicators

Both Fairfield-Suisun and Vallejo programs exceeded the applicable WQO for *E. coli* in WY 2017 (Table 4-5). Fecal coliform results were similarly high and exceeded thresholds established for this constituent in MRP 1.

Table 4-5. Fecal coliform and E. coli levels measured from water samples taken at Solano County locations in WY 2017. Values in bold exceed the applicable WQO identified in Table 3-2.

Site ID	Creek	Fecal Coliform (MPN/100mL)	*E.Coli* (MPN/100mL)
207LED020	Ledgewood	130	130
207UAV030	Union Avenue	5000	**5000**
207SSL010	Suisun Slough	50	50
207R03504	Rindler	1700	**2800**
207BRS010	Blue Rock Springs	11000	**11000**
207BRS004	Blue Rock Springs	800	23

The upper reaches of Blue Rock Springs Creek in Vallejo clearly have a pathogen issue, as all samples drawn from this stretch (WY 2013, 2014, 2015 and 2017) exceed the E. coli threshold. The problem appears to disappear by site 207BRS004, where the creek goes underground.

Due to extensive urbanization and channel modification, neither of these streams has much realistic potential for supporting salmonid fisheries.

5.0 Next Steps

- FSURMP and Vallejo permittees will continue to conduct local/targeted water quality monitoring as required in WY 2018 and 2019
- 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 follow-up investigations and/or monitoring

6.0 References

ADH Environmental. March 12, 2013. Local Urban Creeks Monitoring Report, Water Year 2012 (Oct 2011 – Sept 2012). Submitted to the San Francisco Bay Regional Water Quality Control Board in compliance with provision C.8.g.iii, NPDES permits No. CAS612008 and CAS083313 on behalf of the Contra Costa Clean Water Program.

Bay Area Stormwater Management Agencies Association (BASMAA). 2016a. Regional Monitoring Coalition Creek Status and Pesticides & Toxicity Monitoring Program Quality Assurance Project Plan. Version 3, March.

Bay Area Stormwater Management Agencies Association (BASMAA). 2016b. Regional Monitoring Coalition Creek Status and Pesticides & Toxicity Monitoring Standard Operating Procedures. Prepared by EOA Inc. and Applied Marine Sciences. Version 3, March.

San Francisco Regional Water Quality Control Board (SFRWQCB). 2013. Water Quality Control Plan (Basin Plan). http://www.waterboards.ca.gov/sanfranciscobay/basin_planning.shtml

U.S. EPA. 2012. 2012 Recreational Water Quality Criteria. U.S. Environmental Protection Agency, EPA-820-F-12-061. 2 pp. Fact Sheet.

URBAN CREEKS MONITORING REPORT

Appendix C: BASMAA Regional Monitoring Coalition Stressor/Source Identification Studies Status Report

Water Year 2017 (October 1, 2016 – September 30, 2017)

Submitted in Compliance with Provision C.8.h.iii
NPDES Permit No. CAS612008

March 31, 2018

Submitted by the Fairfield-Suisun Urban Runoff Management Program and the City of Vallejo and Vallejo Flood and Wastewater District

MRP 2.0 SSID Project Locations, Rationales, Status

Updated March 2018

SSID Project ID	Date Updated	County/ 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	Current Status of SSID Project or Date Completed	EO Concurrence of project completion (per C.8.e.iii.(b))
						Bioassess	General WQ	Chlorine	Temp	Water Tox	Sed Tox	Sed Chem	Pathogen Indicators	Other				
AL-1	2/23/18	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	2/1/18	CCCWP	Lower Marsh Creek		Stressor Source Identification Study of Marsh Creek Fish Kills					X					9 fish kills have been documented in Marsh Creek between September 2005 and October 2017. A conclusive cause has not been 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	1/22/18	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	1/31/18	SMCWPPP	Pillar Point / Deer Creek / Denniston Creek		Pillar Point Harbor Bacteria SSID Project								X		FIB samples from 2008, 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.	

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	County/ 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	Current Status of SSID Project or Date Completed	EO Concurrence of project completion (per C.8.e.iii.(b))
						Bioassess	General WQ	Chlorine	Temp	Water Tox	Sed Tox	Sed Chem	Pathogen Indicators	Other				
FS-1		FSURMP																
TBD		RMC/TBD																

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.

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[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).

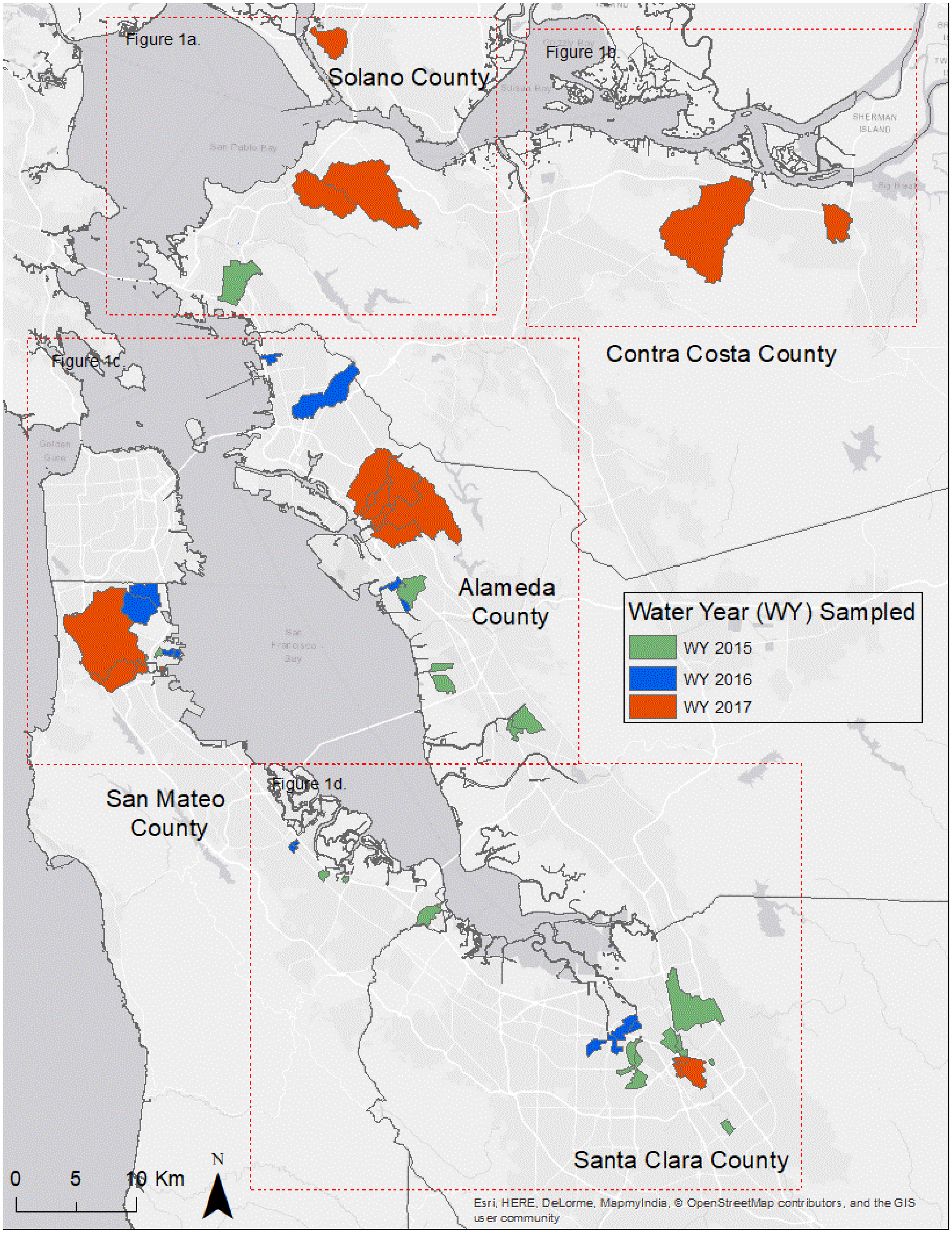

Figure 1. Watersheds sampled in water years 2015, 2016, and 2017.

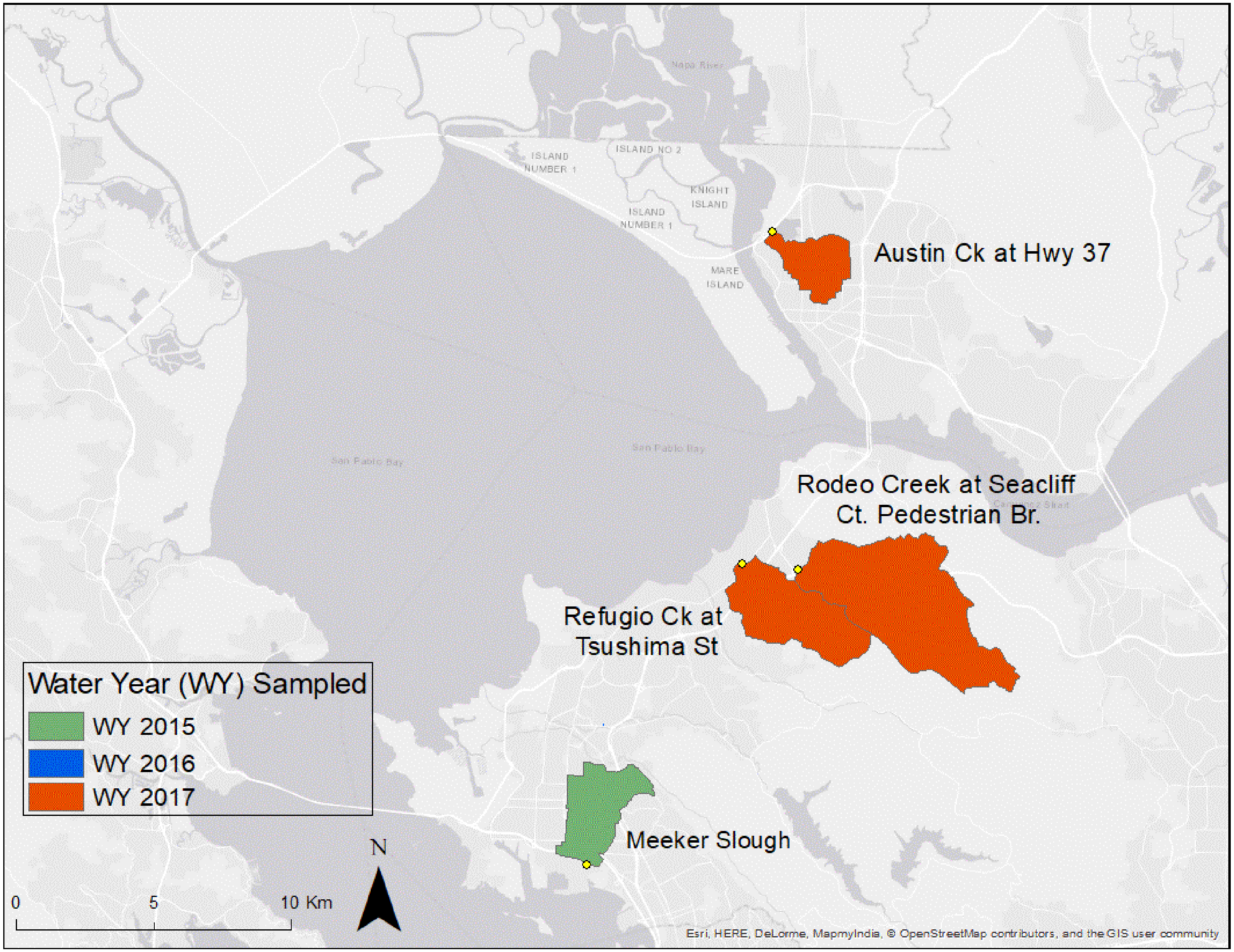

Figure 1a. Sampling locations (marked by yellow dots) and watershed boundaries in western Contra Costa County and Solano County.

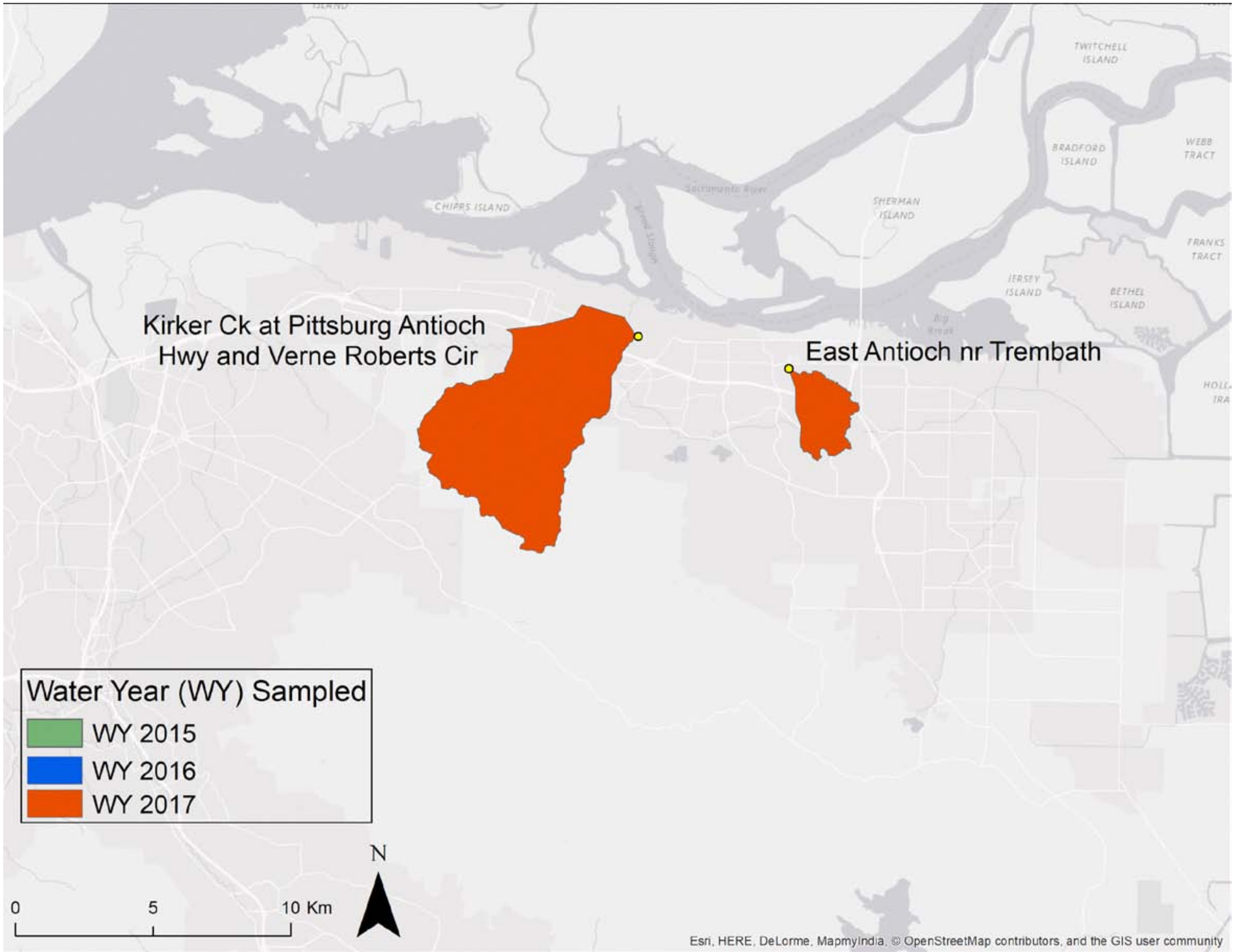

Figure 1b. Sampling locations (marked by yellow dots) and watershed boundaries in eastern Contra Costa County.

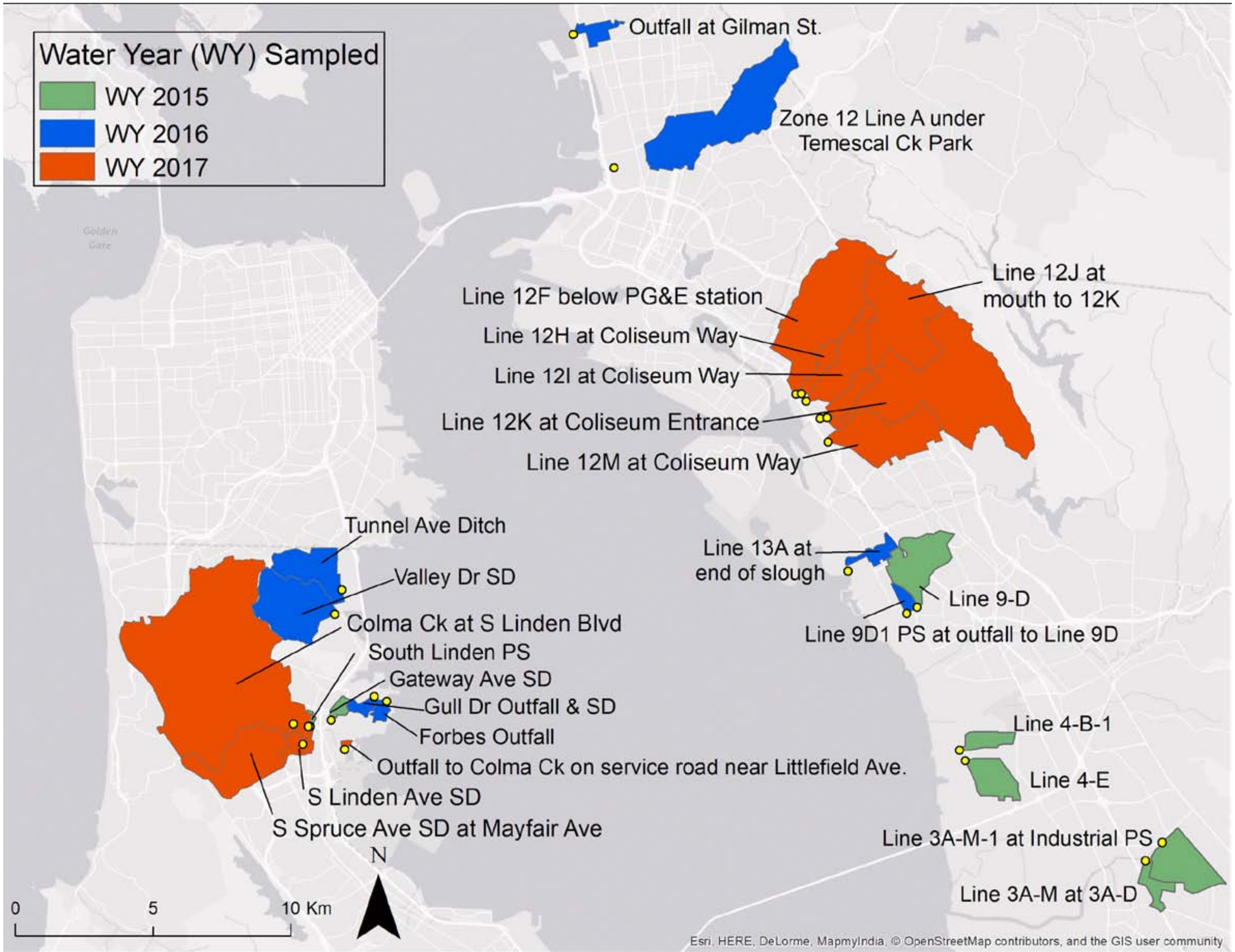

Figure 1c. Sampling locations (marked by yellow dots) and watershed boundaries in Alameda County and northern San Mateo County.

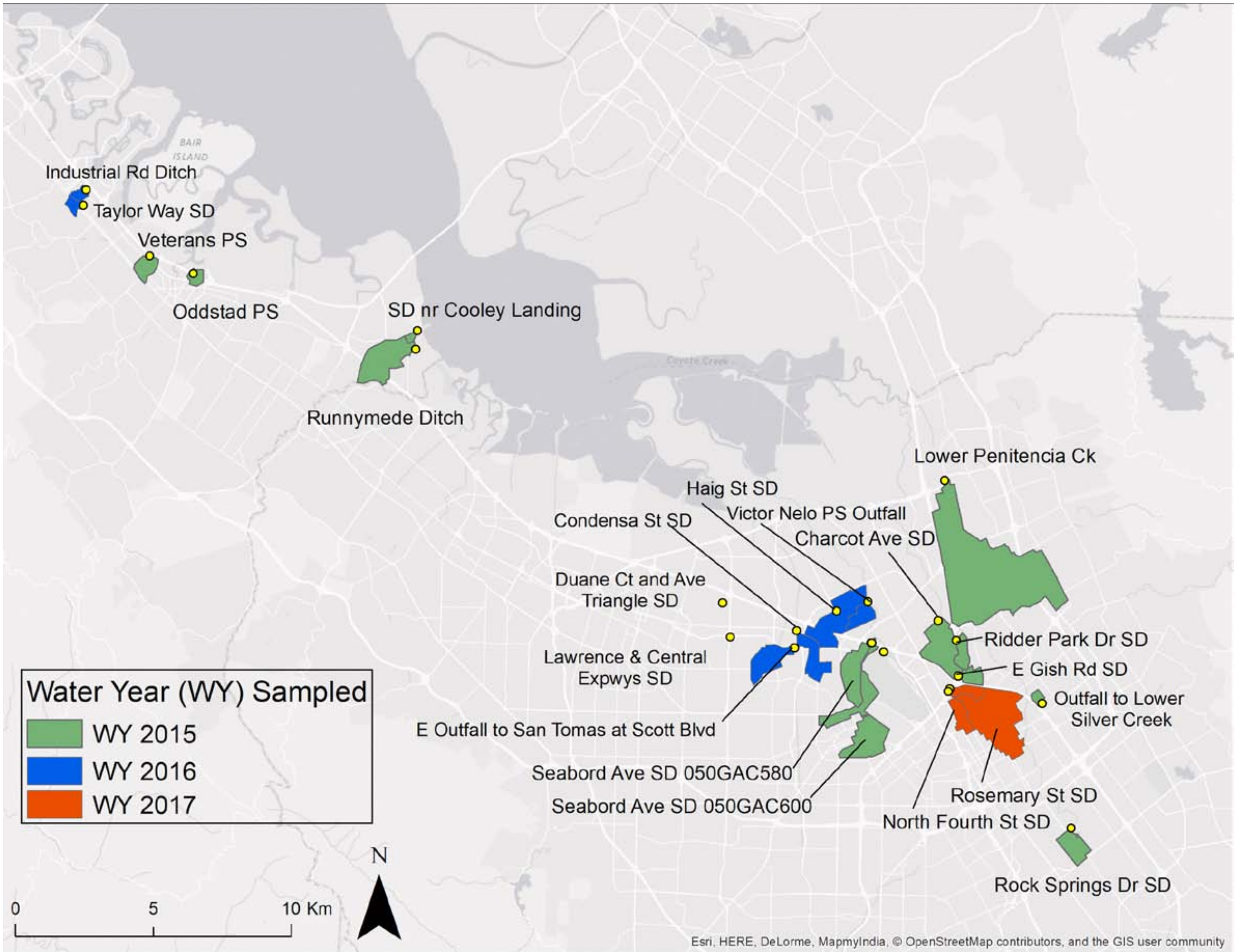

Figure 1d. Sampling locations (marked by yellow dots) and watershed boundaries in northern San Mateo County and Santa Clara County.

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

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[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.

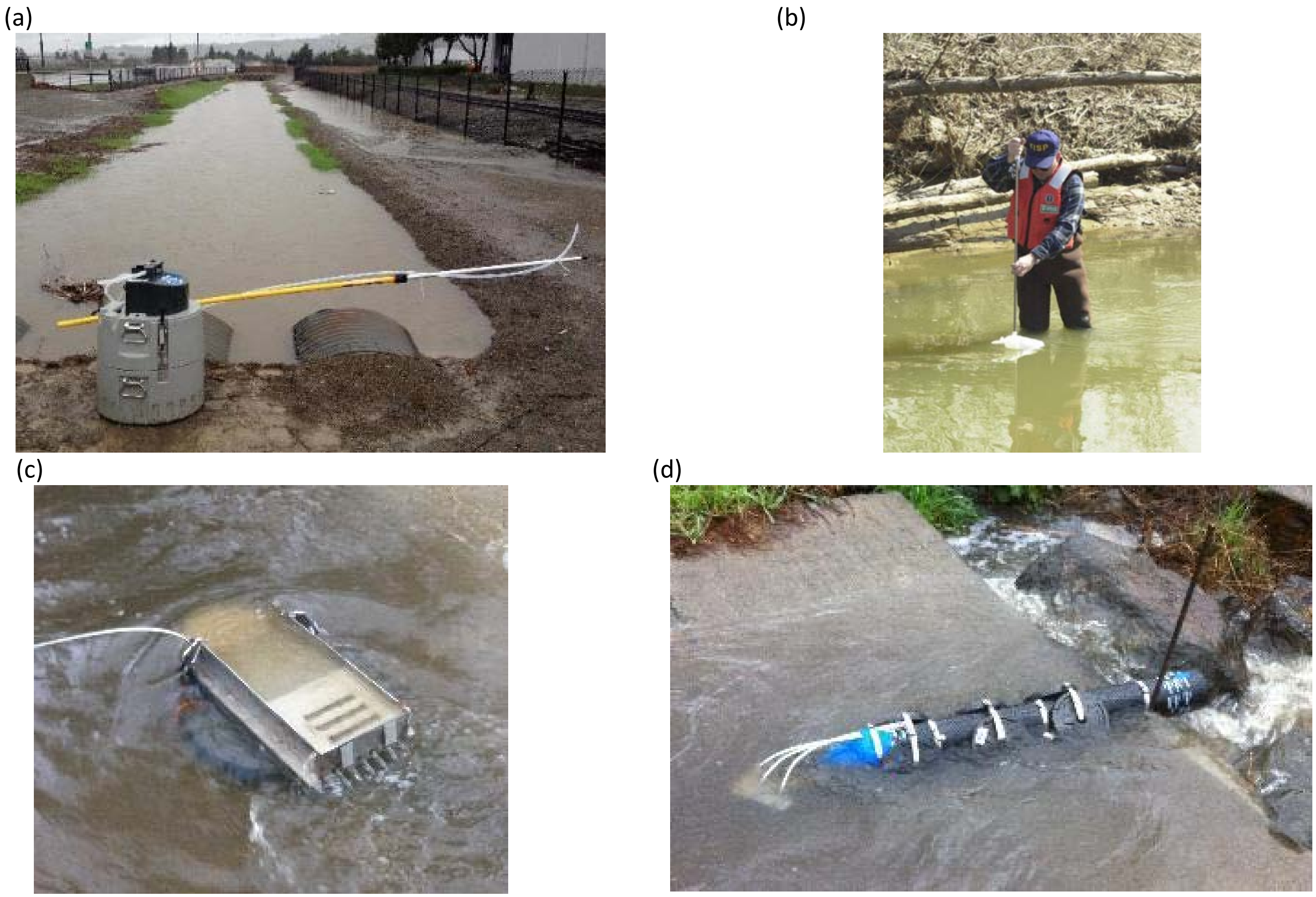

Figure 2. Sampling equipment used in the field. (a) Painter's pole, Teflon tubing and an ISCO used as a slave pump; (b) Teflon bottle attached to the end of a DH81 sampling pole; (c) a Hamlin suspended sediment sampler secured atop a 45 lb plate; and (d) a Walling tube suspended sediment sampler secured 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.

[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					557		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	No data				640	No data	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%

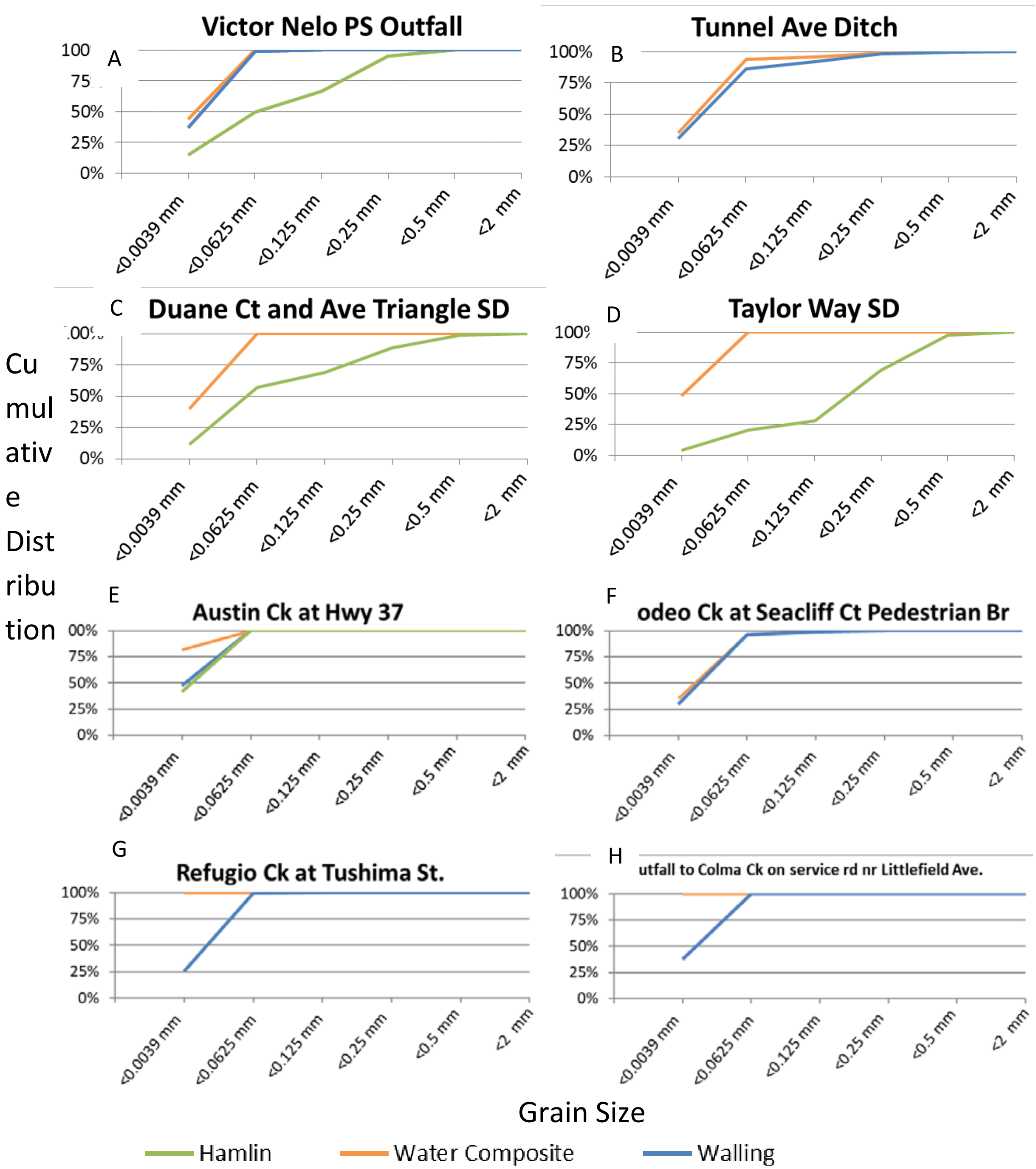

Figure 3. Cumulative grain size distribution in the Hamlin suspended-sediment sampler, Walling tube suspended-sediment sampler, and water composite samples at eight of the sampling locations. Note that both samplers were only used at two of these eight sites.

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.

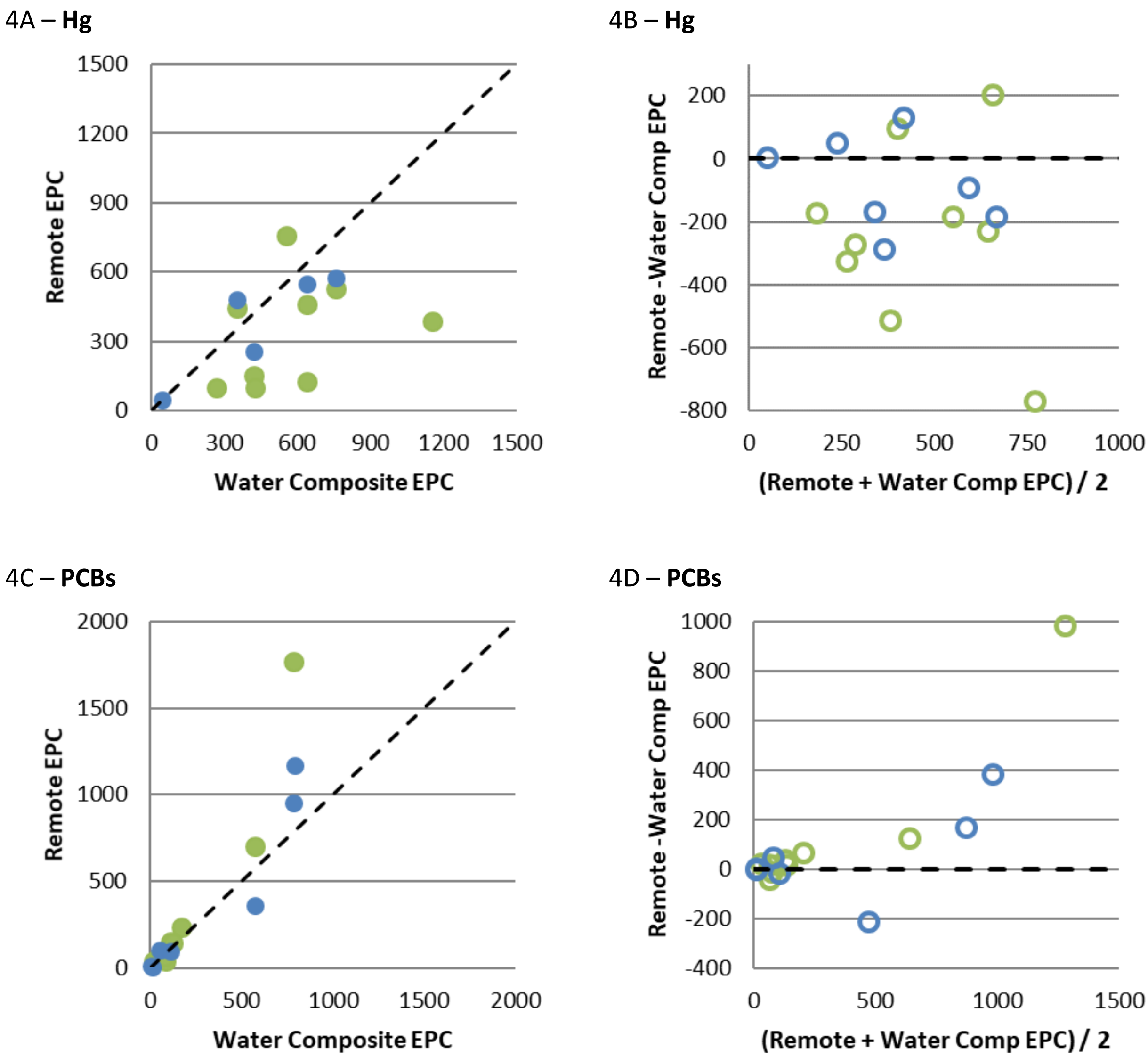

Figure 4. Estimated particle concentration comparisons between remote suspended-sediment samples versus manually collected composite samples, and comparisons of the differences between the methods against their means. Figures 4A and 4C show the 1:1 line (dashed black line), and Figures 4B and 4D show 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: $\mathrm{RPD} = \frac{\text{Difference (between replicate samples)}}{\text{Average (replicate samples)}} \times 100\%$

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	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
066GAC550B													
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	Santa Clara	2016	1.0	79%	23%	17	65	832	73	0.27	54	13	66

Watershed/Catchment	County	Water Year Sampled	Area (km²)	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
SD													
Lower Penitencia Creek	Santa Clara	2011, 2015	12	65%	2%	16	66	1,588	70	0.16	69.5	17	57.5
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.

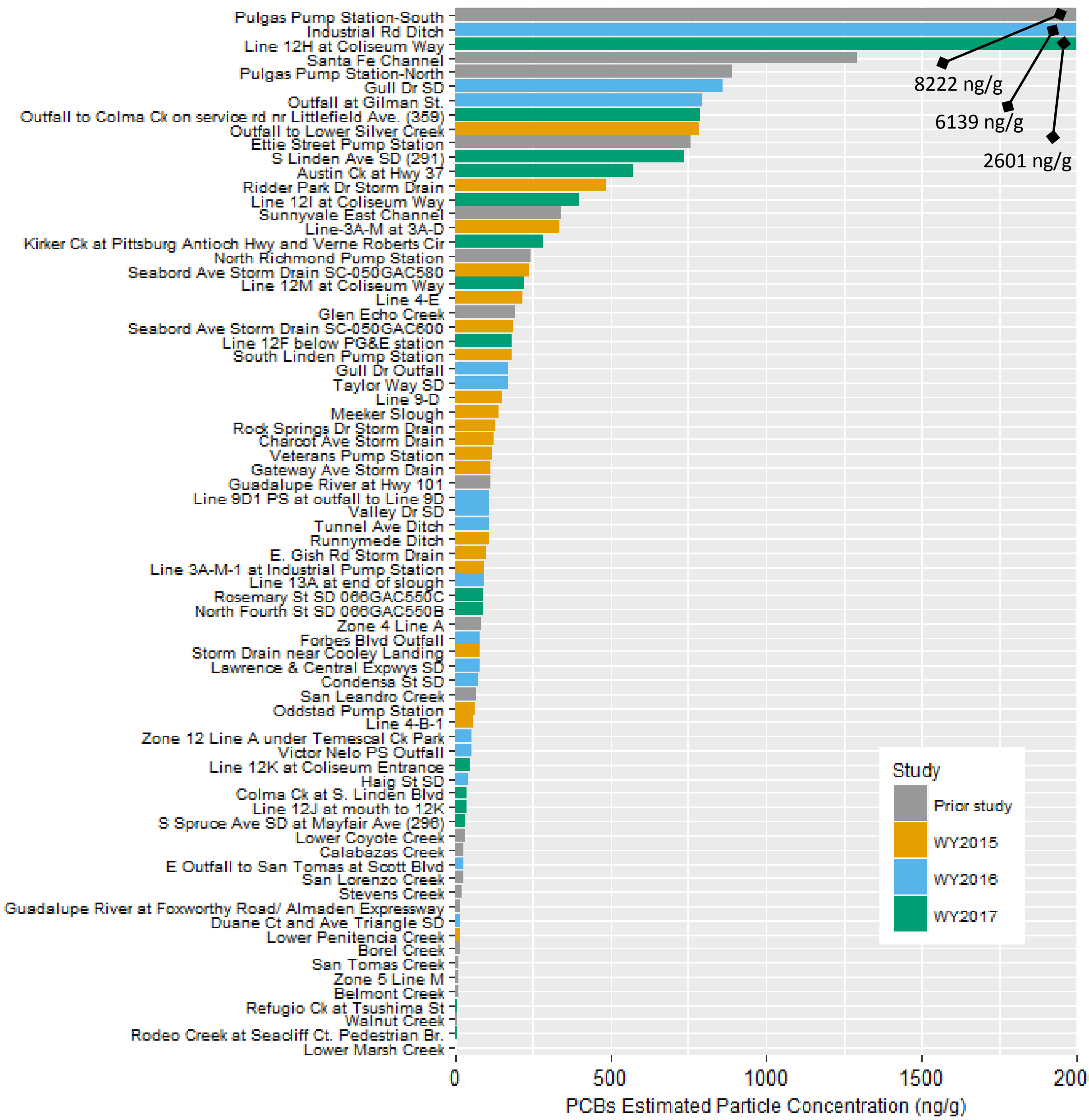

Figure 6. PCB estimated particle concentrations for watershed sampling sites measured to date (water years 2003-2017; where more than one storm is sampled at a site, the reported value is the average of the storm composite samples). Note that PCB EPCs for Pulgas Pump Station-South (8,222 ng/g), Industrial 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.

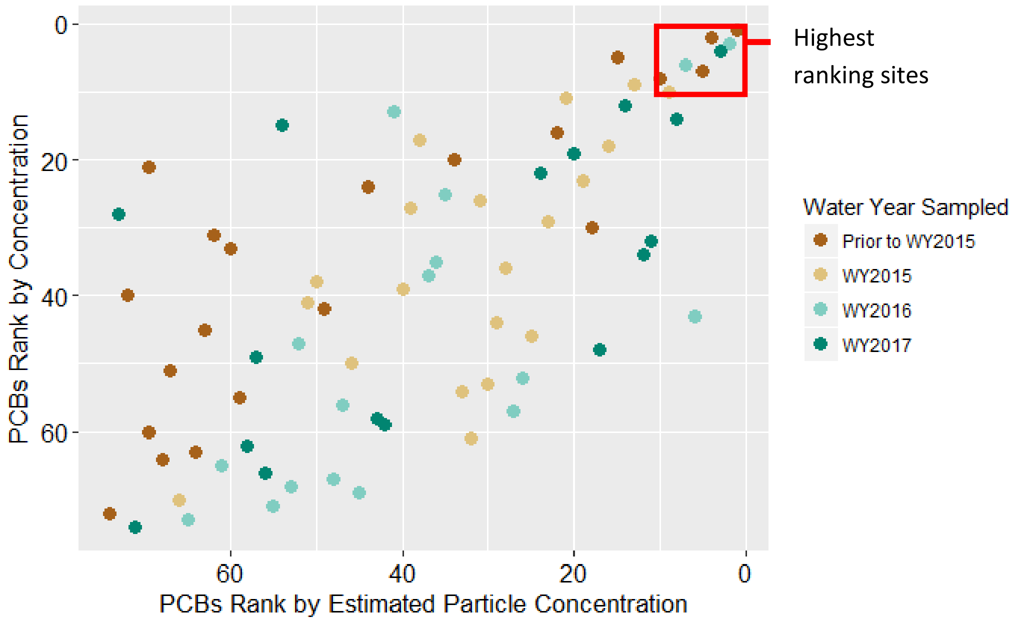

Figure 7. Comparison of site rankings for PCBs based on estimated particle concentrations versus water concentrations. 1 = highest rank; 75 = lowest rank.

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 $\mu g/m^2/y$ (Tsai and Hoenicke, 2001) and 4.4 $\mu g/m^2/y$ (Steding and Flegal, 2002), and Tsai and Hoenicke reported a total (wet + dry) deposition rate of 18-21 $\mu g/m^2/y$. 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).

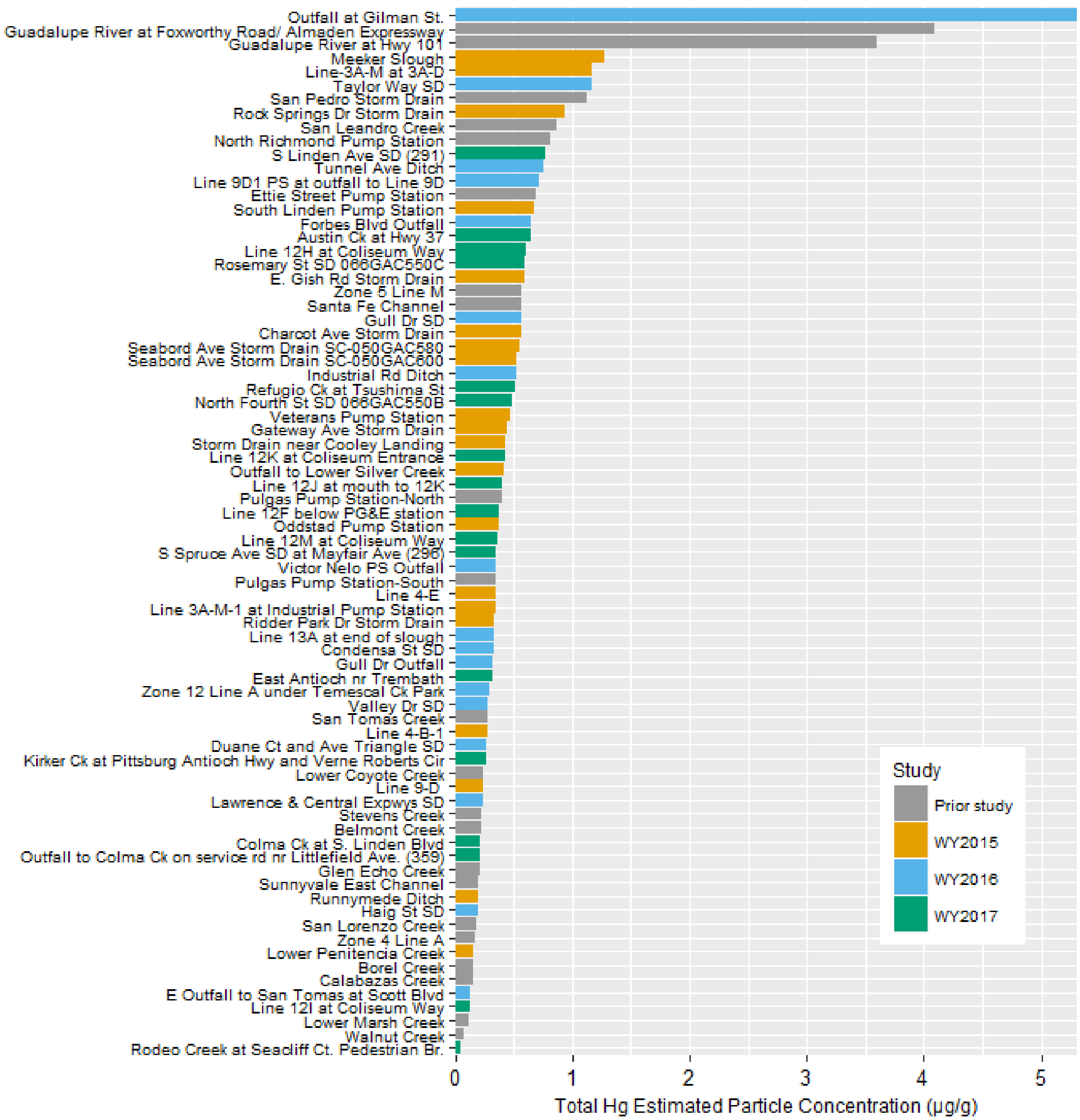

Figure 8. All watershed sampling locations measured to date (water years 2003-2017) ranked by total mercury (HgT) estimated particle concentrations. The sample count represented by each bar in the graph is provided in Appendix B.

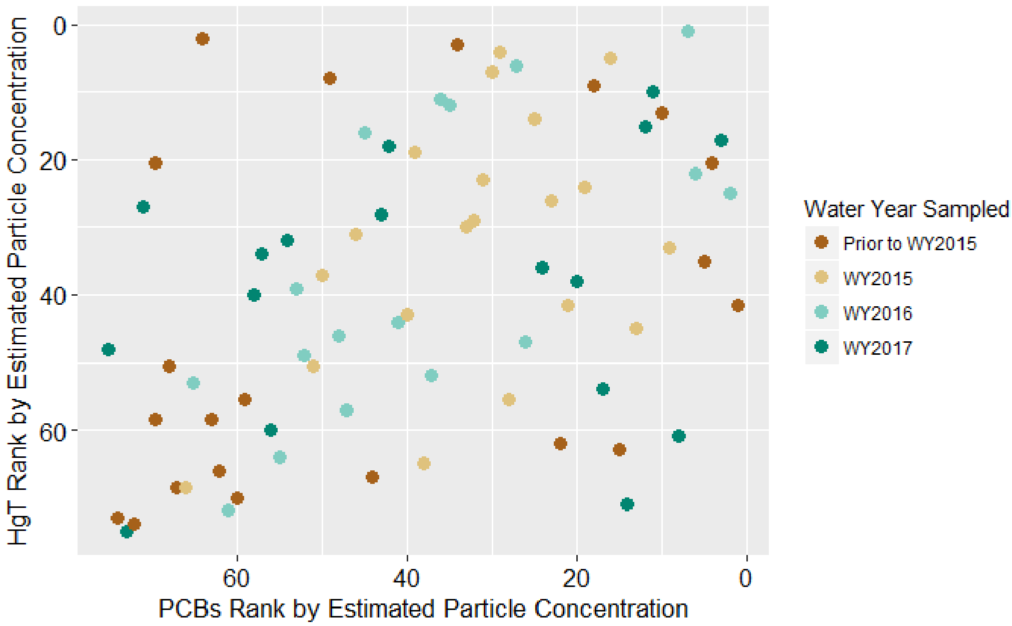

Figure 9. Comparison of site rankings for PCB and total mercury (HgT) estimated particle concentrations. 1 = highest rank; 75 = lowest rank. One watershed ranks in the top 10 for both PCBs and HgT, and nine watersheds rank in the top 20 for both pollutants.

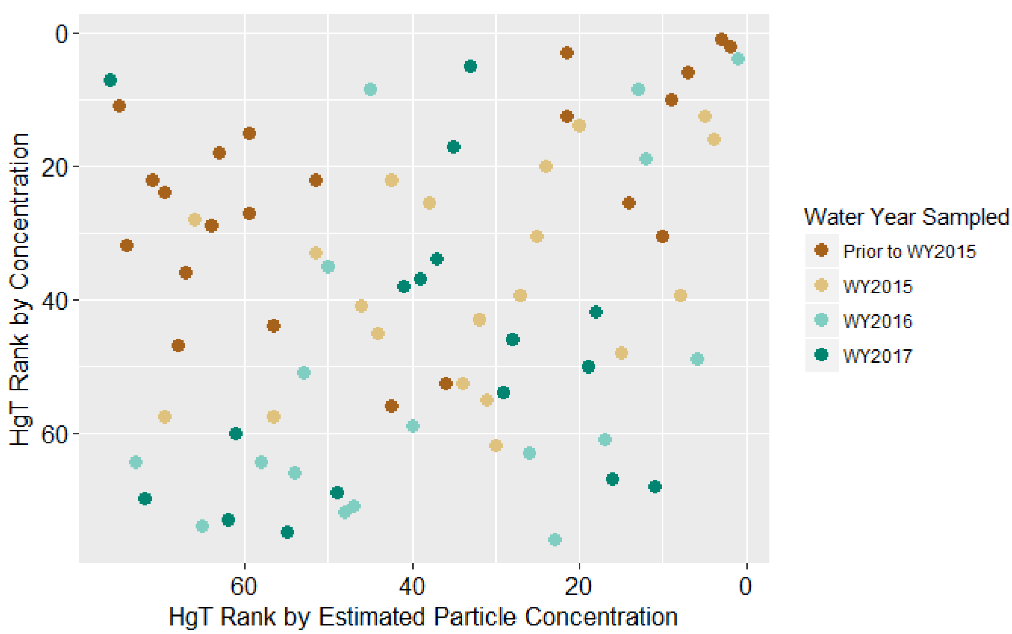

Figure 10. Comparison of site rankings for total mercury (HgT) estimated particle concentrations and water concentrations. 1 = highest rank; 76 = lowest rank.

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

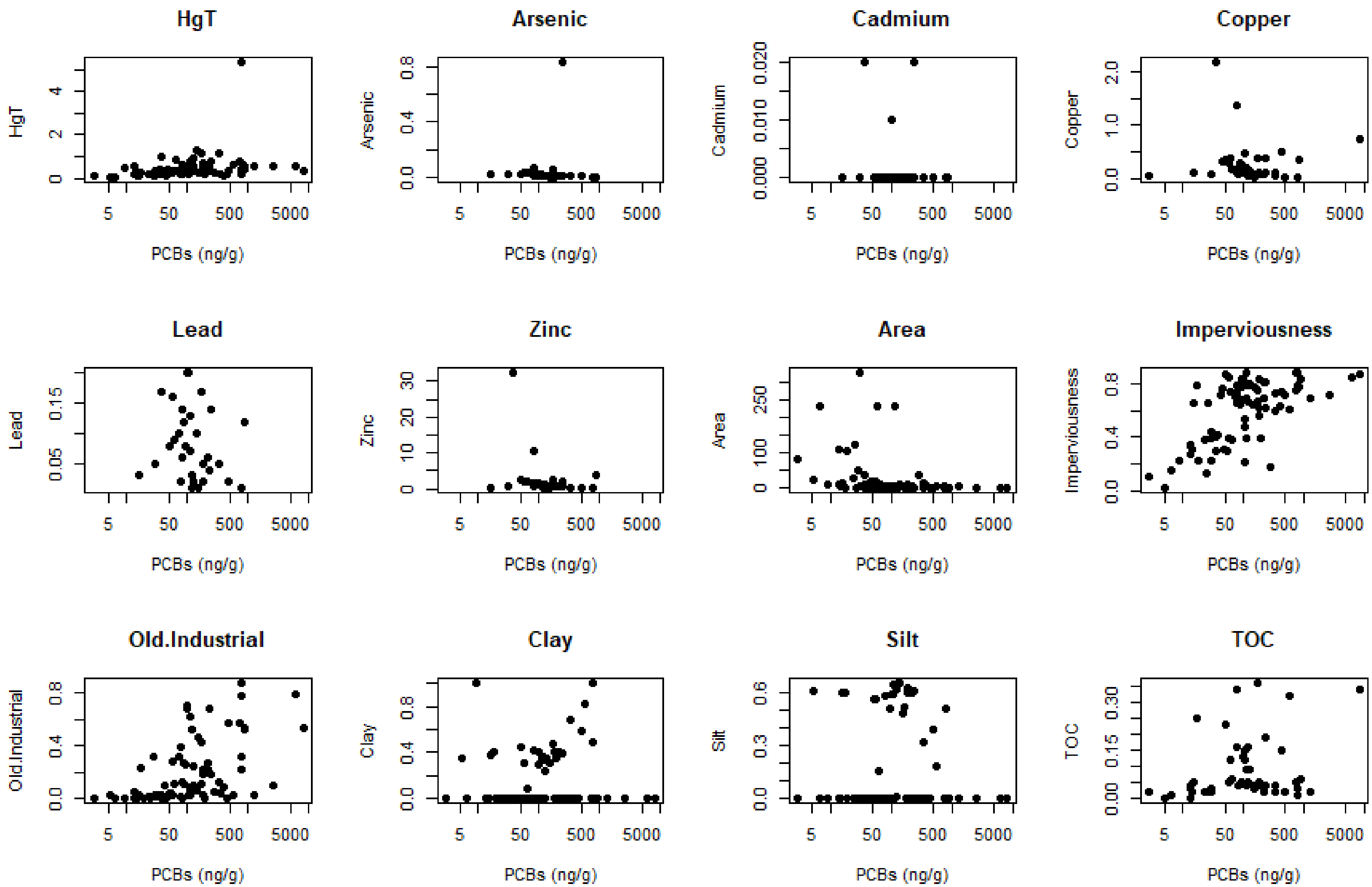

Figure 11. Relationships between observed estimated particle concentrations of PCBs and total mercury (HgT), trace elements, and impervious land cover and old industrial land use.

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.

[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